



FSG: AC: KR: 7203/DELNP/2012

**THE CONTROLLER OF PATENTS
THE PATENT OFFICE
DELHI**

May 23, 2019

Dear Sir,

re: **WEIR MINERALS AUSTRALIA LTD.**
Indian [National Phase] Patent Application No. 7203/DELNP/2012
Filed: August 17, 2012
Out of International Appln. PCT/AU2011/000092 date February 1, 2011
Priority dates: February 5, 2010 – Australian Application No. 2010900457
October 1, 2010 – Australian Application No. 2010904416


In order to meet the Seventh formal requirement raised in Part III of the first examination report we have the honour to submit herewith a further statement and undertaking on Form 3 embodying updated details of the corresponding foreign patent applications.

We also submit herewith copies of the following documents to meet the Seventh formal requirement raised in Part III of the first examination report under Section 8 (2) of the Patents Act, 1970:

- (1) An office action dated March 09, 2018 issued in respect of the corresponding US Patent Application No. 13/577,371;
- (2) An office action dated June 02, 2017 issued in respect of the corresponding US Patent Application No. 13/577,371;
- (3) An office action dated May 19, 2016 issued in respect of the corresponding US Patent Application No. 13/577,371;
- (4) An office action dated July 27, 2015 issued in respect of the corresponding US Patent Application No. 13/577,371;
- (5) Extended European search report dated March 04, 2014 issued in respect of the corresponding European Patent Application No. 11739260.5;
- (6) An office action dated May 16, 2019 issued in respect of the corresponding European Patent Application No. 11739260.5;
- (7) An office action dated October 18, 2017 issued in respect of the corresponding European Patent Application No. 11739260.5;
- (8) An office action dated March 02, 2016 issued in respect of the corresponding European Patent Application No. 11739260.5;

- (9) An office action dated May 15, 2015 issued in respect of the corresponding European Patent Application No. 11739260.5;
- (10) Certificate of Mexican Patent no. 345311 dated January 25, 2017 issued in respect of the corresponding Mexican patent Application No. MX/a/2012/009049;
- (11) Certificate of Canadian Patent no.2788673 dated April 09, 2019 issued in respect of the corresponding Canadian patent Application No.2788673;
- (12) International Preliminary report on Patentability;
- (13) International search report

Yours faithfully,


RAJESH KUMAR
(IN/PA No – 1107)
of GROSER & GROSER
AGENT FOR THE APPLICANTS

Enclosures:
Form 3;
Copies of US, EP, MX and CA documents identified above



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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/577,371	10/29/2012	Kevin Dolman	043153-9170-US00	6743
23409	7590	03/09/2018	EXAMINER	
MICHAEL BEST & FRIEDRICH LLP (Mke) 100 E WISCONSIN AVENUE Suite 3300 MILWAUKEE, WISCONSIN 53202			HILL, STEPHANIA	
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Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

mkeipdocket@michaelbest.com

DETAILED ACTION

Remarks

Claim 51 is amended. Claim 69 is new. Claims 1-50, 52, 56, and 66-68 are cancelled. Claims 51, 53-55, 57-65, and 69 are examined below.

Notice of Pre-AIA or AIA Status

The present application is being examined under the pre-AIA first to invent provisions.

Information Disclosure Statement

The examiner appreciates applicant's clarification of document D4 and D5 for the European Patent Office Action for Application No. 11739260.5 dated March 2, 2016 (6 pages) filed with the May 2, 2016 information disclosure statement (IDS). The applicant stated D4 is DE 2063181 A1 and D5 is WO 2004/104253, both of which were considered as part of the IDS filed May 2, 2016.

Drawings

The drawings filed on August 6, 2012 are accepted.

Claim Rejections - 35 USC § 103

The following is a quotation of pre-AIA 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

The factual inquiries set forth in *Graham v. John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under pre-AIA 35 U.S.C. 103(a) are summarized as follows:

1. Determining the scope and contents of the prior art.
2. Ascertaining the differences between the prior art and the claims at issue.

3. Resolving the level of ordinary skill in the pertinent art.

4. Considering objective evidence present in the application indicating obviousness or nonobviousness.

1. **Claims 51, 53-55, 57-64, and 69** are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '672 (US PG Publication 2009/0293672) in view of Choi (Choi, Hwang, Kim. J. Am. Ceram. Soc. 85 [9] 2313-2318 (2002)) and Lemon (US PG Publication 2008/0193798).

Regarding claims 51, 55, 57, and 58, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles dispersed in a metal or metallic alloy ([0002] and [0031]) where the hard particles comprise carbide particles of at least one transition metal selected from titanium, chromium, vanadium, zirconium, hafnium, tantalum, molybdenum, niobium, and tungsten ([0035]) and the metal or metallic alloy is steel, a nickel alloy, or a cobalt alloy ([0031], [0032], [0033], and [0042]).

Hard particles dispersed in a metal or metallic alloy read on a hard metal material, the hard particles are refractory materials, and the metal or metallic alloy reads on the host metal. The volume of hard particles taught by US '672 overlaps at greater than 10 to 50 volume % with that instantly claimed. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by US '672. See MPEP Section 2144.05.

US '672 teaches permutations of the hard particles include niobium carbide or niobium titanium carbide. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

Choi teaches a $Nb_{1-x}Ti_xC$ -Co alloy where $Nb_{1-x}Ti_xC$ grains are in a cobalt matrix that is manufactured using powder mixtures where x is 0.25 or 0.5 (Abstract, Experimental Procedure, Results, and Conclusion).

It would have been obvious to one of ordinary skill in the art before the invention as instantly claimed was made in the material of US '672 to use $Nb_{1-x}Ti_xC$ particles taught by Choi as the hard

particles because Ti substitution of NbC particles inhibits grain growth and coarsening and prevents the occurrence of large grains and variation in grain size as a result of growth (Choi Abstract, Introduction, and Conclusion). Further, both Choi and US '672 disclose a powder metallurgy process where sintering is performed at 1500°C during which time the NbTiC powders do not melt, but they do undergo grain changes (Choi Conclusion).

US '672 is silent to the hard metal material being at least 100 kgs.

Lemon teaches using a powder metallurgy process that includes applying both a pressure and temperature to form a plate weighing at least 300 kg ([0011], [0017], [0021], [0027], [0030], [0031], [0059], [0061], [0062], [0083], [0084], [0102], and [0108]).

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to form an object of at least 300 kg as taught by Lemon using the powder metallurgy process and hard metal material taught by US '672 because this forms objects with a non-segmented construction that allows the object to be made in one piece instead of having to combine two or more objects together (Lemon [0027] and [0108]). US '672 and Lemon are analogous art because they both in the same field of endeavor of powder metallurgy. MPEP 2141.01(a).

The requirement for the hard metal material to be a casting is product-by-process terminology. The limitation of casting was fully considered, but the casting process was determined to not impart additional structure to the product as instantly claimed. A *prima facie* base of obviousness exists when the product in a product-by-process claim is obvious over a product from the prior art and the claim is unpatentable even through the prior product was made by a different process. See MPEP 2113.

Regarding claims 53 and 54, Choi teaches a $Nb_{1-x}Ti_xC$ -Co alloy where $Nb_{1-x}Ti_xC$ grains are in a cobalt matrix that is manufactured using powder mixtures where x is 0.25 or 0.5 (Abstract, Experimental Procedure, Results, and Conclusion).

Regarding claims 59 and 60, US '672 teaches the product of instant claim 1, including the volume percent of refractory material particles. A hard metal material that has the required volume percent of refractory material particles also has the required weight percent of the particles because both volume percent and weight percent are related to how many particles are present in the host metal. A *prima facie* case of obviousness exists when the claimed and prior art products are identical or substantially identical in structure. See MPEP 2112.01I.

Regarding claims 61-63, Choi teaches the size of the NbTiC particles is in a range of 1 to 150 μm (Fig. 1 and Fig. 2). The scale bars on the figures indicate the particles are within the instantly claimed range because the scale bars on the figures are 10 μm and 25 μm or 50 μm , respectively, and none of the particles in the micrographs are larger than the scale bars. A *prima facie* case of obviousness exists

Regarding claim 64, Choi and US '672 teach the final product has a uniform dispersion of particles of the refractory material in the host metal (Choi Fig. 1 and Fig. 2 and US '672 Fig. 3, [0017], and [0067]).

Regarding claim 69, the limitation regarding the particles being insoluble in the host metal at the casting temperature is a product-by-process limitation. The claims are directed towards a hard metal material where patentability is based on the product itself. The patentability of a product does not depend on its method of production. If the product in the product-by-process claim is the same as or obvious over a product of the prior art, the claim is unpatentable even though the prior product was made by a different process. MPEP 2113I. US '672 in view of Choi and Lemon teaches a hard metal material that reads on that instantly claimed, where the final product contains instantly claimed particles of a mixture of niobium carbide and titanium carbide that are insoluble in the host metal.

2. **Claims 51, 55, 57-60, and 69** are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '459 (US 4119459) and further in view of Wragg (US 5,720,830) and Chen (K. Chen, L. Zhao. "Elastic properties, thermal expansion coefficients and electronic structures of $\text{Ti}_{0.75}\text{X}_{0.25}\text{C}$ carbides."

Journal of Physics and Chemistry of Solids 68 (2007) 1805-1811.) as evidenced by OnlineMetals (Melting points of various metals. www.onlinemetals.com/meltpt.cfm. February 4, 2001.).

Regarding claims 51, 55, 57, 58, US '459 teaches a cast composite body composed of cast iron and sintered cemented carbide to make constructional elements of different kinds used under wearing conditions for example cutting tips or inserts in rock drilling (1:35-37 and 48-63 and 2:40-50). A composite body with sintered cemented carbide reads on a hard metal material and the cast iron reads on a ferrous alloy host metal. Constructional elements as taught read on materials of at least 100 kgs.

According to US '459 the cemented carbides can comprise carbides of Ti, Ta, Nb or other metals (2:40-50), which includes carbides containing niobium or carbides containing titanium and niobium. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

Chen teaches adding Nb to TiC to form $Ti_{0.75}Nb_{0.25}C$ carbides (Abstract, page 1807, and Conclusions).

It would have been obvious to one of ordinary skill in the art before the invention as instantly claimed was made in the casting of US '459 to include $Ti_{0.75}Nb_{0.25}C$ carbides as taught by Chen because adding Nb to TiC increases the shear and Young's moduli of the carbides, which enhances hardness, enhances the ductility, and reduces the thermal expansion coefficient between the metallic substrate and TiNbC particles, where these properties improve wear coating performance (Chen Abstract, page 1807, and Conclusions).

US '459 is silent to the amount of refractory material particles in the host metal matrix.

Wragg teaches a ferrous metal comprising 0.1 to 20% by volume carbide particles (1:8-20, 4:62-67).

It would have been obvious to one of ordinary skill in the art before the filing of the instant invention for the cast product of US '459 to include 0.1 to 20% by volume carbide particles as taught by

Wragg because this amount of carbide particles in the solid metal achieves a hardening effect (Wragg 4:59-67). Further, both US '459 and Wragg are directed towards forming the bodies by casting, indicating the volume % taught by Wragg is known to work for the casting process of US '459. The volume % of refractory material particles in US '459 in view of Wragg overlaps with that instantly claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material volume percent overlap with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claims 53 and 54, Chen teaches $Ti_{0.75}Nb_{0.25}C$ carbides (Abstract, page 1807, and Conclusions).

Regarding claims 59 and 60, US '459 in view of Wragg teach the product of instant claim 1, including the volume percent of refractory material particles. It is expected that a hard metal material that has the required volume percent of refractory material particles would also have the required weight percent of the particles because both volume percent and weight percent are related to how many particles are present in the host metal. A *prima facie* case of obviousness exists when the claimed and prior art products are identical or substantially identical in structure. See MPEP 2112.01I.

Regarding claim 64, US '459 depicts a uniform distribution of the cemented carbide particles (Fig. 1).

Regarding claim 69, US '459 teaches making the instantly claimed product by casting where in the casting the cemented carbide is present as pieces, crushed material, powder, pressed bodies, or some shape, some of the hard metal particles dissolve, and the casting temperature is 150 to 400°C greater than the liquidus temperature of the cast alloy (2:40-50, 3:5-23, and 4:17-30). While some of the carbide particles dissolve into the cast iron alloy matrix, some of the carbide particles remain intact as indicated by Fig. 1 (5: 11-18), where A the undissolved hard metal grains or particles are the insoluble refractory material particles in the host matrix. Further, the melting temperature of cast iron is 1204°C (as evidenced by OnlineMetals), and 150 to 400°C greater than this is 1354 to 1604°C, which is still less

than the melting temperature of NbC and the melting temperature of TiNbC. This indicates that NbC and TiNbC particles will not fully dissolve in the cast iron alloy, where the particles that do not dissolve are the insoluble particles in the host metal matrix.

3. **Claim 65** is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '459 (US 4119459) in view of Wragg (US 5,720,830) and Chen (K. Chen, L. Zhao. "Elastic properties, thermal expansion coefficients and electronic structures of $Ti_{0.75}X_{0.25}C$ carbides." Journal of Physics and Chemistry of Solids 68 (2007) 1805-1811.) as evidenced by OnlineMetals (Melting points of various metals. www.onlinemetals.com/meltpt.cfm. February 4, 2001.) as applied to claim 51 above, and further in view of US '936 (US PG Publication 20080226936).

Regarding claim 65, US '459 further in view of Wragg is silent to the hard metal material including a non-uniform dispersion of particles of the refractory material in the host metal.

US '936 teaches a method of centrifugally casting an iron alloy with MC carbides in the matrix in order to form an outer layer that has more MC carbides dispersed ([0011]-[0014], [0019]-[0023], and Fig. 4(a)), where the MC particles preferentially gather along one edge of the casting due to the applied centrifugal force during casting.

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to perform the casting process of US '459 as a centrifugal casting process in order to create a non-uniform dispersion of refractory material particles because it creates a final product that has excellent wear resistance, surface roughening resistance, and seizure resistance without the problem of MC carbide segregation (US '936 [0010]).

4. **Claims 51, 53-55, 57-65, and 69** are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Wragg (US 5,720,830) in view of Chen (K. Chen, L. Zhao. "Elastic properties, thermal expansion coefficients and electronic structures of $Ti_{0.75}X_{0.25}C$ carbides." Journal of Physics and Chemistry of Solids 68 (2007) 1805-1811.) as evidenced by Uralmashplant (Uralmashplant "Rolls for Rolling Mills.").

Regarding claims 51, 55, 57, and 58, Wragg teaches a cast iron and steel comprising carbide particles in an amount of up to 20% by volume where the alloy carbide is selected from the group comprising chromium, molybdenum, titanium, tungsten, niobium, vanadium, or mixed carbides thereof where the product is formed by introducing alloy carbide particles into molten engineering ferrous metal and pouring the mixture into a mould where the material is used to make a rolling mill roll in a hot strip or cold strip mill for iron or steel (1:7-8 and 25-45, 4:29-32 and 62-67, and 6:20-36).

A cast iron and steel read on the host metal being a ferrous alloy. The amount of carbide particles taught overlaps with the amount instantly claimed. A *prima facie* case of obviousness exists where the claimed ranges or amounts overlap or lie inside those taught by the prior art. MPEP 2144.05I. Using the material to make a rolling mill roll in a hot strip or cold strip mill for iron or steel reads on the material being at least 100 kgs as evidenced by Uralmashplant where rolls for hot-rolling mills and cold-rolling mills have a maximum weight of 5 to 55 tons (about 4,500 to 50,000 kgs) (pages 4 and 5).

The carbide particles read on particles of a refractory metal, where both niobium carbide and a mixed carbide of niobium titanium are taught. When the species is clearly name, the species claim is anticipated no matter how many other species are additionally named. MPEP 2131.02II.

Chen teaches $Ti_{0.75}Nb_{0.25}C$ carbides (Abstract, Tables 104, 6. Conclusions).

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made in the process of Wragg to include $Ti_{0.75}Nb_{0.25}C$ carbide particles as taught by Chen because these particles have enhanced hardness, good ductility, and a better match to thermal expansion coefficients of metallic substrates relative to TiC particles (Chen 6. Conclusions). One of ordinary skill in the art would understand that these particles are harder and at elevated temperatures the better matched thermal expansion coefficient minimizes the occurrence of cracking within the matrix at elevated temperature.

Regarding claims 53 and 54, Chen teaches $Ti_{0.75}Nb_{0.25}C$ carbides (Abstract, Tables 104, 6. Conclusions).

Regarding claims 59 and 60, Wragg teaches the amount of alloy carbide particles added is such as to achieve up to 20% by volume of alloy carbide particles in the solid metal, where the alloy carbide particles include niobium carbide and the solid metal is a ferrous metal (column 1 lines 7-8 and column 4 lines 29-32 and 62-67). Assuming the refractory particles are niobium carbide with a density of 7.82 g/cm³ and the host metal is a ferrous metal with a density ranging from 7.75 g/cm³ to 8.05 g/cm³ this results in a maximum weight percent of refractory particles ranging from 19.5 wt% to 20 wt%, which both overlap with that instantly claimed. A *prima facie* case of obviousness exists where the claimed ranges or amounts overlap or lie inside those taught by the prior art. MPEP 2144.05I.

Regarding claims 61-63, Wragg teaches the alloy carbide particles preferably have a maximum dimension of up to 10 μm (column 2 lines 60-67 and column 4 lines 59-61). A *prima facie* case of obviousness exists where the claimed ranges or amounts overlap or lie inside those taught by the prior art. MPEP 2144.05I.

Regarding claim 64, Wragg teaches the alloy carbide particles are distributed uniformly throughout the casting (column 1 lines 54-62).

Regarding claim 65, Wragg teaches forming the material by an electroslag remelting process which causes a relatively high and uniform distribution of alloy carbide adjacent the mold wall and a low uniform distribution of alloy carbide particles at or adjacent to the centre of the ingot, where the electroslag remelting operation forms a part having an outer hardened part, a first inner part having a first composition, and a second outer part having a second composition (column 6 lines 37-67 and column 7 lines 1-22). This results in a variation of alloy carbide particle concentration throughout the final product, which reads on a non-uniform dispersion of refractory material particles in the host metal.

Regarding claim 69, Wragg teaches forming a ferrous metal having a desired carbide content where the solid carbide particles are coated with a metal to allow wetting to occur between the particles and the liquid engineering ferrous metal (1: 20-45). This teaching indicates that the ferrous metal and carbides interact with the coating layer such that the carbides are insoluble in the host metal at the casting temperature as instantly claimed.

5. **Claims 51, 53-55, 57-65, and 69** are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Wragg (US 5,720,830) in view of Choi (Choi, Hwang, Kim. J. Am. Ceram. Soc. 85 [9] 2313-2318 (2002)) as evidenced by Uralmashplant (Uralmashplant "Rolls for Rolling Mills.").

Regarding claims 51, 55, 57, and 58, Wragg teaches a cast iron and steel comprising carbide particles in an amount of up to 20% by volume where the alloy carbide is selected from the group comprising chromium, molybdenum, titanium, tungsten, niobium, vanadium, or mixed carbides thereof where the product is formed by introducing alloy carbide particles into molten engineering ferrous metal and pouring the mixture into a mould where the material is used to make a rolling mill roll in a hot strip or cold strip mill for iron or steel (1:7-8 and 25-45, 4:29-32 and 62-67, and 6:20-36).

A cast iron and steel read on the host metal being a ferrous alloy. The amount of carbide particles taught overlaps with the amount instantly claimed. A *prima facie* case of obviousness exists where the claimed ranges or amounts overlap or lie inside those taught by the prior art. MPEP 2144.05I. Using the material to make a rolling mill roll in a hot strip or cold strip mill for iron or steel reads on the material being at least 100 kgs as evidenced by Uralmashplant where rolls for hot-rolling mills and cold-rolling mills have a maximum weight of 5 to 55 tons (about 4,500 to 50,000 kgs) (pages 4 and 5).

The carbide particles read on particles of a refractory metal, where both niobium carbide and a mixed carbide of niobium titanium are taught. When the species is clearly name, the species claim is anticipated no matter how many other species are additionally named. MPEP 2131.02II.

Choi teaches the impact of sintering temperature and time on the grain changes of $Nb_{0.75}Ti_{0.25}C$ and $Nb_{0.5}Ti_{0.5}C$ particles in a Co matrix during liquid phase sintering (page 2313 abstract and page 2314 Section II. Experimental Procedure).

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to use the $Nb_{0.75}Ti_{0.25}C$ or $Nb_{0.5}Ti_{0.5}C$ powder taught by Choi as the composition for the NbTiC particles in Wragg because these particles exhibit grain growth inhibition, which increases the barrier for grain growth (Choi V. Conclusion). During casting, the mixture of niobium carbide and titanium carbide particles would be expected to maintain size and shape and coarsen less than NbC particles because of the substitution of titanium within the particles.

Regarding claims 53 and 54, Choi teaches the impact of sintering temperature and time on the grain changes of $Nb_{0.75}Ti_{0.25}C$ and $Nb_{0.5}Ti_{0.5}C$ particles in a Co matrix during liquid phase sintering (page 2313 abstract and page 2314 Section II. Experimental Procedure).

Regarding claims 59 and 60, Wragg teaches the amount of alloy carbide particles added is such as to achieve up to 20% by volume of alloy carbide particles in the solid metal, where the alloy carbide particles include niobium carbide and the solid metal is a ferrous metal (column 1 lines 7-8 and column 4 lines 29-32 and 62-67). Assuming the refractory particles are niobium carbide with a density of 7.82 g/cm³ and the host metal is a ferrous metal with a density ranging from 7.75 g/cm³ to 8.05 g/cm³ this results in a maximum weight percent of refractory particles ranging from 19.5 wt% to 20 wt%, which both overlap with that instantly claimed. A *prima facie* case of obviousness exists where the claimed ranges or amounts overlap or lie inside those taught by the prior art. MPEP 2144.05I.

Regarding claims 61-63, Wragg teaches the alloy carbide particles preferably have a maximum dimension of up to 10 μm (column 2 lines 60-67 and column 4 lines 59-61). A *prima facie* case of obviousness exists where the claimed ranges or amounts overlap or lie inside those taught by the prior art. MPEP 2144.05I.

Regarding claim 64, Wragg teaches the alloy carbide particles are distributed uniformly throughout the casting (column 1 lines 54-62).

Regarding claim 65, Wragg teaches forming the material by an electroslag remelting process which causes a relatively high and uniform distribution of alloy carbide adjacent the mold wall and a low uniform distribution of alloy carbide particles at or adjacent to the centre of the ingot, where the electroslag remelting operation forms a part having an outer hardened part, a first inner part having a first composition, and a second outer part having a second composition (column 6 lines 37-67 and column 7 lines 1-22). This results in a variation of alloy carbide particle concentration throughout the final project, which reads on a non-uniform dispersion of refractory material particles in the host metal.

Regarding claim 69, Wragg teaches forming a ferrous metal having a desired carbide content where the solid carbide particles are coated with a metal to allow wetting to occur between the particles and the liquid engineering ferrous metal (1: 20-45). This teaching indicates that the ferrous metal and carbides interact with the coating layer such that the carbides are insoluble in the host metal at the casting temperature as instantly claimed.

Response to Arguments

Applicant's arguments, see page 8, filed December 4, 2017, with respect to the rejection of claims 51, 52, 55, 57, 58, and 61-64 under JP '479 (JP2005068479 machine translation) in view of Lemon (US PG Publication 20080193798) as evidenced by Storms (Storms and Krikorian. The niobium-niobium carbide system. J. Phys. Chem. 64 (10) 1960 pp. 1471-1477.) have been fully considered and are persuasive. The examiner agrees that JP '479 requires the presence of a hexagonal complex compound with solid solution boron. This does not read on the instant claims in light of the casting consisting of a host metal and refractory material where the refractory material consists of niobium-containing particles. The transitional phrase "consisting of" excludes the occurrence of additional elements, such as the hexagonal complex compound, from the prior art. This rejection has been withdrawn.

The applicant argues that claim 51 recites a casting whereas US '672 discloses cermet products manufactured by a powder metallurgy process. The applicant argues that a casting produces inherently a casting-specific structure and a powder metallurgy process inherently produces a powder metallurgy-specific structure where one skilled in the art would not substitute one material for the other because the skilled artisan would recognize they are distinct products with potentially divergent properties. The applicant further argues, as supported by the declaration submitted November 21, 2016 that it is not clear and not possible to say whether the metallurgical bonds in the powder metallurgy structure of US '672 is the same or different than those of the casting of the instant application. Specifically, the applicant cites [0022], [0023], and [0046] of US '672 as characterizing the metallurgical bond of the cermet product, where there is no reason the casting would have the same structure.

The applicant has not met their burden of providing evidence to support the above argument of the differences between cermet products manufactured by casting versus by powder metallurgy. The instant claims also do not distinguish a hard metal material made by casting versus by powder metallurgy. As presented in the above rejection, US '672 teaches a hard metal material that reads on that instantly claimed. Additionally, the instant specification states in [0002] of the PG Publication that "The ASM Materials Engineering Dictionary defines the term "hard metal" as a collective term for a sintered material with a high hardness, strength and wear resistance." This definition supports the examiners position that the product of US '672 produced using powder metallurgy with a sintering process reads on the hard metal material instantly claimed.

The applicant argues that Lemon is a specific and specialized disclosure relating to forming a molybdenum product and does not relate to the cermet materials of US '672 or the instantly claimed castings. Further, the process of Lemon includes a powder metallurgy step to form billets and other intermediate products then carries out subsequent processing to form end-use products.

The applicant is reminded that a reference may be relied upon for all that it would have reasonably suggested to one having ordinary skill in the art. MPEP 2123. Also, a reference is analogous art if the reference is in the same field or endeavor. MPEP 2141.01(a). US '672 and Lemon are in the same field or endeavor of forming components using powder metallurgy. One of ordinary skill in the art would understand that forming a 300 kg billet using powder metallurgy as taught by Lemon indicates that a similarly sized billet can also be formed using powder metallurgy with the material of US '672. The applicant has not met their burden of providing evidence as to why the powder composition of US '672 cannot be formed into a large billet as taught by Lemon. Further, the billet formed in Lemon is larger than the eventual sputtering target, indicating that the size of the billet of Lemon reads on that instantly claimed ([0085]).

The applicant argues that in the powder metallurgy process of US '672 at 1500°C both the host metal and the NbC and TiNbC particles will be solid, which is not the case in the instantly claimed casting because the host metal will be molten.

The applicant is reminded that the claims are directed to a hard metal material where determination of patentability is based on the product itself. The patentability of a product does not depend on its method of production. If the product in the claim is the same as or obvious from a product of the prior art, the claim is unpatentable even though the prior product was made by a different process. MPEP 2113. The applicant has not met their burden of providing evidence to indicate how the product formed by the powder metallurgy process of US '672 is different from that instantly claimed.

The applicant argues US '459 comprises sintered cement carbides where the carbides are WC-Co-type carbides or carbides with at least one of Ti, Ta, and Nb, where amended claim 51 does not comprise these taught carbides.

The above rejection has been modified to be US '459 in view of Chen. Us '459 broadly teaches the presence of cemented carbides and states that "hard metal containing other carbides and binder metals may be suitable" (2:47-48) and "In the composite product consisting of hard metal and cast iron" (3:35-36). A reference may be relied upon for all that it would have reasonably suggested to one having ordinary skill in the art. Disclosed examples and preferred embodiments do not constitute a teaching away from a broader disclosure or nonpreferred embodiments. MPEP 2123. The broad teachings of US '459 do not specify the hard metal required in the invention. Chen teaches the benefits of niobium titanium carbides being the hard metal as discussed in detail in the rejection. Therefore, this rejection reads on that instantly claimed.

The applicant argues that Wragg changes the solid alloy carbide particles by forming a coating on the particles, where coated particles are not a part of the claimed invention. The applicant argues that as taught on page 8 line 29 to page 9 line 8 of the instant specification it is taught that poor bonding does not occur in the method taught in the instant specification due to using an inert atmosphere during casting and the thermal contraction of the refractory particles being much less than that of the host metal during cooling. Therefore independent claim 51 is not obvious over Wragg.

The examiner respectfully disagrees. The claims are directed towards a hard metal material where determination of patentability of based on the product itself. The patentability of a product does not depend on its method of product. If the product in the claim is the same as or obvious from a product of the prior art, the claim is unpatentable even though the prior product was made by a different process. MPEP 2113. Wragg teaches a hard metal material as instantly claimed and presented in the above rejection. The applicant has not met their burden of providing evidence to distinguish the instantly claimed product form that of Bragg.

Conclusion

Applicant's amendment necessitated the new ground(s) of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL**. See MPEP § 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the date of this final action.

Contact Information

Any inquiry concerning this communication or earlier communications from the examiner should be directed to **STEPHANI HILL** whose telephone number is (571)272-2523. The examiner can normally be reached on Monday, Tuesday, Friday 7am-1pm; Wednesday, Thursday 7am-9am and 2pm-5pm.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at <http://www.uspto.gov/interviewpractice>.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, KEITH WALKER can be reached on 571-272-3458. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/S. H./
Examiner, Art Unit 1735

/KEITH WALKER/
Supervisory Patent Examiner, Art Unit 1735



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Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

mkeipdocket@michaelbest.com

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DETAILED ACTION

Continued Examination Under 37 CFR 1.114

A request for continued examination under 37 CFR 1.114, including the fee set forth in 37 CFR 1.17(e), was filed in this application after final rejection. Since this application is eligible for continued examination under 37 CFR 1.114, and the fee set forth in 37 CFR 1.17(e) has been timely paid, the finality of the previous Office action has been withdrawn pursuant to 37 CFR 1.114. Applicant's submission filed on November 21, 2016 has been entered.

Remarks

Claims 51, 52, 59, and 60 are amended. Claims 1-50, 56, and 66-68 are cancelled.

Claims 51-55 and 57-65 are pending examination.

Notice of Pre-AIA or AIA Status

The present application is being examined under the pre-AIA first to invent provisions.

Information Disclosure Statement

While the European Patent Office Action for Application No. 11739260.5 dated March 2, 2016 (6 pages) filed with the May 2, 2016 information disclosure statement (IDS) was considered, it is noted that the document refers to **D4** and **D5** with no indication what documents **D4** and **D5** refer to.

Drawings

The drawings filed on August 6, 2012 are accepted.

Claim Objections

The objection to claim 51 regarding repetition of the word "refractory" is withdrawn due to amendment.

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Claim Rejections - 35 USC § 112

The 112, second paragraph rejection of claim 51 regarding "a dispersion of greater than 10 volume % and up to 50 volume % of particles of a refractory material including (a) niobium carbide containing refractory particles that are insoluble in the host metal at the casting temperature and/or (b) particles of a chemical mixture of niobium carbide and titanium carbide that are insoluble in the host metal at the casting temperature" is withdrawn due to amendment.

The following is a quotation of 35 U.S.C. 112(b):

(b) CONCLUSION.—The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the inventor or a joint inventor regards as the invention.

The following is a quotation of 35 U.S.C. 112 (pre-AIA), second paragraph:

The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

1. **Claim 52** is rejected under 35 U.S.C. 112(b) or 35 U.S.C. 112 (pre-AIA), second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which the inventor or a joint inventor, or for pre-AIA the applicant regards as the invention.

In claim 52 the limitation "further including particles of carbides and/or nitrides and/or borides of tungsten" renders the claim indefinite. Tungsten carbides, tungsten nitrides, and tungsten borides are refractory particles. It is unclear whether these tungsten-based refractory particles are part of "a dispersion of greater than 10 volume % and up to 50 volume % of particles of a refractory material" or if they are in addition to this limitation such that the combination of the dispersion of particles of a refractory material and those based on tungsten can be more than 50 volume %. For the purposes of prosecution, claim 52 will be given the

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broadest reasonable interpretation of the tungsten based refractory particles being in addition to the dispersion of particles of a refractory material of claim 51.

Claim Rejections - 35 USC § 103

The following is a quotation of pre-AIA 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

The factual inquiries set forth in *Graham v. John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under pre-AIA 35 U.S.C. 103(a) are summarized as follows:

1. Determining the scope and contents of the prior art.
 2. Ascertaining the differences between the prior art and the claims at issue.
 3. Resolving the level of ordinary skill in the pertinent art.
 4. Considering objective evidence present in the application indicating obviousness or nonobviousness.
2. **Claims 51, 52, 55, 57-59, 60, and 64** are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '672 (US PG Publication 20090293672) in view of Lemon (US PG Publication 20080193798) as evidenced by Storms (Storms and Krikorian. The niobium-niobium carbide system. J. Phys. Chem. 64 (10) 1960 pp. 1471-1477.) and Rudy (Rudy. Phase equilibria investigation of binary, ternary, and higher order systems. Technical Report AFML-TR-69-117, Part 1. August 1970.).

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Regarding claim 51, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles dispersed in a metal or metallic alloy ([0002] and [0031]) where the hard particles comprise carbide particles of at least one transition metal selected from titanium, chromium, vanadium, zirconium, hafnium, tantalum, molybdenum, niobium, and tungsten ([0035]) and the metal or metallic alloy is steel, a nickel alloy, or a cobalt alloy ([0031], [0032], [0033], and [0042]).

Hard particles dispersed in a metal or metallic alloy read on a hard metal material, the hard particles are refractory materials, and the metal or metallic alloy reads on the host metal. The volume of hard particles taught by US '672 overlaps at greater than 10 to 50 volume % with that instantly claimed. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by US '672. See MPEP Section 2144.05.

According to US '672 permutations of the hard particles include niobium carbide or niobium titanium carbide. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

US '672 is silent to the hard metal material being at least 100 kgs.

Lemon teaches using a powder metallurgy process that includes applying both a pressure and temperature to form a plate weighing at least 300 kg ([0011], [0017], [0021], [0027], [0030], [0031], [0059], [0061], [0062], [0083], [0084], [0102], and [0108]).

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to form an object of at least 300 kg as taught by Lemon using the

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powder metallurgy process and hard metal material taught by US '672 because this forms objects with a non-segmented construction that allows the object to be made in one piece instead of having to combine two or more objects together (Lemon [0027] and [0108]). US '672 and Lemon are analogous art because they both in the same field of endeavor of powder metallurgy. MPEP 2141.01(a)I.

The requirement for the hard metal material to be in the form of a casting is product-by-process terminology. The limitation of casting was fully considered, but the casting process was determined to not impart additional structure to the product as instantly claimed. A *prima facie* base of obviousness exists when the product in a product-by-process claim is obvious over a product from the prior art and the claim is unpatentable even through the prior product was made by a different process. See MPEP 2113.

Further, the limitation that the refractory particles are insoluble at the casting temperature will be interpreted as the refractory particles are insoluble at the processing temperature, where the temperature of any process that results in the instantly claimed product will meet this limitation.

US '672 teaches making the instantly claimed product using a powder metallurgy process where sintering is performed up to 1500°C ([0042]). 1500°C is lower than the melting temperature of either NbC or TiNbC particles as evidenced by the phase diagrams presented in Storms (Fig. 1) and Rudy (Figure 1). During processing the NbC or TiNbC particles will remain insoluble in the host metal because they will not get hot enough to melt and dissolve into the host matrix during processing of the hard metal material.

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Regarding claim 52, US '672 teaches the hard particles comprise carbide particles of at least one transition metal selected from titanium, chromium, vanadium, zirconium, hafnium, tantalum, molybdenum, niobium, and tungsten ([0035]), where the particles include tungsten carbide. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

Regarding claim 55, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles ([0002] and [0031]), which overlaps from greater than 10 to 40 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by US '672. See MPEP Section 2144.05.

Regarding claim 57, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles ([0002] and [0031]). This encompasses the instantly claimed range, where the instant claim is being interpreted such that the hard metal material comprises greater than 15 to 50 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by US '672. See MPEP Section 2144.05.

Regarding claim 58, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles ([0002] and [0031]). This encompasses the instantly claimed range, where the instant claim is being interpreted such that the hard metal material comprises greater than 10 to less than 30 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by US '672. See MPEP Section 2144.05.

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Regarding claim 59, US '672 does not explicitly teach the weight percent of the particles of the refractory material relative to the total weight of the material. However, US '672 does teach the product of instant claim 1, including the volume percent of refractory material particles. It is expected that a hard metal material that has the required volume percent of refractory material particles would also have the required 12 to 33 weight percent of the particles because both volume percent and weight percent are related to how many particles are present in the host metal. A *prima facie* case of obviousness exists when the claimed and prior art products are identical or substantially identical in structure. See MPEP 2112.01I.

Regarding claim 60, US '672 does not explicitly teach the weight percent of the particles of the refractory material relative to the total weight of the material. However, US '672 does teach the product of instant claim 1, including the volume percent of refractory material particles. It is expected that a hard metal material that has the required volume percent of refractory material particles would also have the required 12 to 25 weight percent of the particles because both volume percent and weight percent are related to how many particles are present in the host metal. A *prima facie* case of obviousness exists when the claimed and prior art products are identical or substantially identical in structure. See MPEP 2112.01I.

Regarding claim 64, US '672 teaches a uniform dispersion of tungsten carbide refractory metal particles in the second region of an article (Fig. 3, [0017], and [0067]), where the dark tungsten carbide particles as indicated below in Figure A are uniformly dispersed throughout the host metal.

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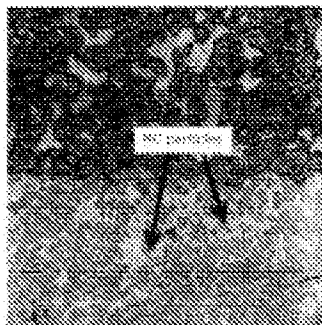


Figure A: Annotated Fig. 3 from US '672 indicating the uniform dispersion of metal carbide (MC) particles throughout the host metal matrix.

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to substitute NbC or TiNbC particles for the tungsten carbide particles in Fig. 3 because US '672 teaches that the taught articles comprises carbide particles of at least one transition metal selected from titanium, chromium, vanadium, zirconium, hafnium, tantalum, molybdenum, niobium, and tungsten ([0035]), where NbC or TiNbC particles serve the same function as the tungsten carbide particles.

3. **Claims 53, 54, and 61-64** are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '672 (US PG Publication 20090293672) in view of Lemon (US PG Publication 20080193798) as evidenced by Storms (Storms and Krikorian. The niobium-niobium carbide system. J. Phys. Chem. 64 (10) 1960 pp. 1471-1477.) and Rudy (Rudy. Phase equilibria investigation of binary, ternary, and higher order systems. Technical Report AFML-TR-69-117, Part 1. August 1970.) as applied to claim 51 above, and further in view of Choi (Choi, Hwang, Kim. J. Am. Ceram. Soc. 85 [9] 2313-2318 (2002)).

Regarding claim 53, US '672 teaches the hard particles can comprise niobium carbide of niobium titanium carbide as detailed above in the analysis of claim 51.

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US '672 is silent to the composition of the niobium titanium carbide particles when they are the composition of the refractory material particles.

Choi teaches the impact of sintering temperature and time on the grain changes of $Nb_{1-x}Ti_xC$ particles in a Co matrix during liquid phase sintering (page 2313 abstract and page 2314 Section I. Introduction column 1 lines 1-12), where 1-x reads on x and x reads on y.

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to use the $Nb_{1-x}Ti_xC$ powder taught by Choi as the composition for the NbTiC particles in US '672 because both Choi and US '672 disclose a powder metallurgy process where sintering is performed at 1500°C during which time the NbTiC powders do not melt, but they do undergo grain changes (Choi page 2317 section V. Conclusion).

Regarding claim 54, US '672 teaches the hard particles can comprise niobium carbide of niobium titanium carbide as detailed above in the analysis of claim 51.

US '672 is silent to the composition of the niobium titanium carbide particles when they are the composition of the refractory material particles.

Choi teaches the impact of sintering temperature and time on the grain changes of $Nb_{0.75}Ti_{0.25}C$ and $Nb_{0.5}Ti_{0.5}C$ particles in a Co matrix during liquid phase sintering (page 2313 abstract and page 2314 Section II. Experimental Procedure).

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to use the $Nb_{0.75}Ti_{0.25}C$ or $Nb_{0.5}Ti_{0.5}C$ powder taught by Choi as the composition for the NbTiC particles in US '672 because the powders are specific compositions of NbTiC powders and both Choi and US '672 disclose a powder metallurgy process where

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sintering is performed at 1500°C during which time the NbTiC powders do not melt, but they do undergo grain changes (Choi page 2317 section V. Conclusion).

Regarding claim 61, Choi teaches the size of the NbTiC particles is in a range of 1 to 150 μm (Fig. 1 and Fig. 2), where the scale bars on the figures indicate the particles are within the instantly claimed range.

Regarding claim 62, Choi teaches the size of the NbTiC particles have a size of less than 500 μm (Fig. 1 and Fig. 2), where the scale bars on the figures are 10 μm and 25 μm or 50 μm, respectively, and none of the particles in the micrographs are larger than the scale bars.

Regarding claim 63, Choi teaches the size of the NbTiC particles have a size of less than 200 μm (Fig. 1 and Fig. 2), where the scale bars on the figures are 10 μm and 25 μm or 50 μm, respectively, and none of the particles in the micrographs are larger than the scale bars.

Regarding claim 64, both Choi and US '672 teach the final product has a uniform dispersion of particles of the refractory material in the host metal (Choi Fig. 1 and Fig. 2 and US '672 Fig. 3).

4. **Claims 51, 52, 55, 57, 58, and 61-64** are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over JP '479 (JP2005068479 machine translation) in view of Lemon (US PG Publication 20080193798) as evidenced by Storms (Storms and Krikorian. The niobium-niobium carbide system. J. Phys. Chem. 64 (10) 1960 pp. 1471-1477.).

Regarding claim 51, JP '479 teaches a cemented carbide ([0001]) comprising 0 to 40 (excluding 0) percent by volume of a cubic compound, specifically, VC, TaC, NbC, TiN, HfN, (W,Ti)(C,B), (W,Ti,Ta)C, (W,Ti,Ta)(C,N), (W,Zr)(C,B), (Ti,W,Cr)C, or (Ti,W,Mo)(C,N,B) ([0015]) with an iron group metal as a main component ([0013]).

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A cemented carbide reads on a hard metal material, a cubic compound reads on a refractory material, and the volume % of cubic compound overlaps from greater than 10 to 40 volume percent. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material volume percent overlap with the range taught by JP '479. See MPEP Section 2144.05.

According to JP '479 the hard particles can comprise NbC. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

An iron group metal reads on a ferrous alloy, a stainless steel, an austenitic-manganese steel, and an iron-based or a nickel-based or a cobalt-based superalloy because Fe, Ni, and Co are all part of the iron group metals, and an alloy based on any of these metals will include that because as the main component.

The requirement for the hard metal material to be in the form of a casting is product-by-process terminology. The limitation of casting was fully considered, but the casting process was determined to not impart additional structure to the product as instantly claimed. A *prima facie* base of obviousness exists when the product in a product-by-process claim is obvious over a product from the prior art and the claim is unpatentable even through the prior product was made by a different process. See MPEP 2113.

Further, the limitation that the refractory particles are insoluble at the casting temperature will be interpreted as the refractory particles are insoluble at the processing temperature, where the temperature of any process that results in the instantly claimed product will meet this limitation.

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JP '479 teaches making the instantly claimed product using a powder metallurgy process where sintering is performed between 1360 and 1420°C ([0023] and Table 2 in the original document). 1360 to 1420°C is lower than the melting temperature of the NbC particles as evidenced by Storms (Fig. 1), indicating that during the processing the NbC particles will remain insoluble in the host metal because they will not get hot enough to melt and dissolve into the host matrix during processing of the hard metal material.

JP '479 is silent to the hard metal material being at least 100 kgs.

Lemon teaches using a powder metallurgy process that includes applying both a pressure and temperature to form a plate weighing at least 300 kg ([0011], [0017], [0021], [0027], [0030], [0031], [0059], [0061], [0062], [0083], [0084], [0102], and [0108]).

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to form an object of at least 300 kg as taught by Lemon using the powder metallurgy process and hard metal material taught by JP '479 because this forms objects with a non-segmented construction that allows the object to be made in one piece instead of having to combine two or more objects together (Lemon [0027] and [0108]). JP '479 and Lemon are analogous art because they both in the same field of endeavor of powder metallurgy. MPEP 2141.01(a)I.

Regarding claim 52, JP '479 teaches the hard metal material contains 0 to 5 volume percent of an iron group metal with tungsten and boride ([0010] and [0016]), where the presence of tungsten and boride indicates the formation of tungsten boride particles. This increases the amount of refractory material particles present in JP '479 to be from 0 to 45 (excluding 0) percent by volume, which is the sum of the percent volume of the cubic compound and the

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tungsten boride compound. This overlaps from 5 to 45 percent by volume with instant claim 51. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material volume percent overlap with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 55, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from 5 – 40 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 57, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from greater than 15 – 40 volume % with the instant claim, where the instant claim is being interpreted such that the hard metal material comprises greater than 15 to 50 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 58, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from 5 – less than 30 volume % with the instant claim, where the instant claim is being interpreted such that the hard metal material comprises 5 to less than 30 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

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Regarding claim 61, JP '479 does not explicitly teach the size of the NbC particles.

However, JP '479 does teach the average particle diameter of comparable cubic compound particles range from about 0.1 to about 1.7 μm ([0020] and [0023]), with specific examples such as Mo₂C being 0.1 μm , TaC being 1.1 μm , (W,Ti,Ta)C being 1.2 μm , and Cr₃C₂ being 1.7 μm .

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made for the NbC particles taught by JP '479 to also be around this range of average particle diameters because these are all examples of cubic compounds, which serve the same functional purpose in the final product of improving wear resistance ([0015]).

Therefore, this range of particle size overlaps from 1 to about 1.7 μm with the instant claims. A *prima facie* case of obviousness exists when the instantly claimed ranges of average particle diameter overlap with ranges taught by JP '479. See MPEP Section 2144.05.

Regarding claim 62, JP '479 does not explicitly teach the size of the NbC particles.

However, JP '479 does teach the average particle diameter of comparable cubic compound particles range from about 0.1 to about 1.7 μm ([0020] and [0023]), with specific examples such as Mo₂C being 0.1 μm , TaC being 1.1 μm , (W,Ti,Ta)C being 1.2 μm , and Cr₃C₂ being 1.7 μm .

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made for the NbC particles taught by JP '479 to also be around this range of average particle diameters because these are all examples of cubic compounds, which serve the same functional purpose in the final product of improving wear resistance ([0015]).

Therefore, this range of particle sizes is less than the maximum 500 μm diameter of the instant claims. A *prima facie* case of obviousness exists when the instantly claimed ranges of average particle diameter falls within the range taught by JP '479. See MPEP Section 2144.05.

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Regarding claim 63, JP '479 does not explicitly teach the size of the NbC particles.

However, JP '479 does teach the average particle diameter of comparable cubic compound particles range from about 0.1 to about 1.7 μm ([0020] and [0023]), with specific examples such as Mo₂C being 0.1 μm , TaC being 1.1 μm , (W,Ti,Ta)C being 1.2 μm , and Cr₃C₂ being 1.7 μm .

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made for the NbC particles taught by JP '479 to also be around this range of average particle diameters because these are all examples of cubic compounds, which serve the same functional purpose in the final product of improving wear resistance ([0015]).

Therefore, this range of particle sizes is less than the maximum 200 μm diameter of the instant claims. A *prima facie* case of obviousness exists when the instantly claimed ranges of average particle diameter falls within the range taught by JP '479. See MPEP Section 2144.05.

Regarding claim 64, JP '479 does not explicitly teach a uniform dispersion of the particles of the refractory material in the host material. However, JP '479 does teach the cemented carbide is made through a powder metallurgy process where prior to forming the green compact, the powders are mixed together ([0023]). Mixing the powders together indicates a uniform dispersion of all particle types throughout the cemented carbide, such that, upon formation of the final product, the resulting microstructure, which includes the dispersion of the refractory material particles, will be uniform.

5. **Claims 51, 52, 55, 57-60** is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '459 (US 4119459) and further in view of JP '479 (JP2005068479 machine translation) as evidenced by OnlineMetals (Melting points of various metals. www.onlinemetals.com/meltpt.cfm. February 4, 2001.).

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Regarding claim 51, US '459 teaches a cast composite body composed of cast iron and sintered cemented carbide where the carbides are WC-Co-type carbides, or carbides with at least one of Ti, Ta, and Nb to make constructional elements of different kinds used under wearing conditions for example cutting tips or inserts in rock drilling (column 1 lines 35-37 and 48-63 and column 2 lines 40-50). A composite body with sintered cemented carbide reads on a hard metal material and the cast iron reads on a ferrous alloy host metal. Constructional elements as taught read on materials of at least 100 kgs.

According to US '459 the cemented carbides can comprise carbides of Ti, Ta, Nb or other metals (column 2 lines 40-50), which includes carbides containing niobium or carbides containing titanium and niobium. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

US '459 teaches making the instantly claimed product by casting where some of the hard metal particles dissolve (column 3 lines 5-23) and the casting temperature is 150 to 400°C greater than the liquidus temperature of the cast alloy (column 4 lines 17-30). While some of the carbide particles dissolve into the cast iron alloy matrix, some of the carbide particles remain intact as indicated by Fig. 1 (column 5 lines 11-18), where A the undissolved hard metal grains or particles are the insoluble refractory material particles in the host matrix. Further, the melting temperature of cast iron is 1204°C (as evidenced by OnlineMetals), and 150 to 400°C is 1354 to 1604°C, which is still less than the melting temperature of NbC (as evidenced by Storms) and the melting temperature of TiNbC (as evidenced by Rudy?). This indicates that NbC and TiNbC

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particles will not fully dissolve in the cast iron alloy, where the particles that do not dissolve are the insoluble particles in the host metal matrix.

US '459 is silent to the amount of refractory material particles in the host metal matrix.

JP '479 teaches a cemented carbide ([0001]) comprising 0 to 40 (excluding 0) percent by volume of a cubic compound, specifically, VC, TaC, NbC, TiN, HfN, (W,Ti)(C,B), (W,Ti,Ta)C, (W,Ti,Ta)(C,N), (W,Zr)(C,B), (Ti,W,Cr)C, or (Ti,W,Mo)(C,N,B) ([0015]) with an iron group metal as a main component ([0013]). A cemented carbide reads on a hard metal material and a cubic compound reads on a refractory material.

According to US '672 the hard particles can comprise NbC. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

An iron group metal reads on a ferrous alloy, a stainless steel, an austenitic-manganese steel, and an iron-based or a nickel-based or a cobalt-based superalloy because Fe, Ni, and Co are all part of the iron group metals, and an alloy based on any of these metals will include that because as the main component.

JP '479 teaches making the instantly claimed product using a powder metallurgy process where sintering is performed between 1360 and 1420°C ([0023] and Table 2 in the original document). 1360 to 1420°C is lower than the melting temperature of the NbC particles as evidenced by Storms (Fig. 1), indicating that during the processing the NbC particles will remain insoluble in the host metal because they will not get hot enough to melt and dissolve into the host matrix during processing of the hard metal material.

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It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to include 0 to 40 (excluding 0) volume percent of the refractory material particles as taught by JP '479 as the amount of particles in the cast iron alloy of US '672 because both teach a hard metal material as indicated above that undergo comparable processing temperatures and the particles are needed to improve the wear resistance of the alloy, but are limited to 40 volume percent because more than that decreases the effect of improving the wear resistance (JP '479 [0015]).

Therefore the volume % of refractory material particles in US '459 and further in view of JP '479 overlaps from greater than 10 to 40 percent with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material volume percent overlap with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 52, US '459 teaches a cast composite body composed of cast iron and sintered cemented carbide where the carbides are normally WC-Co-type carbides with possible additions of carbides with at least one of Ti, Ta, and Nb (column 1 lines 35-37 and 48-63 and column 2 lines 40-50, where WC-Co-type carbides read on particles of tungsten carbide.

Regarding claim 55, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from greater than 10 to 40 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

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Regarding claim 57, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from greater than 15 – 40 volume % with the instant claim, where the instant claim is being interpreted such that the hard metal material comprises greater than 15 to 50 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 58, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from greater than 10 – less than 30 volume % with the instant claim, where the instant claim is being interpreted such that the hard metal material comprises 5 to less than 30 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 59, US '459 and JP '479 do not explicitly teach the weight percent of the particles of the refractory material relative to the total weight of the material. However, US '459 further in view of JP '479 teach the product of instant claim 1, including the volume percent of refractory material particles. It is expected that a hard metal material that has the required volume percent of refractory material particles would also have the required 12 to 33 weight percent of the particles because both volume percent and weight percent are related to how many particles are present in the host metal. A *prima facie* case of obviousness exists when the claimed and prior art products are identical or substantially identical in structure. See MPEP 2112.01I.

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Regarding claim 60, US '459 and JP '479 do not explicitly teach the weight percent of the particles of the refractory material relative to the total weight of the material. However, US '459 further in view of JP '479 teach the product of instant claim 1, including the volume percent of refractory material particles. It is expected that a hard metal material that has the required volume percent of refractory material particles would also have the required 12 to 25 weight percent of the particles because both volume percent and weight percent are related to how many particles are present in the host metal. *A prima facie* case of obviousness exists when the claimed and prior art products are identical or substantially identical in structure. See MPEP 2112.01I.

6. **Claim 65** is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '459 (US 4119459) and further in view of JP '479 (JP2005068479 machine translation) as applied to claim 51 above, and further in view of US '936 (US PG Publication 20080226936).

Regarding claim 65, US '459 further in view of JP '479 is silent to the hard metal material including a non-uniform dispersion of particles of the refractory material in the host metal.

US '936 teaches a method of centrifugally casting an iron alloy with MC carbides in the matrix in order to form an outer layer that has more MC carbides dispersed ([0011]-[0014], [0019]-[0023], and Fig. 4(a)), where the MC particles preferentially gather along one edge of the casting due to the applied centrifugal force during casting.

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to perform the casting process of US '459 as a centrifugal casting process in order to create a non-uniform dispersion of refractory material particles because it

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creates a final product that has excellent wear resistance, surface roughening resistance, and seizure resistance without the problem of MC carbide segregation (US '936 [0010]).

7. **Claims 51, 52, 55, and 57-65** are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Wragg (US 5,720,830) as evidenced by Uralmashplant (Uralmashplant "Rolls for Rolling Mills.").

Regarding claim 51, Wragg teaches a cast iron and steel comprising carbide particles in an amount of up to 20% by volume where the alloy carbide is selected from the group comprising chromium, molybdenum, titanium, tungsten, niobium, vanadium, or mixed carbides thereof where the product is formed by introducing alloy carbide particles into molten engineering ferrous metal and pouring the mixture into a mould where the material is used to make a rolling mill roll in a hot strip or cold strip mill for iron or steel (column 1 lines 7-8 and 25-45, column 4 lines 29-32 and 62-67, and column 6 lines 20-36).

The carbide particles read on particles of a refractory metal, where both niobium carbide and a mixed carbide of niobium titanium are taught. When the species is clearly name, the species claim is anticipated no matter how many other species are additionally named. MPEP 2131.02II. A cast iron and steel read on the host metal being a ferrous alloy. The amount of carbide particles taught overlaps with the amount instantly claimed. A *prima facie* case of obviousness exists where the claimed ranges or amounts overlap or lie inside those taught by the prior art. MPEP 2144.05I. Using the material to make a rolling mill roll in a hot strip or cold strip mill for iron or steel reads on the material being at least 100 kgs as evidenced by Uralmashplant where rolls for hot-rolling mills and cold-rolling mills have a maximum weight of 5 to 55 tons (about 4,500 to 50,000 kgs) (pages 4 and 5).

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Regarding claim 52, Wragg teaches the alloy carbide is selected from the group comprising chromium, molybdenum, titanium, tungsten, niobium, vanadium or mixed carbides thereof (column 4 lines 29-32). Therefore Wragg teaches carbides of tungsten. When the species is clearly name, the species claim is anticipated no matter how many other species are additionally named. MPEP 2131.02II.

Regarding claims 55, 57, and 58, Wragg teaches the amount of alloy carbide particles added is such as to achieve up to 20% by volume of alloy carbide particles in the solid metal (column 4 lines 62-67). This overlaps with that instantly claimed. A *prima facie* case of obviousness exists where the claimed ranges or amounts overlap or lie inside those taught by the prior art. MPEP 2144.05I.

Regarding claims 59 and 60, Wragg teaches the amount of alloy carbide particles added is such as to achieve up to 20% by volume of alloy carbide particles in the solid metal, where the alloy carbide particles include niobium carbide and the solid metal is a ferrous metal (column 1 lines 7-8 and column 4 lines 29-32 and 62-67). Assuming the refractory particles are niobium carbide with a density of 7.82 g/cm^3 and the host metal is a ferrous metal with a density ranging from 7.75 g/cm^3 to 8.05 g/cm^3 this results in a maximum weight percent of refractory particles ranging from 19.5 wt% to 20 wt%, which both overlap with that instantly claimed. A *prima facie* case of obviousness exists where the claimed ranges or amounts overlap or lie inside those taught by the prior art. MPEP 2144.05I.

Regarding claims 61-63, Wragg teaches the alloy carbide particles preferably have a maximum dimension of up to $10 \mu\text{m}$ (column 2 lines 60-67 and column 4 lines 59-61). A *prima*

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facie case of obviousness exists where the claimed ranges or amounts overlap or lie inside those taught by the prior art. MPEP 2144.05I.

Regarding claim 64, Wragg teaches the alloy carbide particles are distributed uniformly throughout the casting (column 1 lines 54-62).

Regarding claim 65, Wragg teaches forming the material by an electroslag remelting process which causes a relatively high and uniform distribution of alloy carbide adjacent the mold wall and a low uniform distribution of alloy carbide particles at or adjacent to the centre of the ingot, where the electroslag remelting operation forms a part having an outer hardened part, a first inner part having a first composition, and a second outer part having a second composition (column 6 lines 37-67 and column 7 lines 1-22). This results in a variation of alloy carbide particle concentration throughout the final product, which reads on a non-uniform dispersion of refractory material particles in the host metal.

8. **Claims 53 and 54** are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Wragg (US 5,720,830) as evidenced by Uralmashplant (Uralmashplant “Rolls for Rolling Mills.”) as applied to claim 51 above, and further in view of Chen (K. Chen, L. Zhao. “Elastic properties, thermal expansion coefficients and electronic structures of $Ti_{0.75}X_{0.25}C$ carbides.” Journal of Physics and Chemistry of Solids 68 (2007) 1805-1811.).

Regarding claims 53 and 54, Wragg teaches the alloy carbide is selected from the group comprising chromium, molybdenum, titanium, tungsten, niobium, vanadium or mixed carbides thereof (column 4 lines 29-32). Mixed carbides of titanium and niobium read on a chemical mixture of niobium carbide and titanium carbide.

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Wragg is silent to the formula of the mixture of niobium carbide and titanium carbide particles.

Chen teaches $Ti_{0.75}Nb_{0.25}C$ carbides (Abstract, Tables 104, 6. Conclusions).

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made in the process of Wragg to include $Ti_{0.75}Nb_{0.25}C$ carbide particles as taught by Chen because these particles have enhanced hardness, good ductility, and a better match to thermal expansion coefficients of metallic substrates relative to TiC particles (Chen 6. Conclusions). One of ordinary skill in the art would understand that these particles are harder and at elevated temperatures the better matched thermal expansion coefficient minimizes the occurrence of cracking within the matrix at elevated temperature.

9. **Claims 53 and 54** are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Wragg (US 5,720,830) as evidenced by Uralmashplant (Uralmashplant “Rolls for Rolling Mills.”) as applied to claim 51 above, and further in view of Choi (Choi, Hwang, Kim. J. Am. Ceram. Soc. 85 [9] 2313-2318 (2002)).

Regarding claims 53 and 54, Wragg teaches the alloy carbide is selected from the group comprising chromium, molybdenum, titanium, tungsten, niobium, vanadium or mixed carbides thereof (column 4 lines 29-32). Mixed carbides of titanium and niobium read on a chemical mixture of niobium carbide and titanium carbide.

Wragg is silent to the formula of the mixture of niobium carbide and titanium carbide particles.

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Choi teaches the impact of sintering temperature and time on the grain changes of $\text{Nb}_{0.75}\text{Ti}_{0.25}\text{C}$ and $\text{Nb}_{0.5}\text{Ti}_{0.5}\text{C}$ particles in a Co matrix during liquid phase sintering (page 2313 abstract and page 2314 Section II. Experimental Procedure).

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to use the $\text{Nb}_{0.75}\text{Ti}_{0.25}\text{C}$ or $\text{Nb}_{0.5}\text{Ti}_{0.5}\text{C}$ powder taught by Choi as the composition for the NbTiC particles in Wragg because these particles exhibit grain growth inhibition, which increases the barrier for grain growth (Choi V. Conclusion). During casting, the mixture of niobium carbide and titanium carbide particles would be expected to maintain size and shape and coarsen less than NbC particles because of the substitution of titanium within the particles.

Response to Declaration of Kevin Dolman under 37 C.F.R. §1.132 and Arguments

Applicant's arguments and the declaration of Kevin Dolman filed under 37 C.F.R. §1.132 filed November 21, 2016 have been fully considered but they are not persuasive. The arguments presented in the response and in the declaration are similar. Therefore, they have all been addressed below.

In the declaration, the applicant argues that the components manufactured in US '672 are approximately 0.5 – 1.0 kg depending on the densities of the different types of cermets and that the high pressures and long heat treatment times at elevated temperatures to ensure sintering limits the mass of powder metallurgy products to items much less than 10 kgs. Further, the applicant argues in the declaration that components with masses of at least 100 kgs are well outside the capabilities of and could not be manufactured by powder metallurgy manufacturing processes. Finally, the applicant argues in the declaration that it is not possible to determine from

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the information provided whether US '672 could produce products of at least 100 kgs, and it is the applicant's expectation that this would not be possible. Similarly, in the response the applicant argues that the application explains on page 1 line 28 to page 2 line 20 that sintered powder products of the type disclosed in US '672 and JP '479 are different products compared to those recited in the claims because those of ordinary skill in the art would recognize that the powder metallurgy techniques described in US '672 are unsuitable for preparing products of at least 100 kgs.

The examiner respectfully disagrees. As evidenced by Lemon (US 2008/0193798), it is known in the art of powder metallurgy that parts on the order of 300 kgs can be made using a powder metallurgy process that includes both pressing the powder and sintering at elevated temperature ([0011], [0017], [0021], [0027]). 300 kgs is more than the at least 100 kg instant claimed. The instant specification teaches "Powder metallurgy is a useful process for manufacturing relatively small, simple-shaped, wear resistant components...However, powder metallurgy is not a practical process for manufacturing larger, complex-shaped, hard metal, wear resistant components" in [0009]. Instant claim 51 limits the size of the hard metal material, but not the shape. Therefore, a large, simple-shaped component reads on the instant claims.

In the declaration the applicant argues that it is not clear whether the microstructures and metallurgical bonds of products made by the powder metallurgy and casting processes would be the same or different. In the response the applicant argues that the precise form of the metallurgical bonds described in US '672 and JP '479 is not clear, so it is not possible to say whether the microstructures and metallurgical bond is the same as the castings recited in claim 51.

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These arguments include all possibilities that the microstructures can be the same or different. The instant claims do not include language that distinguishes the product of a casting from that produced by powder metallurgy. The current prior art that uses powder metallurgy forms a product that has all the instantly claimed product features, therefore it has not been overcome.

In the declaration the applicant argues that the sintered products of US '672 would not include the refractory material particles that are insoluble in the host metal at the casting temperature because it is highly likely there would be diffusion between the first and second regions of the cermets disclosed. In the response the applicant argues that sintering processes as described in US '672 involve solid state diffusion between powders compacted together at high temperatures and pressures, which would not result in a product in which refractory material particles (NbC and (Nb,Ti)C) are insoluble in the host metal at the casting temperature.

US '672 define the first region as a cemented hard particle material with at least 60 percent by volume dispersed hard particles and the second region in a composite article with 0 up to 50 volume percent of hard particles ([0029] and [0030]). It is unclear in this argument what is diffusing between the first and second regions of the cermet. It appears to be the hard particles. It is unclear to the examiner that if diffusion is occurring between the first and second regions why it would not include insoluble refractory material particles. US '672 requires these different amounts of hard particles in each region in a composite article, which results in the article having two regions with different amounts of hard particles.

Further, claim 51 uses the transitional phrase "comprise" such as "wherein the particles of the refractory material comprise". This language is open-ended and does not exclude the

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occurrence of additional, unrecited elements from the prior art. MPEP 2111.03. Therefore, as long as at least part of the hard particles remain insoluble they read on the comprising language of the claim.

In the response the applicant argues that in US '672 the cemented hard particles of the sintered powder metal articles must be at least 60 volume % of the total volume of the product, which does not overlap with the recitation in claim 51 of a dispersion of greater than 10 volume % and up to 50 volume % of particles of a refractory material.

The examiner agrees that US '672 defines a "cemented hard particle material" as a composite material with at least 60 volume % of the hard particle discontinuous phase ([0029]). However, US '672 also teaches that the second region of the composite article may include 0 up to 50 volume % of hard particles ([0030]). This volume percent of hard particles overlaps with that instantly claimed. A *prima facie* case of obviousness exists where the claimed ranges or amounts overlap or lie inside those taught by the prior art. MPEP 214405.I.

In the declaration the applicant argues that based on the English language translation of JP '479 [0008] and [0009] teach that tungsten carbide is a key component of the alloy, there is no mention of using other materials, and it is not obvious to substitute NbC and (Nb,Ti)C refractory material particles for the tungsten carbide-containing compound. In the response the applicant argues that JP '479 specifies the use of tungsten carbide (WC) as a critical feature of the disclosed composites and it provides no mention of using other materials.

The examiner respectfully disagrees. A reference may be relied upon for all it would have reasonably suggested to one having ordinary skill in the art, including nonpreferred embodiments. MPEP 2123I. Further, a reference that clearly names the claimed species

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anticipates the claim no matter how many other species are named. MPEP 2131.02II. JP '479 contains more than just [0008] and [0009]. As indicated by both the machine translation and the written English translation, [0015] of JP '479 teaches the component can replace some of the hexagonal crystal compound and can contain 0 – 40% (excluding 0) by volume of a hexagonal crystal compound, and in this paragraph JP '479 specifically mentions NbC as a hexagonal crystal compound. Further, instant claim 51 uses the transitional phrase "comprise", which is inclusive or open-ended and does not exclude the occurrence of other elements from the prior art. This allows for the occurrence of both the tungsten carbide and the NbC within the material taught by JP '479, such that it still reads on the instant claims.

In the declaration the applicant argues that US '459 teaches an "alloying phase or intermetallic zone" which is not part of the casting defined in amended claim 51.

The examiner respectfully disagrees. Instant claim 51 recites "the casting comprises a host metal and a dispersion" and "the particles of the refractory material comprise...particles that are insoluble in the host metal at the casting temperature". This claim language uses the transitional phrase "comprise". The term "comprise" is inclusive or open-ended and does not exclude additional, unrecited elements from the prior art. MPEP 2111.03. Therefore, as long as at least part of the particle is insoluble in the host metal at the casting temperature, this reads on the instant claims. While an alloying phase or intermetallic zone does exist between the particle and the host metal, part of the particle remains intact. The intact part of the particle reads on a particle that is insoluble in the host metal at the casting temperature, where the comprising language allows for part of the particle to be soluble and part of the particle to be insoluble.

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In the declaration the applicant argues that US '459 is a composite of WC particles and Co particles and does not disclose the use of WC or other refractory material particles on its own. Further, the applicant argues that the composite body of US '459 is based on wear elements formed from "WC-Co bonded in graphitic cast iron", where WC is known to be very soluble in molten iron, therefore it can be expected that there will be dissolution of WC from the sintered cemented carbide into the cast iron. In the response the applicant argues that persons of ordinary skill in the art would recognize that WC is very soluble in molten iron, which would result in expected dissolution of WC from the sintered cemented carbide into the cast iron of the composites disclosed in US '459, therefore the castings of claim 51 are not obvious.

The examiner notes that the claim language uses the transitional phrase "comprise". In claim 51 it recites "the casting comprises a host metal and a dispersion" and "the particles of the refractory material comprise". This language is inclusive or open-ended and does not exclude additional, unrecited elements from the prior art. MPEP 2111.03. This language allows for the occurrence of other refractory particles in the matrix aside from those instantly claimed. It also allows for the WC-Co refractory particles to be part of the refractory particles as long as at least some of the refractory particles comprise NbC and/or (Nb,Ti)C. As presented below, US '459 does teach the occurrence of NbC particles.

The applicant argues that US '459 does not disclose castings that comprise refractory material particles of NbC and/or (Nb,Ti)C as instantly claimed.

The examiner respectfully disagrees. A patent may be relied upon for all it would have reasonably suggested to one having ordinary skill in the art, including nonpreferred embodiments. MPEP 2123I. Further, a reference that clearly names the claimed species

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anticipates the claim no matter how many other species are named. MPEP 2131.02II. US '459 teaches "the cemented carbide is present as pieces, crushed material, powder, pressed bodies, or some other shape. The cemented carbide, which contains at least one carbide besides binder metal, is normally of WC-Co-type with possible additions of carbides of Ti, Ta, Nb or other metals" (column 2 lines 40-50). This teachings includes the occurrence of carbides of Nb, which read on refractory material particles of NbC. Therefore it is unclear to the examiner in light of this teaching, how US '459 does not disclose castings comprising refractory material particles of NbC as argued by the applicant.

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Contact Information

Any inquiry concerning this communication or earlier communications from the examiner should be directed to **STEPHANI HILL** whose telephone number is (571)272-2523. The examiner can normally be reached on MON - FRI: 10:00AM-4:00PM EST.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at <http://www.uspto.gov/interviewpractice>.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Keith Walker can be reached on (571) 272-3458. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/S. H./
Examiner, Art Unit 1735

/KEITH WALKER/
Supervisory Patent Examiner, Art Unit 1735

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Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

mkeipdocket@michaelbest.com

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DETAILED ACTION

Remarks

Claims 51, 55, 57, and 58 are amended. Claims 1-50, 56, and 66-68 are cancelled.

Claims 51-55 and 57-65 are pending examination.

Notice of Pre-AIA or AIA Status

The present application is being examined under the pre-AIA first to invent provisions.

Information Disclosure Statement

While the European Patent Office Action for Application No. 11739260.5 dated March 2, 2016 (6 pages) filed with the May 2, 2016 information disclosure statement (IDS) was considered, it is noted that the document refers to **D4** and **D5** with no indication what documents **D4** and **D5** refer to.

Abstract

The objection to the abstract is withdrawn due to argument, where it is acknowledged that for a 371 application the cover page of the corresponding international application can be used for the abstract.

Drawings

The drawings filed on August 6, 2012 are accepted.

Claim Objections

Claim 51 is objected to because of the following informalities: in lines 2-3 repetition of the word "refractory" as "particles of a refractory material including (a) niobium carbide containing refractory particles" which can be written as "particles of a refractory material include (a) niobium carbide containing particles". Appropriate correction is required.

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Claim Rejections - 35 USC § 112

The rejection of claims 34, 35, and 56 under 112, fourth paragraph are withdrawn due to cancellation of these claims. The rejection of claims 52, 57, and 58 under 112, fourth paragraph are withdrawn due to amendment.

The following is a quotation of 35 U.S.C. 112(b):

(b) CONCLUSION.—The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the inventor or a joint inventor regards as the invention.

The following is a quotation of 35 U.S.C. 112 (pre-AIA), second paragraph:

The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

1. Claims 51-55 and 57-65 are rejected under 35 U.S.C. 112(b) or 35 U.S.C. 112 (pre-AIA), second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which the inventor or a joint inventor, or for pre-AIA the applicant regards as the invention.

In claim 51 lines 2-5 the limitation of "a dispersion of greater than 10 volume % and up to 50 volume % of particles of a refractory material including (a) niobium carbide containing refractory particles that are insoluble in the host metal at the casting temperature and/or (b) particles of a chemical mixture of niobium carbide and titanium carbide that are insoluble in the host metal at the casting temperature" renders the claim indefinite. It is unclear if this limitation requires all of the particles of a refractory material of (a) and/or (b) and all other particles of a refractory material to be limited to greater than 10 volume % and up to 50 volume % or if only the particles of a refractory material of (a) and/or (b) to be limited to greater than 10 volume % and up to 50 volume %. For the purposes of prosecution it will be given the broadest reasonable

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interpretation of requiring a dispersion of greater than 10 volume % and up to 50 volume % of only the particles (a) and/or (b) as instantly claimed.

Claims 52-55 and 57-65 are rejected as depending from claim 51.

Claim Rejections - 35 USC § 103

The following is a quotation of pre-AIA 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

The factual inquiries set forth in *Graham v. John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under pre-AIA 35 U.S.C. 103(a) are summarized as follows:

1. Determining the scope and contents of the prior art.
2. Ascertaining the differences between the prior art and the claims at issue.
3. Resolving the level of ordinary skill in the pertinent art.
4. Considering objective evidence present in the application indicating obviousness or nonobviousness.

2. Claims 51, 52, 55, 57-59, 60, and 64 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '672 (US PG Publication 20090293672) as evidenced by Storms (Storms and Krikorian. The niobium-niobium carbide system. J. Phys. Chem. 64 (10) 1960 pp. 1471-1477.) and Rudy (Rudy. Phase equilibria investigation of binary, ternary, and higher order systems. Technical Report AFML-TR-69-117, Part 1. August 1970.).

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Regarding claim 51, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles dispersed in a metal or metallic alloy ([0002] and [0031]) where the hard particles comprise carbide particles of at least one transition metal selected from titanium, chromium, vanadium, zirconium, hafnium, tantalum, molybdenum, niobium, and tungsten ([0035]) and metal or metallic alloy is steel, a nickel alloy, or a cobalt alloy ([0031], [0032], [0033], and [0042]).

Hard particles dispersed in a metal or metallic alloy read on a hard metal material, the hard particles are refractory materials, and the metal or metallic alloy reads on the host metal. The volume of hard particles taught by US '672 overlaps at greater than 10 to 50 volume % with that instantly claimed. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by US '672. See MPEP Section 2144.05.

According to US '672 permutations of the hard particles include niobium carbide or niobium titanium carbide. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

The requirement for the hard metal material to be in the form of a casting is product-by-process terminology. The limitation of casting was fully considered, but the casting process was determined to not impart additional structure to the product as instantly claimed. A *prima facie* base of obviousness exists when the product in a product-by-process claim is obvious over a product from the prior art and the claim is unpatentable even through the prior product was made by a different process. See MPEP 2113.

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Further, the limitation that the refractory particles are insoluble at the casting temperature will be interpreted as the refractory particles are insoluble at the processing temperature, where the temperature of any process that results in the instantly claimed product will meet this limitation.

US '672 teaches making the instantly claimed product using a powder metallurgy process where sintering is performed up to 1500°C ([0042]). 1500°C is lower than the melting temperature of either NbC or TiNbC particles as evidenced by the phase diagrams presented in Storms (Fig. 1) and Rudy (Figure 1). During processing the NbC or TiNbC particles will remain insoluble in the host metal because they will not get hot enough to melt and dissolve into the host matrix during processing of the hard metal material.

Regarding claim 52, US '672 teaches the hard particles comprise carbide particles of at least one transition metal selected from titanium, chromium, vanadium, zirconium, hafnium, tantalum, molybdenum, niobium, and tungsten ([0035]), where the particles include tungsten carbide. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

Regarding claim 55, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles ([0002] and [0031]), which overlaps from 5 to 40 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by US '672. See MPEP Section 2144.05.

Regarding claim 57, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles ([0002] and [0031]). This encompasses the instantly claimed

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range, where the instant claim is being interpreted such that the hard metal material comprises greater than 15 to 50 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by US '672. See MPEP Section 2144.05.

Regarding claim 58, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles ([0002] and [0031]). This encompasses the instantly claimed range, where the instant claim is being interpreted such that the hard metal material comprises 5 to less than 30 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by US '672. See MPEP Section 2144.05.

Regarding claim 59, US '672 does not explicitly teach the weight percent of the particles of the refractory material relative to the total weight of the material. However, US '672 does teach the product of instant claim 1, including the volume percent of refractory material particles. It is expected that a hard metal material that has the required volume percent of refractory material particles would also have the required 12 to 33 weight percent of the particles because both volume percent and weight percent are related to how many particles are present in the host metal. A *prima facie* case of obviousness exists when the claimed and prior art products are identical or substantially identical in structure. See MPEP 2112.01I.

Regarding claim 60, US '672 does not explicitly teach the weight percent of the particles of the refractory material relative to the total weight of the material. However, US '672 does teach the product of instant claim 1, including the volume percent of refractory material particles. It is expected that a hard metal material that has the required volume percent of refractory

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material particles would also have the required 12 to 25 weight percent of the particles because both volume percent and weight percent are related to how many particles are present in the host metal. A *prima facie* case of obviousness exists when the claimed and prior art products are identical or substantially identical in structure. See MPEP 2112.01I.

Regarding claim 64, US '672 teaches a uniform dispersion of tungsten carbide refractory metal particles in the second region of an article (Fig. 3, [0017], and [0067]), where the dark tungsten carbide particles as indicated below in Figure A are uniformly dispersed throughout the host metal.

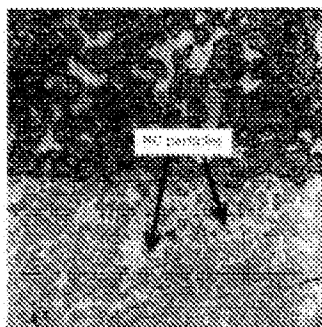


Figure A: Annotated Fig. 3 from US '672 indicating the uniform dispersion of metal carbide (MC) particles throughout the host metal matrix.

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to substitute NbC or TiNbC particles for the tungsten carbide particles in Fig. 3 because US '672 teaches that the taught articles comprises carbide particles of at least one transition metal selected from titanium, chromium, vanadium, zirconium, hafnium, tantalum, molybdenum, niobium, and tungsten ([0035]), where NbC or TiNbC particles serve the same function as the tungsten carbide particles.

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3. Claims 53, 54, and 61-64 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '672 (US PG Publication 20090293672) as applied to claim 51 above, and further in view of Choi (Choi, Hwang, Kim. J. Am. Ceram. Soc. 85 [9] 2313-2318 (2002)).

Regarding claim 53, US '672 teaches the hard particles can comprise niobium carbide of niobium titanium carbide as detailed above in the analysis of claim 51.

US '672 is silent to the composition of the niobium titanium carbide particles when they are the composition of the refractory material particles.

Choi teaches the impact of sintering temperature and time on the grain changes of $Nb_{1-x}Ti_xC$ particles in a Co matrix during liquid phase sintering (page 2313 abstract and page 2314 Section I. Introduction column 1 lines 1-12), where 1-x reads on x and x reads on y.

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to use the $Nb_{1-x}Ti_xC$ powder taught by Choi as the composition for the NbTiC particles in US '672 because both Choi and US '672 disclose a powder metallurgy process where sintering is performed at 1500°C during which time the NbTiC powders do not melt, but they do undergo grain changes (Choi page 2317 section V. Conclusion).

Regarding claim 54, US '672 teaches the hard particles can comprise niobium carbide of niobium titanium carbide as detailed above in the analysis of claim 51.

US '672 is silent to the composition of the niobium titanium carbide particles when they are the composition of the refractory material particles.

Choi teaches the impact of sintering temperature and time on the grain changes of $Nb_{0.75}Ti_{0.25}C$ and $Nb_{0.5}Ti_{0.5}C$ particles in a Co matrix during liquid phase sintering (page 2313 abstract and page 2314 Section II. Experimental Procedure).

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It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to use the $\text{Nb}_{0.75}\text{Ti}_{0.25}\text{C}$ or $\text{Nb}_{0.5}\text{Ti}_{0.5}\text{C}$ powder taught by Choi as the composition for the NbTiC particles in US '672 because the powders are specific compositions of NbTiC powders and both Choi and US '672 disclose a powder metallurgy process where sintering is performed at 1500°C during which time the NbTiC powders do not melt, but they do undergo grain changes (Choi page 2317 section V. Conclusion).

Regarding claim 61, Choi teaches the size of the NbTiC particles is in a range of 1 to 150 μm (Fig. 1 and Fig. 2), where the scale bars on the figures indicate the particles are within the instantly claimed range.

Regarding claim 62, Choi teaches the size of the NbTiC particles have a size of less than 500 μm (Fig. 1 and Fig. 2), where the scale bars on the figures are 10 μm and 25 μm or 50 μm , respectively, and none of the particles in the micrographs are larger than the scale bars.

Regarding claim 63, Choi teaches the size of the NbTiC particles have a size of less than 200 μm (Fig. 1 and Fig. 2), where the scale bars on the figures are 10 μm and 25 μm or 50 μm , respectively, and none of the particles in the micrographs are larger than the scale bars.

Regarding claim 64, both Choi and US '672 teach the final product has a uniform dispersion of particles of the refractory material in the host metal (Choi Fig. 1 and Fig. 2 and US '672 Fig. 3).

4. Claims 51, 52, 55, 57, 58, and 61-64 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over JP '479 (JP2005068479 machine translation) as evidenced by Storms (Storms and Krikorian. The niobium-niobium carbide system. J. Phys. Chem. 64 (10) 1960 pp. 1471-1477.).

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Regarding claim 51, JP '479 teaches a cemented carbide ([0001]) comprising 0 to 40 (excluding 0) percent by volume of a cubic compound, specifically, VC, TaC, NbC, TiN, HfN, (W,Ti)(C,B), (W,Ti,Ta)C, (W,Ti,Ta)(C,N), (W,Zr)(C,B), (Ti,W,Cr)C, or (Ti,W,Mo)(C,N,B) ([0015]) with an iron group metal as a main component ([0013]).

A cemented carbide reads on a hard metal material, a cubic compound reads on a refractory material, and the volume % of cubic compound overlaps from greater than 10 to 40 volume percent. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material volume percent overlap with the range taught by JP '479. See MPEP Section 2144.05.

According to US '672 the hard particles can comprise NbC. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

An iron group metal reads on a ferrous alloy, a stainless steel, an austenitic-manganese steel, and an iron-based or a nickel-based or a cobalt-based superalloy because Fe, Ni, and Co are all part of the iron group metals, and an alloy based on any of these metals will include that because as the main component.

The requirement for the hard metal material to be in the form of a casting is product-by-process terminology. The limitation of casting was fully considered, but the casting process was determined to not impart additional structure to the product as instantly claimed. A *prima facie* base of obviousness exists when the product in a product-by-process claim is obvious over a

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product from the prior art and the claim is unpatentable even through the prior product was made by a different process. See MPEP 2113.

Further, the limitation that the refractory particles are insoluble at the casting temperature will be interpreted as the refractory particles are insoluble at the processing temperature, where the temperature of any process that results in the instantly claimed product will meet this limitation.

JP '479 teaches making the instantly claimed product using a powder metallurgy process where sintering is performed between 1360 and 1420°C ([0023] and Table 2 in the original document). 1360 to 1420°C is lower than the melting temperature of the NbC particles as evidenced by Storms (Fig. 1), indicating that during the processing the NbC particles will remain insoluble in the host metal because they will not get hot enough to melt and dissolve into the host matrix during processing of the hard metal material.

Regarding claim 52, JP '479 teaches the hard metal material contains 0 to 5 volume percent of an iron group metal with tungsten and boride ([0010] and [0016]), where the presence of tungsten and boride indicates the formation of tungsten boride particles. This increases the amount of refractory material particles present in JP '479 to be from 0 to 45 (excluding 0) percent by volume, which is the sum of the percent volume of the cubic compound and the tungsten boride compound. This overlaps from 5 to 45 percent by volume with instant claim 51. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material volume percent overlap with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 55, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as

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discussed above in claim 51. This overlaps from 5 – 40 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 57, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from greater than 15 – 40 volume % with the instant claim, where the instant claim is being interpreted such that the hard metal material comprises greater than 15 to 50 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 58, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from 5 – less than 30 volume % with the instant claim, where the instant claim is being interpreted such that the hard metal material comprises 5 to less than 30 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 61, JP '479 does not explicitly teach the size of the NbC particles. However, JP '479 does teach the average particle diameter of comparable cubic compound particles range from about 0.1 to about 1.7 μm ([0020] and [0023]), with specific examples such as Mo₂C being 0.1 μm , TaC being 1.1 μm , (W,Ti,Ta)C being 1.2 μm , and Cr₃C₂ being 1.7 μm .

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It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made for the NbC particles taught by JP '479 to also be around this range of average particle diameters because these are all examples of cubic compounds, which serve the same functional purpose in the final product of improving wear resistance ([0015]).

Therefore, this range of particle size overlaps from 1 to about 1.7 μm with the instant claims. A *prima facie* case of obviousness exists when the instantly claimed ranges of average particle diameter overlap with ranges taught by JP '479. See MPEP Section 2144.05.

Regarding claim 62, JP '479 does not explicitly teach the size of the NbC particles. However, JP '479 does teach the average particle diameter of comparable cubic compound particles range from about 0.1 to about 1.7 μm ([0020] and [0023]), with specific examples such as Mo₂C being 0.1 μm , TaC being 1.1 μm , (W,Ti,Ta)C being 1.2 μm , and Cr₃C₂ being 1.7 μm .

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made for the NbC particles taught by JP '479 to also be around this range of average particle diameters because these are all examples of cubic compounds, which serve the same functional purpose in the final product of improving wear resistance ([0015]).

Therefore, this range of particle sizes is less than the maximum 500 μm diameter of the instant claims. A *prima facie* case of obviousness exists when the instantly claimed ranges of average particle diameter falls within the range taught by JP '479. See MPEP Section 2144.05.

Regarding claim 63, JP '479 does not explicitly teach the size of the NbC particles. However, JP '479 does teach the average particle diameter of comparable cubic compound particles range from about 0.1 to about 1.7 μm ([0020] and [0023]), with specific examples such as Mo₂C being 0.1 μm , TaC being 1.1 μm , (W,Ti,Ta)C being 1.2 μm , and Cr₃C₂ being 1.7 μm .

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It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made for the NbC particles taught by JP '479 to also be around this range of average particle diameters because these are all examples of cubic compounds, which serve the same functional purpose in the final product of improving wear resistance ([0015]).

Therefore, this range of particle sizes is less than the maximum 200 μm diameter of the instant claims. A *prima facie* case of obviousness exists when the instantly claimed ranges of average particle diameter falls within the range taught by JP '479. See MPEP Section 2144.05.

Regarding claim 64, JP '479 does not explicitly teach a uniform dispersion of the particles of the refractory material in the host material. However, JP '479 does teach the cemented carbide is made through a powder metallurgy process where prior to forming the green compact, the powders are mixed together ([0023]). Mixing the powders together indicates a uniform dispersion of all particle types throughout the cemented carbide, such that, upon formation of the final product, the resulting microstructure, which includes the dispersion of the refractory material particles, will be uniform.

5. Claims 51, 52, 55, 57-60 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '459 (US 4119459) and further in view of JP '479 (JP2005068479 machine translation) as evidenced by OnlineMetals (Melting points of various metals. www.onlinemetals.com/meltpt.cfm. February 4, 2001.).

Regarding claim 51, US '459 teaches a cast composite body composed of cast iron and sintered cemented carbide where the carbides are WC-Co-type carbides, or carbides with at least one of Ti, Ta, and Nb (column 1 lines 35-37 and 48-63 and column 2 lines 40-50). A composite

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body with sintered cemented carbide reads on a hard metal material and the cast iron reads on a ferrous alloy host metal.

According to US '459 the cemented carbides can comprise carbides of Ti, Ta, Nb or other metals (column 2 lines 40-50), which includes carbides containing niobium or carbides containing titanium and niobium. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

US '459 teaches making the instantly claimed product by casting where some of the hard metal particles dissolve (column 3 lines 5-23) and the casting temperature is 150 to 400°C greater than the liquidus temperature of the cast alloy (column 4 lines 17-30). While some of the carbide particles dissolve into the cast iron alloy matrix, some of the carbide particles remain intact as indicated by Fig. 1 (column 5 lines 11-18), where A the undissolved hard metal grains or particles are the insoluble refractory material particles in the host matrix. Further, the melting temperature of cast iron is 1204°C (as evidenced by OnlineMetals), and 150 to 400°C is 1354 to 1604°C, which is still less than the melting temperature of NbC (as evidenced by Storms) and the melting temperature of TiNbC (as evidenced by Rudy?). This indicates that NbC and TiNbC particles will not fully dissolve in the cast iron alloy, where the particles that do not dissolve are the insoluble particles in the host metal matrix.

US '459 is silent to the amount of refractory material particles in the host metal matrix.

JP '479 teaches a cemented carbide ([0001]) comprising 0 to 40 (excluding 0) percent by volume of a cubic compound, specifically, VC, TaC, NbC, TiN, HfN, (W,Ti)(C,B), (W,Ti,Ta)C, (W,Ti,Ta)(C,N), (W,Zr)(C,B), (Ti,W,Cr)C, or (Ti,W,Mo)(C,N,B) ([0015]) with an iron group

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metal as a main component ([0013]). A cemented carbide reads on a hard metal material and a cubic compound reads on a refractory material.

According to US '672 the hard particles can comprise NbC. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

An iron group metal reads on a ferrous alloy, a stainless steel, an austenitic-manganese steel, and an iron-based or a nickel-based or a cobalt-based superalloy because Fe, Ni, and Co are all part of the iron group metals, and an alloy based on any of these metals will include that because as the main component.

JP '479 teaches making the instantly claimed product using a powder metallurgy process where sintering is performed between 1360 and 1420°C ([0023] and Table 2 in the original document). 1360 to 1420°C is lower than the melting temperature of the NbC particles as evidenced by Storms (Fig. 1), indicating that during the processing the NbC particles will remain insoluble in the host metal because they will not get hot enough to melt and dissolve into the host matrix during processing of the hard metal material.

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to include 0 to 40 (excluding 0) volume percent of the refractory material particles as taught by JP '479 as the amount of particles in the cast iron alloy of US '672 because both teach a hard metal material as indicated above that undergo comparable processing temperatures and the particles are needed to improve the wear resistance of the alloy, but are limited to 40 volume percent because more than that decreases the effect of improving the wear resistance (JP '479 [0015]).

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Therefore the volume % of refractory material particles in US '459 and further in view of JP '479 overlaps from greater than 10 to 40 percent with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material volume percent overlap with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 52, US '459 teaches a cast composite body composed of cast iron and sintered cemented carbide where the carbides are normally WC-Co-type carbides with possible additions of carbides with at least one of Ti, Ta, and Nb (column 1 lines 35-37 and 48-63 and column 2 lines 40-50, where WC-Co-type carbides read on particles of tungsten carbide.

Regarding claim 55, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from 5 – 40 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 57, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from greater than 15 – 40 volume % with the instant claim, where the instant claim is being interpreted such that the hard metal material comprises greater than 15 to 50 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

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Regarding claim 58, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from 5 – less than 30 volume % with the instant claim, where the instant claim is being interpreted such that the hard metal material comprises 5 to less than 30 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 59, US '459 and JP '479 do not explicitly teach the weight percent of the particles of the refractory material relative to the total weight of the material. However, US '459 further in view of JP '479 teach the product of instant claim 1, including the volume percent of refractory material particles. It is expected that a hard metal material that has the required volume percent of refractory material particles would also have the required 12 to 33 weight percent of the particles because both volume percent and weight percent are related to how many particles are present in the host metal. A *prima facie* case of obviousness exists when the claimed and prior art products are identical or substantially identical in structure. See MPEP 2112.01I.

Regarding claim 60, US '459 and JP '479 do not explicitly teach the weight percent of the particles of the refractory material relative to the total weight of the material. However, US '459 further in view of JP '479 teach the product of instant claim 1, including the volume percent of refractory material particles. It is expected that a hard metal material that has the required volume percent of refractory material particles would also have the required 12 to 25 weight percent of the particles because both volume percent and weight percent are related to how many

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particles are present in the host metal. A *prima facie* case of obviousness exists when the claimed and prior art products are identical or substantially identical in structure. See MPEP 2112.01I.

6. Claim 65 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '459 (US 4119459) and further in view of JP '479 (JP2005068479 machine translation) as applied to claim 51 above, and further in view of US '936 (US PG Publication 20080226936).

Regarding claim 65, US '459 further in view of JP '479 is silent to the hard metal material including a non-uniform dispersion of particles of the refractory material in the host metal.

US '936 teaches a method of centrifugally casting an iron alloy with MC carbides in the matrix in order to form an outer layer that has more MC carbides dispersed ([0011]-[0014], [0019]-[0023], and Fig. 4(a)), where the MC particles preferentially gather along one edge of the casting due to the applied centrifugal force during casting.

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to perform the casting process of US '459 as a centrifugal casting process in order to create a non-uniform dispersion of refractory material particles because it creates a final product that has excellent wear resistance, surface roughening resistance, and seizure resistance without the problem of MC carbide segregation (US '936 [0010]).

Response to Arguments

Applicant's arguments, see page 6 paragraphs 1 and 2, filed February 18, 2016, with respect to the rejection of claims 31, 33, 35, 36, 51, 55, 58, and 64 under WO '354 (WO 94/10354) have been fully considered and are persuasive. The rejection under WO '354 (WO 94/10354) has been withdrawn.

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Applicant's arguments filed February 18, 2015 regarding the rejection of claims 31-36, 51, 52, 55-58, and 64 under US '672 (US 2009/0293672) have been fully considered but they are not persuasive.

The applicant argues that sintered hard material products of the type disclosed in US '672 are different products compared to those of the invention, and that on page 1 line 28 to page 2 line 20 of the instant specification it is taught that "Powder metallurgy is a useful process for manufacturing relatively small, simple-shaped wear resistant components... However, powder metallurgy is not a practical process for manufacturing larger, complex-shaped, hard metal, wear resistant components."

The examiner respectfully disagrees. As stated in the rejection, the requirement for the hard metal material to be in the form of a casting is product-by-process terminology. The limitation of casting was fully considered, but the casting process was determined to not impart additional structure to the product as instantly claimed. *A prima facie* base of obviousness exists when the product in a product-by-process claim is obvious over a product from the prior art and the claim is unpatentable even through the prior product was made by a different process. See MPEP 2113.

There is no evidence presented about how the structure or composition of the hard metal material as instantly claimed is different when cast versus sintered. While it is argued that larger objects cannot be formed through a sintering process, the size of the hard metal material is not claimed and there is no indication about how the structure of a sintered material is different from that of a cast one. Further, the limitation that the refractory particles are insoluble at the casting temperature will be interpreted as the refractory particles are insoluble at the processing

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temperature, where the temperature of any process that results in the instantly claimed product will meet this limitation.

In response to applicant's argument that the references fail to show certain features of applicant's invention, it is noted that the features upon which applicant relies (i.e., that the hard metal materials formed by sintered are different from those formed by casting because powder metallurgy cannot be used for manufacturing larger, complex-shaped, hard metal, wear resistant components) are not recited in the rejected claim(s). Although the claims are interpreted in light of the specification, limitations from the specification are not read into the claims. See *In re Van Geuns*, 988 F.2d 1181, 26 USPQ2d 1057 (Fed. Cir. 1993).

The applicant argues that the requirements that the product of the invention defined in claim 51 be a casting that the refractory material particles of this product be insoluble in the host metal at the casting temperature.

The examiner respectfully disagrees. The requirement of casting is product-by-process terminology, where determination of patentability is based on the product itself. If the product in the product-by-process claim is the same or obvious from a product of the prior art, then the claim is unpatentable even though the prior product was made by a different process. Once the examiner provides a rationale tending to show that the claimed product appears to be the same or similar to that of the prior art, although produced by a different process, the burden shifts to applicant to come forward with evidence establishing an unobvious difference between the claimed product and the prior art product. See MPEP 2113. Evidence establishing an unobvious difference of the product of US '672 over that instantly claimed has not been presented.

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Applicant's arguments filed February 18, 2015 regarding the rejection of claims 31-36, 51, 52, 55-58, and 61-64 under JP '479 (JP 2005-068479) have been fully considered but they are not persuasive.

The applicant argues that the machine translation is very unclear and it is difficult to form a clear view of the relevance of the disclosure in the citation.

In response to this, the examiner has provided a partial written English translation of [0010] and [0015] from JP '479, which clearly indicates the occurrence of 0 - 40 % (excluding 0) by volume of a hexagonal crystal compound comprised, specifically such as NbC in the boron-containing superhard alloy (see attached English translation).

The applicant argues that as shown in Table 4 on page 8 of JP '479, the total content of hard particles is above 80 vol.%, which is far above the upper limit of refractory material in the pending claims.

The examiner respectfully disagrees. The language of claim 51 is being interpreted as requiring greater than 10 volume % and up to 50 volume % of particles of a refractory material including (a) and/or (b) as discussed above in the 112, second paragraph rejection. Table 4 on page 8 of JP '479 indicates that the WC (tungsten carbide) content is above 80 vol. %, where the content of tungsten carbide is not limited by the claims.

The applicant argues that interstitial boron in the tungsten carbide hexagonal complex compound is essential for the cemented materials disclosed in JP '479, but is not a requirement for the hard metal material casting of the pending claims and that the "cubic" compounds disclosed in [0015] of JP '479 are an optional addition to the cemented carbide materials disclosed in JP '479.

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It is noted that claim 51 line 1 states "A hard metal material...including". The term "including" is synonymous with the transitional term "comprising", which is inclusive or open-ended and does not exclude additional, unrecited elements or method steps from the prior art. See MPEP 2111.03. Therefore, the tungsten carbide hexagonal complex compound that is essential for the cemented materials disclosed in JP '479 is allowed because of the open language of the instant claims.

Further, a reference may be relied upon for all that it would have reasonably suggested to one having ordinary skill in the art, including nonpreferred embodiments. See MPEP 2123. Even though the "cubic" compounds disclosed in [0015] of JP '479 are an optional addition, they are taught that they can be included from 0 to 40 volume %, which overlaps with that instantly claimed.

Applicant's arguments filed February 18, 2015 regarding the rejection of claims 51, 52, 55-60 under US '459 (US 4,119,459) have been fully considered but they are not persuasive.

The applicant argues that in US '459 the dissolution of carbide particles is essential, while the subject matter in claim 51 requires the refractory particles of the claimed casting to be insoluble in the host metal at the casting temperature and that this requirement does not allow for partial dissolution of the refractory particles.

The examiner respectfully disagrees. The instant claim uses comprising language, which is inclusive or open-ended and does not exclude additional unrecited elements. See MPEP 2111.03. Therefore, instant claim 1 requires a dispersion of refractory particles as claimed in a host metal, but also allows for the occurrence of other elements in the hard metal material such as the diffusion layer that forms between the hard metal particles and the host matrix in the prior

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art. As taught in column 3 lines 12-24 of US '459 and presented in the arguments on page 12, some of the hard metal particles are completely dissolved, but must not occur to such a great extent that most hard metal grains are completely transformed and lose the original wear resistance and hardness. This indicates that some of the hard metal grains remain as hard metal grains in the host metal in order to impart wear resistance and hardness to the host metal. This is further supported by Fig. 1 where hard metal particles are present after casting (column 5 lines 11-18).

Conclusion

THIS ACTION IS MADE FINAL. Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire **THREE MONTHS** from the mailing date of this action. In the event a first reply is filed within **TWO MONTHS** of the mailing date of this final action and the advisory action is not mailed until after the end of the **THREE-MONTH** shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than **SIX MONTHS** from the mailing date of this final action.

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Contact Information

Any inquiry concerning this communication or earlier communications from the examiner should be directed to **STEPHANI HILL** whose telephone number is (571)272-2523. The examiner can normally be reached on MON - FRI: 8:00AM-2:00PM EST.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Keith Walker can be reached on (571) 272-3458. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/S. H./
Examiner, Art Unit 1735

/KEITH WALKER/
Supervisory Patent Examiner, Art Unit 1735



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Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

mkeipdocket@michaelbest.com

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DETAILED ACTION

Response to Restriction Election

Applicant's election without traverse of Group I, claims 31-36, in the reply filed on June 16, 2015 is acknowledged.

Notice of Pre-AIA or AIA Status

The present application is being examined under the pre-AIA first to invent provisions.

Abstract

The abstract of the disclosure is objected to because the abstract of the disclosure does not commence on a separate sheet in accordance with 37 CFR 1.52(b)(4) and 1.72(b). A new abstract of the disclosure is required and must be presented on a separate sheet, apart from any other text.

Correction is required. See MPEP § 608.01(b).

Drawings

The drawings filed on August 6, 2012 are accepted.

Claim Rejections - 35 USC § 112

The following is a quotation of 35 U.S.C. 112(d):

(d) REFERENCE IN DEPENDENT FORMS.—Subject to subsection (e), a claim in dependent form shall contain a reference to a claim previously set forth and then specify a further limitation of the subject matter claimed. A claim in dependent form shall be construed to incorporate by reference all the limitations of the claim to which it refers.

The following is a quotation of 35 U.S.C. 112 (pre-AIA), fourth paragraph:

Subject to the [fifth paragraph of 35 U.S.C. 112 (pre-AIA)], a claim in dependent form shall contain a reference to a claim previously set forth and then specify a further limitation of the subject matter claimed. A claim in dependent form shall be construed to incorporate by reference all the limitations of the claim to which it refers.

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1. Claims 34, 35, 52, 56, 57, and 58 are rejected under 35 U.S.C. 112(d) or pre-AIA 35 U.S.C. 112, 4th paragraph, as being of improper dependent form for failing to further limit the subject matter of the claim upon which it depends, or for failing to include all the limitations of the claim upon which it depends.

Claims 34 and 56 require greater than 10 volume % particles of the refractory material dispersed in the host metal, which encompasses anything that contains greater than 10 volume % to 100 volume % particles. This range is broader than the 5 volume % to 50 volume % of particles of independent claims 31 and 51, which claims 34 and 56 depend from, respectively.

For the purposes of prosecution, claims 34 and 56 will be given the broadest reasonable interpretation to require greater than 10 volume % to 50 volume % of particles of the refractory material dispersed in the host matrix.

Claims 35 and 58 require less than 30 volume % particles of the refractory material dispersed in the host metal, which encompasses anything that contains 0 volume % to less than 30 volume % particles. This range is broader than the 5 volume % to 50 volume % of particles of claims 31 and 51, which claims 35 and 58 depend from respectively.

For the purposes of prosecution, claims 35 and 58 will be given the broadest reasonable interpretation to require 5 volume % to less than 30 volume % of particles of the refractory material dispersed in the host matrix.

Claim 52 adds carbides and/or nitrides and/or borides of tungsten to the particles of a refractory material from claim 51. However, in claim 51 line 2 the language “selected from” indicates a Markush-type claim, which implies “selected from the group consisting of (a) and (b)” (see MPEP 803.02), where the consisting of is closed languages that limits the particles of

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the refractory material to only (a) or (b) as recited in claim 51. The closed language prevents any dependent claims from adding other types of materials to the particles of a refractory material.

Claims 57 requires greater than 15 volume % particles of the refractory material dispersed in the host metal, which encompasses anything that contains greater than 15 volume % to 100 volume % particles. This range is broader than the 5 volume % to 50 volume % of particles of independent claim 51, which claim 57 depends from.

For the purposes of prosecution, claim 57 will be given the broadest reasonable interpretation to require greater than 15 volume % to 50 volume % of particles of the refractory material dispersed in the host matrix.

Applicant may cancel the claim(s), amend the claim(s) to place the claim(s) in proper dependent form, rewrite the claim(s) in independent form, or present a sufficient showing that the dependent claim(s) complies with the statutory requirements.

Claim Rejections - 35 USC § 103

The following is a quotation of pre-AIA 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

The factual inquiries set forth in *Graham v. John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under pre-AIA 35 U.S.C. 103(a) are summarized as follows:

1. Determining the scope and contents of the prior art.
2. Ascertaining the differences between the prior art and the claims at issue.

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3. Resolving the level of ordinary skill in the pertinent art.
 4. Considering objective evidence present in the application indicating obviousness or nonobviousness.
2. Claims 31, 33, 35, 36, 51, 55, 58, and 64 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over WO '354 (WO 9410354) as evidenced by Storms (Storms and Krikorian. The niobium-niobium carbide system. J. Phys. Chem. 64 (10) 1960 pp. 1471-1477.) and OnlineMetals (Melting points of various metals. www.onlinemetals.com/meltpt.cfm. February 4, 2001.).

Regarding claim 31, WO '354 teaches a pearlitic, bainitic, martensitic, or ferritic gray cast iron matrix containing 0.5 to 5 volume % MC type carbide particles, where M is at least one of Ti, Ta, Zr, Hf, Cr, V, and Nb (page 1 lines 33-37 and page 2 lines 1-5). A gray cast iron with carbide precipitates reads on a hard metal material, the MC type carbide particles read on the refractory material, and the amount of refractory material particles taught by WO '354 overlaps at 5 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by WO '354. See MPEP Section 2144.05.

Regarding claim 33, WO '354 teaches the gray cast iron matrix contains 0.5 to 5 volume % MC type carbide particles (page 1 lines 33-37 and page 2 lines 1-5), which overlaps at 5 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by WO '354. See MPEP Section 2144.05.

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Regarding claim 35, WO '354 teaches the gray cast iron matrix contains 0.5 to 5 volume % MC type carbide particles (page 1 lines 33-37 and page 2 lines 1-5). The instant claim is being interpreted such that that hard metal material comprises 5 to less than 30 volume % particles of the refractory metal, which overlaps at 5 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by WO '354. See MPEP Section 2144.05.

Regarding claim 36, WO '354 teaches a pearlitic, bainitic, martensitic, or ferritic gray cast iron matrix with MC type carbide particles (page 1 lines 33-37 and page 2 lines 1-5), where a pearlitic, bainitic, martensitic, or ferritic gray cast iron matrix reads on a ferrous alloy host metal.

Regarding claim 51, WO '354 teaches a pearlitic, bainitic, martensitic, or ferritic gray cast iron matrix containing 0.5 to 5 volume % MC type carbide particles, where M is preferably Nb and/or V (page 1 lines 33-37, page 2 lines 1-5, page 4 lines 20-23) and the material is achieved through a conventional casting process (page 5 lines 19-23). The niobium carbide (NbC) particles, which have high hardness and a high melting point, are added to the gray cast iron (page 4 lines 9-36), and they have a low solubility in the ferrous matrix with a 90% recovery of additions (page 5 lines 2-13). The 90% recovery of additions of the niobium carbide particles reads on the refractory particles that are insoluble in the host metal at the casting temperature.

A gray cast iron with carbide particles dispersed therein reads on a hard metal material, the refractory material particles are niobium carbide precipitates, and a pearlitic, bainitic, martensitic, or ferritic gray cast iron matrix reads on a ferrous alloy host metal. A reference that

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clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

The amount of refractory material particles taught by WO '354 overlaps at 5 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by WO '354. See MPEP Section 2144.05.

Alternatively regarding claim 51, WO '354 teaches a pearlitic, bainitic, martensitic, or ferritic gray cast iron matrix containing 0.5 to 5 volume % MC type carbide particles, where M is at least one of Ti, Ta, Zr, Hf, Cr, V, and Nb (page 1 lines 33-37, page 2 lines 1-5) and the material is achieved through a conventional casting process (page 5 lines 19-23). The carbide particles, which have high hardness and a high melting point, are added to the gray cast iron (page 4 lines 9-19).

A gray cast iron with carbide particles dispersed therein reads on a hard metal material, the refractory material particles are niobium carbide precipitates, and a pearlitic, bainitic, martensitic, or ferritic gray cast iron matrix reads on a ferrous alloy host metal. The reference teaches a multitude of MC type carbide particles, where titanium niobium carbides are one possible combination, which read on the particles of a chemical mixture of niobium carbide and titanium carbide. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

The amount of refractory material particles taught by WO '354 overlaps at 5 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range

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of refractory material particle volume % overlaps with the range disclosed by WO '354. See MPEP Section 2144.05.

The titanium niobium carbides have a much higher melting point than that of cast iron as evidenced by Storms (Fig. 1) and OnlineMetals (Cast Iron). The casting process occurs above the melting point of the cast iron, but below the melting temperature of the carbides as indicated by the fact that carbides are added to the cast iron (page 4 lines 24-29) where carbides indicates particles are added. Therefore, the carbide particles will remain insoluble in the host metal during the casting process.

Regarding claim 55, WO '354 teaches the gray cast iron matrix contains 0.5 to 5 volume % carbide particles (page 1 lines 33-37, page 2 lines 1-5, and page 4 lines 20-23), which overlaps at 5 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by WO '354. See MPEP Section 2144.05.

Regarding claim 58, WO '354 teaches the gray cast iron matrix contains 0.5 to 5 volume % carbide particles (page 1 lines 33-37, page 2 lines 1-5, and page 4 lines 20-23). The instant claim is being interpreted such that that hard metal material comprises 5 to less than 30 volume % particles of the refractory metal, which overlaps at 5 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by WO '354. See MPEP Section 2144.05.

Regarding claim 64, WO '354 teaches a uniform dispersion of the NbC particles in the cast iron matrix (Fig. 2, Fig. 3, and page 3 lines 7-18), where the NbC particles are depicted to be uniformly dispersed in the cast iron matrix.

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3. Claim 65 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over as WO '354 (WO 9410354) applied to claim 51 above, and further in view of US '936 (US PG Publication 20080226936).

Regarding claim 65, WO '354 is silent to the hard metal material including a non-uniform dispersion of particles of the refractory material in the host metal.

US '936 teaches a method of centrifugally casting an iron alloy with MC carbides in the matrix in order to form an outer layer that has more MC carbides dispersed ([0011]-[0014], [0019]-[0023], and Fig. 4(a)), where the MC particles preferentially gather along one edge of the casting due to the applied centrifugal force during casting.

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to perform the casting process of WO '354 as a centrifugal casting process in order to create a non-uniform dispersion of refractory material particles because it creates a final product that has excellent wear resistance, surface roughening resistance, and seizure resistance without the problem of MC carbide segregation (US '936 [0010]).

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4. Claim 66 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over WO '354 (WO 9410354) as applied to claim 51 above, and further in view of US '548 (US PG Publication 2004-0028548).

Regarding claim 66, WO '354 is silent to the hard metal material being used as a pump impeller.

US '548 teaches a pump impeller with parts exposed to abrasive wear made of a carbide steel ([0081]), where a carbide steel is a hard metal material with carbide particles in a steel matrix.

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to make the pump impeller taught in US '548 out of the hard metal material of WO '354 because it is a specific type of carbide steel as it contains both carbide particles and a cast iron matrix as discussed above in claim 51.

5. Claim 67 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over WO '354 (WO 9410354) as applied to claim 51 above, and further in view of WO '511 (WO2009149511).

Regarding claim 67, WO '354 is silent to the hard metal material being used as a pump throatbush.

WO '511 teaches a pump with a throatbush (page 15 lines 23-24) that is made from a hard metal (page 39 lines 23-28).

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to use the hard metal material taught in WO '354 to make the pump

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throatbush in WO '511 because the hard metal material required in WO '511 needs to be wear resistant (page 39 lines 23-28) and the hard metal material of WO '354 is wear resistant (page 1 lines 26-32).

6. Claim 68 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over WO '354 (WO 9410354) as applied to claim 51 above, and further in view of US '389 (US 5184389).

Regarding claim 68, WO '354 is silent to the hard metal material being used as a liner of a primary rock crusher.

US '389 teaches it is well known in the art to make liners of a primary rock crusher with a hard metal due to its abrasion resistance (column 1 lines 11-12, column 2 lines 67-68, column 3 lines 1-5).

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to use the hard metal material taught in WO '354 as the material to make the rock crusher liner in US '389 because the rock crusher liner needs to be made out of an abrasion resistant hard metal, where the hard metal material of WO '354 meets these limitations (page 1 lines 26-32), where wear resistant reads on abrasion resistance.

7. Claims 31-36, 51, 52, 55-58, and 64 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '672 (US PG Publication 20090293672) as evidenced by Storms (Storms and Krikorian. The niobium-niobium carbide system. J. Phys. Chem. 64 (10) 1960 pp. 1471-1477.) and Rudy (Rudy. Phase equilibria investigation of binary, ternary, and higher order systems. Technical Report AFML-TR-69-117, Part 1. August 1970.).

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Regarding claim 31, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles dispersed in a metal or metallic alloy ([0002] and [0031]) where the hard particles comprise carbide particles of at least one transition metal selected from titanium, chromium, vanadium, zirconium, hafnium, tantalum, molybdenum, niobium, and tungsten ([0035]). Hard particles dispersed in a metal or metallic alloy read on a hard metal material.

The occurrence of tungsten carbides is not part of the 5-50 volume % of refractory material particles of the instant claim, but the comprising language allows for the occurrence of additional particles in the hard metal material not listed in the claim. To satisfy the instant claim limitation at least one of the above carbides other than tungsten has to be present between 5-50 volume % in the material. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

Regarding claim 32, US '672 teaches the hard particles comprise carbide particles of at least one transition metal selected from titanium, chromium, vanadium, zirconium, hafnium, tantalum, molybdenum, niobium, and tungsten ([0035]), where the particles include tungsten carbide. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

Regarding claim 33, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles ([0002] and [0031]), which overlaps from 5 to 40 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range

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of refractory material particle volume % overlaps with the range disclosed by US '672. See MPEP Section 2144.05.

Regarding claim 34, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles ([0002] and [0031]). This encompasses the instantly claimed range, where the instant claim is being interpreted such that the hard metal material comprises greater than 10 to 50 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by US '672. See MPEP Section 2144.05.

Regarding claim 35, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles ([0002] and [0031]). This encompasses the instantly claimed range, where the instant claim is being interpreted such that the hard metal material comprises 5 to less than 30 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by US '672. See MPEP Section 2144.05.

Regarding claim 36, US '672 teaches the metal or metallic alloy of the second region of the article is steel, a nickel alloy, or a cobalt alloy ([0031], [0032], [0033], and [0042]). Steel reads on a ferrous alloy, a stainless steel, and an austenitic-manganese steel, a nickel alloy reads on a nickel-based superalloy, and a cobalt alloy reads on a cobalt-based superalloy.

Regarding claim 51, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles dispersed in a metal or metallic alloy ([0002] and [0031]) where the hard particles comprise carbide particles of at least one transition metal selected from titanium, chromium, vanadium, zirconium, hafnium, tantalum, molybdenum, niobium, and

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tungsten ([0035]) and metal or metallic alloy is steel, a nickel alloy, or a cobalt alloy ([0031], [0032], [0033], and [0042]). Hard particles dispersed in a metal or metallic alloy read on a hard metal material, the hard particles are refractory materials, and the metal or metallic alloy reads on the host metal.

According to US '672 permutations of the hard particles include niobium carbide or niobium titanium carbide. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

The requirement for the hard metal material to be in the form of a casting is product-by-process terminology. The limitation of casting was fully considered, but the casting process was determined to not impart additional structure to the product as instantly claimed. A *prima facie* base of obviousness exists when the product in a product-by-process claim is obvious over a product from the prior art and the claim is unpatentable even through the prior product was made by a different process. See MPEP 2113.

Further, the limitation that the refractory particles are insoluble at the casting temperature will be interpreted as the refractory particles are insoluble at the processing temperature, where the temperature of any process that results in the instantly claimed product will meet this limitation.

US '672 teaches making the instantly claimed product using a powder metallurgy process where sintering is performed up to 1500°C ([0042]). 1500°C is lower than the melting temperature of either NbC or TiNbC particles as evidenced by the phase diagrams presented in Storms (Fig. 1) and Rudy (Figure 1). During processing the NbC or TiNbC particles will remain

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insoluble in the host metal because they will not get hot enough to melt and dissolve into the host matrix during processing of the hard metal material.

Regarding claim 52, US '672 teaches the hard particles comprise carbide particles of at least one transition metal selected from titanium, chromium, vanadium, zirconium, hafnium, tantalum, molybdenum, niobium, and tungsten ([0035]), where the particles include tungsten carbide. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

Regarding claim 55, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles ([0002] and [0031]), which overlaps from 5 to 40 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by US '672. See MPEP Section 2144.05.

Regarding claim 56, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles ([0002] and [0031]). This encompasses the instantly claimed range, where the instant claim is being interpreted such that the hard metal material comprises greater than 10 to 50 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by US '672. See MPEP Section 2144.05.

Regarding claim 57, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles ([0002] and [0031]). This encompasses the instantly claimed range, where the instant claim is being interpreted such that the hard metal material comprises greater than 15 to 50 volume % particles of the refractory metal. A *prima facie* case of

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obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by US '672. See MPEP Section 2144.05.

Regarding claim 58, US '672 teaches a second region of an article contains 0 to 50 percent by volume of hard particles ([0002] and [0031]). This encompasses the instantly claimed range, where the instant claim is being interpreted such that the hard metal material comprises 5 to less than 30 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by US '672. See MPEP Section 2144.05.

Regarding claim 59, US '672 does not explicitly teach the weight percent of the particles of the refractory material relative to the total weight of the material. However, US '672 does teach the product of instant claim 1, including the volume percent of refractory material particles. It is expected that a hard metal material that has the required volume percent of refractory material particles would also have the required 12 to 33 weight percent of the particles because both volume percent and weight percent are related to how many particles are present in the host metal. A *prima facie* case of obviousness exists when the claimed and prior art products are identical or substantially identical in structure. See MPEP 2112.01I.

Regarding claim 60, US '672 does not explicitly teach the weight percent of the particles of the refractory material relative to the total weight of the material. However, US '672 does teach the product of instant claim 1, including the volume percent of refractory material particles. It is expected that a hard metal material that has the required volume percent of refractory material particles would also have the required 12 to 25 weight percent of the particles because both volume percent and weight percent are related to how many particles are present in the host

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metal. A *prima facie* case of obviousness exists when the claimed and prior art products are identical or substantially identical in structure. See MPEP 2112.01I.

Regarding claim 64, US '672 teaches a uniform dispersion of tungsten carbide refractory metal particles in the second region of an article (Fig. 3, [0017], and [0067]), where the dark tungsten carbide particles as indicated below in Figure A are uniformly dispersed throughout the host metal.



Figure A: Annotated Fig. 3 from US '672 indicating the uniform dispersion of metal carbide (MC) particles throughout the host metal matrix.

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to substitute NbC or TiNbC particles for the tungsten carbide particles in Fig. 3 because US '672 teaches that the taught articles comprises carbide particles of at least one transition metal selected from titanium, chromium, vanadium, zirconium, hafnium, tantalum, molybdenum, niobium, and tungsten ([0035]), where NbC or TiNbC particles serve the same function as the tungsten carbide particles.

8. Claims 53, 54, and 61-64 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '672 (US PG Publication 20090293672) as applied to claim 51 above, and further in view of Choi (Choi, Hwang, Kim. J. Am. Ceram. Soc. 85 [9] 2313-2318 (2002)).

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Regarding claim 53, US '672 teaches the hard particles can comprise niobium carbide of niobium titanium carbide as detailed above in the analysis of claim 51.

US '672 is silent to the composition of the niobium titanium carbide particles when they are the composition of the refractory material particles.

Choi teaches the impact of sintering temperature and time on the grain changes of $Nb_{1-x}Ti_xC$ particles in a Co matrix during liquid phase sintering (page 2313 abstract and page 2314 Section I. Introduction column 1 lines 1-12), where $1-x$ reads on x and x reads on y .

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to use the $Nb_{1-x}Ti_xC$ powder taught by Choi as the composition for the NbTiC particles in US '672 because both Choi and US '672 disclose a powder metallurgy process where sintering is performed at $1500^{\circ}C$ during which time the NbTiC powders do not melt, but they do undergo grain changes (Choi page 2317 section V. Conclusion).

Regarding claim 54, US '672 teaches the hard particles can comprise niobium carbide of niobium titanium carbide as detailed above in the analysis of claim 51.

US '672 is silent to the composition of the niobium titanium carbide particles when they are the composition of the refractory material particles.

Choi teaches the impact of sintering temperature and time on the grain changes of $Nb_{0.75}Ti_{0.25}C$ and $Nb_{0.5}Ti_{0.5}C$ particles in a Co matrix during liquid phase sintering (page 2313 abstract and page 2314 Section II. Experimental Procedure).

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to use the $Nb_{0.75}Ti_{0.25}C$ or $Nb_{0.5}Ti_{0.5}C$ powder taught by Choi as the composition for the NbTiC particles in US '672 because the powders are specific compositions

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of NbTiC powders and both Choi and US '672 disclose a powder metallurgy process where sintering is performed at 1500°C during which time the NbTiC powders do not melt, but they do undergo grain changes (Choi page 2317 section V. Conclusion).

Regarding claim 61, Choi teaches the size of the NbTiC particles is in a range of 1 to 150 μm (Fig. 1 and Fig. 2), where the scale bars on the figures indicate the particles are within the instantly claimed range.

Regarding claim 62, Choi teaches the size of the NbTiC particles have a size of less than 500 μm (Fig. 1 and Fig. 2), where the scale bars on the figures are 10 μm and 25 μm or 50 μm , respectively, and none of the particles in the micrographs are larger than the scale bars.

Regarding claim 63, Choi teaches the size of the NbTiC particles have a size of less than 200 μm (Fig. 1 and Fig. 2), where the scale bars on the figures are 10 μm and 25 μm or 50 μm , respectively, and none of the particles in the micrographs are larger than the scale bars.

Regarding claim 64, both Choi and US '672 teach the final product has a uniform dispersion of particles of the refractory material in the host metal (Choi Fig. 1 and Fig. 2 and US '672 Fig. 3).

9. Claim 66 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '672 (US PG Publication 20090293672) as applied to claim 51 above, and further in view of US '548 (US PG Publication 2004-0028548).

Regarding claim 66, US '672 is silent to the hard metal material being used as a pump impeller.

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US '548 teaches a pump impeller with parts exposed to abrasive wear made of a carbide steel ([0081]), where a carbide steel is a hard metal material with carbide particles in a steel matrix.

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to make the pump impeller taught in US '548 out of the hard metal material of US '672 because it is a specific type of carbide steel as it contains both carbide particles and a cast iron matrix as discussed above in claim 51.

10. Claim 67 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '672 as applied to claim 51 above, and further in view of WO '511 (WO2009149511).

Regarding claim 67, US '672 is silent to the hard metal material being used as a pump throatbush.

WO '511 teaches a pump with a throatbush (page 15 lines 23-24) that is made from a hard metal (page 39 lines 23-28).

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to use the hard metal material taught in US '672 to make the pump throatbush in WO '511 because the hard metal material required in WO '511 needs to be wear resistant (page 39 lines 23-28) and the hard metal material of US '672 is wear resistant ([0002] and [0003]).

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11. Claim 68 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '672 (US PG Publication 20090293672) as applied to claim 51 above, and further in view of US '389 (US 5184389).

Regarding claim 68, US '672 is silent to the hard metal material being used as a liner of a primary rock crusher.

US '389 teaches it is well known in the art to make liners of a primary rock crusher with a hard metal due to its abrasion resistance (column 1 lines 11-12, column 2 lines 67-68, column 3 lines 1-5).

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to use the hard metal material taught in US '672 as the material to make the rock crusher liner in US '389 because the rock crusher liner needs to be made out of an abrasion resistant hard metal, where the hard metal material of US '672 meets these limitations ([0002] and [0003]), where wear resistant reads on abrasion resistance.

12. Claims 31-36, 51, 52, 55-58, and 61-64 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over JP '479 (JP2005068479 machine translation) as evidenced by Storms (Storms and Krikorian. The niobium-niobium carbide system. J. Phys. Chem. 64 (10) 1960 pp. 1471-1477.).

Regarding claim 31, JP '479 teaches a cemented carbide ([0001]) comprising 0 to 40 (excluding 0) percent by volume of a cubic compound, specifically, VC, TaC, NbC, TiN, HfN, (W,Ti)(C,B), (W,Ti,Ta)C, (W,Ti,Ta)(C,N), (W,Zr)(C,B), (Ti,W,Cr)C, or (Ti,W,Mo)(C,N,B) ([0015]). Any compound that contains at least one of C, N, and B and at least one of Ti, Zr, Hf,

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V, Nb, Ta, Cr, and Mo reads on the instant claim, where additional elements are also allowable in the cubic compound because of the open comprising language of the claim. A cemented carbide reads on a hard metal material, a cubic compound reads on a refractory material, and the volume % of cubic compound overlaps from 5 to 40 percent. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material volume percent overlap with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 32, JP '479 teaches the hard metal material contains 0 to 5 volume percent of an iron group metal with tungsten and boride ([0010] and [0016]), where the presence of tungsten and boride indicates the formation of tungsten boride particles. This increases the amount of refractory material particles present in JP '479 to be from 0 to 45 (excluding 0) percent by volume, which is the sum of the percent volume of the cubic compound and the tungsten boride compound. This overlaps from 5 to 45 percent by volume with instant claim 31. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material volume percent overlap with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 33, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound reads on a refractory material. This overlaps from 5 to 40 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 34, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound reads on a refractory material. This overlaps from greater than 10 – 40 volume % with the instant claim,

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where the instant claim is being interpreted such that the hard metal material comprises greater than 10 to 50 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 35, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound reads on a refractory material. This overlaps from 5 – less than 30 volume % with the instant claim, where the instant claim is being interpreted such that the hard metal material comprises 5 to less than 30 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 36, JP '479 teaches the binder phase has an iron group metal as a main component ([0013]), where an iron group metal reads on a ferrous alloy, a stainless steel, an austenitic-manganese steel, and an iron-based or a nickel-based or a cobalt-based superalloy because Fe, Ni, and Co are all part of the iron group metals, and an alloy based on any of these metals will include that because as the main component.

Regarding claim 51, JP '479 teaches a cemented carbide ([0001]) comprising 0 to 40 (excluding 0) percent by volume of a cubic compound, specifically, VC, TaC, NbC, TiN, HfN, (W,Ti)(C,B), (W,Ti,Ta)C, (W,Ti,Ta)(C,N), (W,Zr)(C,B), (Ti,W,Cr)C, or (Ti,W,Mo)(C,N,B) ([0015]) with an iron group metal as a main component ([0013]).

A cemented carbide reads on a hard metal material, a cubic compound reads on a refractory material, and the volume % of cubic compound overlaps from 5 to 40 percent. A

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prima facie case of obviousness exists when the instantly claimed range of refractory material volume percent overlap with the range disclosed by JP '479. See MPEP Section 2144.05.

According to US '672 the hard particles can comprise NbC. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

An iron group metal reads on a ferrous alloy, a stainless steel, an austenitic-manganese steel, and an iron-based or a nickel-based or a cobalt-based superalloy because Fe, Ni, and Co are all part of the iron group metals, and an alloy based on any of these metals will include that because as the main component.

The requirement for the hard metal material to be in the form of a casting is product-by-process terminology. The limitation of casting was fully considered, but the casting process was determined to not impart additional structure to the product as instantly claimed. A *prima facie* base of obviousness exists when the product in a product-by-process claim is obvious over a product from the prior art and the claim is unpatentable even through the prior product was made by a different process. See MPEP 2113.

Further, the limitation that the refractory particles are insoluble at the casting temperature will be interpreted as the refractory particles are insoluble at the processing temperature, where the temperature of any process that results in the instantly claimed product will meet this limitation.

JP '479 teaches making the instantly claimed product using a powder metallurgy process where sintering is performed between 1360 and 1420°C ([0023] and Table 2 in the original document). 1360 to 1420°C is lower than the melting temperature of the NbC particles as

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evidenced by Storms (Fig. 1), indicating that during the processing the NbC particles will remain insoluble in the host metal because they will not get hot enough to melt and dissolve into the host matrix during processing of the hard metal material.

Regarding claim 52, JP '479 teaches the hard metal material contains 0 to 5 volume percent of an iron group metal with tungsten and boride ([0010] and [0016]), where the presence of tungsten and boride indicates the formation of tungsten boride particles. This increases the amount of refractory material particles present in JP '479 to be from 0 to 45 (excluding 0) percent by volume, which is the sum of the percent volume of the cubic compound and the tungsten boride compound. This overlaps from 5 to 45 percent by volume with instant claim 51. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material volume percent overlap with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 55, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from 5 – 40 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 56, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from greater than 10 – 40 volume % with the instant claim, where the instant claim is being interpreted such that the hard metal material comprises greater than 10 to 50 volume % particles of the refractory metal. A *prima facie* case of

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obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 57, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from greater than 15 – 40 volume % with the instant claim, where the instant claim is being interpreted such that the hard metal material comprises greater than 15 to 50 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 58, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from 5 – less than 30 volume % with the instant claim, where the instant claim is being interpreted such that the hard metal material comprises 5 to less than 30 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 61, JP '479 does not explicitly teach the size of the NbC particles. However, JP '479 does teach the average particle diameter of comparable cubic compound particles range from about 0.1 to about 1.7 μm ([0020] and [0023]), with specific examples such as Mo₂C being 0.1 μm , TaC being 1.1 μm , (W,Ti,Ta)C being 1.2 μm , and Cr₃C₂ being 1.7 μm .

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made for the NbC particles taught by JP '479 to also be around this range

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of average particle diameters because these are all examples of cubic compounds, which serve the same functional purpose in the final product of improving wear resistance ([0015]).

Therefore, this range of particle size overlaps from 1 to about 1.7 μm with the instant claims. A *prima facie* case of obviousness exists when the instantly claimed ranges of average particle diameter overlap with ranges taught by JP '479. See MPEP Section 2144.05.

Regarding claim 62, JP '479 does not explicitly teach the size of the NbC particles. However, JP '479 does teach the average particle diameter of comparable cubic compound particles range from about 0.1 to about 1.7 μm ([0020] and [0023]), with specific examples such as Mo₂C being 0.1 μm , TaC being 1.1 μm , (W,Ti,Ta)C being 1.2 μm , and Cr₃C₂ being 1.7 μm .

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made for the NbC particles taught by JP '479 to also be around this range of average particle diameters because these are all examples of cubic compounds, which serve the same functional purpose in the final product of improving wear resistance ([0015]).

Therefore, this range of particle sizes is less than the maximum 500 μm diameter of the instant claims. A *prima facie* case of obviousness exists when the instantly claimed ranges of average particle diameter falls within the range taught by JP '479. See MPEP Section 2144.05.

Regarding claim 63, JP '479 does not explicitly teach the size of the NbC particles. However, JP '479 does teach the average particle diameter of comparable cubic compound particles range from about 0.1 to about 1.7 μm ([0020] and [0023]), with specific examples such as Mo₂C being 0.1 μm , TaC being 1.1 μm , (W,Ti,Ta)C being 1.2 μm , and Cr₃C₂ being 1.7 μm .

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made for the NbC particles taught by JP '479 to also be around this range

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of average particle diameters because these are all examples of cubic compounds, which serve the same functional purpose in the final product of improving wear resistance ([0015]).

Therefore, this range of particle sizes is less than the maximum 200 μm diameter of the instant claims. A *prima facie* case of obviousness exists when the instantly claimed ranges of average particle diameter falls within the range taught by JP '479. See MPEP Section 2144.05.

Regarding claim 64, JP '479 does not explicitly teach a uniform dispersion of the particles of the refractory material in the host material. However, JP '479 does teach the cemented carbide is made through a powder metallurgy process where prior to forming the green compact, the powders are mixed together ([0023]). Mixing the powders together indicates a uniform dispersion of all particle types throughout the cemented carbide, such that, upon formation of the final product, the resulting microstructure, which includes the dispersion of the refractory material particles, will be uniform.

13. Claim 66 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over JP '479 (JP2005068479 machine translation) as applied to claim 51 above, and further in view of US '548 (US PG Publication 2004-0028548).

Regarding claim 66, JP '479 is silent to the hard metal material being used as a pump impeller.

US '548 teaches a pump impeller with parts exposed to abrasive wear made of a carbide steel ([0081]), where a carbide steel is a hard metal material with carbide particles in a steel matrix.

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It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to make the pump impeller taught in US '548 out of the hard metal material of JP '479 because it is a specific type of carbide steel as it contains both carbide particles and a cast iron matrix as discussed above in claim 51.

14. Claim 67 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over JP '479 (JP2005068479 machine translation) as applied to claim 51 above, and further in view of WO '511 (WO2009149511).

Regarding claim 67, JP '479 is silent to the hard metal material being used as a pump throatbush.

WO '511 teaches a pump with a throatbush (page 15 lines 23-24) that is made from a hard metal (page 39 lines 23-28).

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to use the hard metal material taught in JP '479 to make the pump throatbush in WO '511 because the hard metal material required in WO '511 needs to be wear resistant (page 39 lines 23-28) and the hard metal material of JP '479 is wear resistant ([0001]).

15. Claim 68 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over JP '479 (JP2005068479 machine translation) as applied to claim 51 above, and further in view of US '389 (US 5184389).

Regarding claim 68, JP '479 is silent to the hard metal material being used as a linear of a primary rock crusher.

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US '389 teaches it is well known in the art to make liners of a primary rock crusher with a hard metal due to its abrasion resistance (column 1 lines 11-12, column 2 lines 67-68, column 3 lines 1-5).

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to use the hard metal material taught in JP '479 as the material to make the rock crusher liner in US '389 because the rock crusher liner needs to be made out of an abrasion resistant hard metal, where the hard metal material of JP '479 meets these limitations ([0001]), where wear resistant reads on abrasion resistance.

16. Claims 51, 52, 55-60 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '459 (US 4119459) and further in view of JP '479 (JP2005068479 machine translation) as evidenced by OnlineMetals(Melting points of various metals. www.onlinemetals.com/meltpt.cfm. February 4, 2001.).

Regarding claim 51, US '459 teaches a cast composite body composed of cast iron and sintered cemented carbide where the carbides are WC-Co-type carbides, or carbides with at least one of Ti, Ta, and Nb (column 1 lines 35-37 and 48-63 and column 2 lines 40-50). A composite body with sintered cemented carbide reads on a hard metal material and the cast iron reads on a ferrous alloy host metal.

According to US '459 the cemented carbides can comprise carbides of Ti, Ta, Nb or other metals (column 2 lines 40-50), which includes carbides containing niobium or carbides containing titanium and niobium. A reference that clearly names the instantly claimed species

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anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

US '459 teaches making the instantly claimed product by casting where some of the hard metal particles dissolve (column 3 lines 5-23) and the casting temperature is 150 to 400°C greater than the liquidus temperature of the cast alloy (column 4 lines 17-30). While some of the carbide particles dissolve into the cast iron alloy matrix, some of the carbide particles remain intact as indicated by Fig. 1 (column 5 lines 11-18), where A the undissolved hard metal grains or particles are the insoluble refractory material particles in the host matrix. Further, the melting temperature of cast iron is 1204°C (as evidenced by OnlineMetals), and 150 to 400°C is 1354 to 1604°C, which is still less than the melting temperature of NbC (as evidenced by Storms) and the melting temperature of TiNbC (as evidenced by Rudy?). This indicates that NbC and TiNbC particles will not fully dissolve in the cast iron alloy, where the particles that do not dissolve are the insoluble particles in the host metal matrix.

US '459 is silent to the amount of refractory material particles in the host metal matrix.

JP '479 teaches a cemented carbide ([0001]) comprising 0 to 40 (excluding 0) percent by volume of a cubic compound, specifically, VC, TaC, NbC, TiN, HfN, (W,Ti)(C,B), (W,Ti,Ta)C, (W,Ti,Ta)(C,N), (W,Zr)(C,B), (Ti,W,Cr)C, or (Ti,W,Mo)(C,N,B) ([0015]) with an iron group metal as a main component ([0013]). A cemented carbide reads on a hard metal material and a cubic compound reads on a refractory material.

According to US '672 the hard particles can comprise NbC. A reference that clearly names the instantly claimed species anticipates the claim no matter how many other species are additionally named. See MPEP 2131.02II.

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An iron group metal reads on a ferrous alloy, a stainless steel, an austenitic-manganese steel, and an iron-based or a nickel-based or a cobalt-based superalloy because Fe, Ni, and Co are all part of the iron group metals, and an alloy based on any of these metals will include that because as the main component.

JP '479 teaches making the instantly claimed product using a powder metallurgy process where sintering is performed between 1360 and 1420°C ([0023] and Table 2 in the original document). 1360 to 1420°C is lower than the melting temperature of the NbC particles as evidenced by Storms (Fig. 1), indicating that during the processing the NbC particles will remain insoluble in the host metal because they will not get hot enough to melt and dissolve into the host matrix during processing of the hard metal material.

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to include 0 to 40 (excluding 0) volume percent of the refractory material particles as taught by JP '479 as the amount of particles in the cast iron alloy of US '672 because both teach a hard metal material as indicated above that undergo comparable processing temperatures and the particles are needed to improve the wear resistance of the alloy, but are limited to 40 volume percent because more than that decreases the effect of improving the wear resistance (JP '479 [0015]).

Therefore the volume % of refractory material particles in US '459 and further in view of JP '479 overlaps from 5 to 40 percent with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material volume percent overlap with the range disclosed by JP '479. See MPEP Section 2144.05.

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Regarding claim 52, US '459 teaches a cast composite body composed of cast iron and sintered cemented carbide where the carbides are normally WC-Co-type carbides with possible additions of carbides with at least one of Ti, Ta, and Nb (column 1 lines 35-37 and 48-63 and column 2 lines 40-50, where WC-Co-type carbides read on particles of tungsten carbide.

Regarding claim 55, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from 5 – 40 volume % with the instant claim. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 56, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from greater than 10 – 40 volume % with the instant claim, where the instant claim is being interpreted such that the hard metal material comprises greater than 10 to 50 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 57, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from greater than 15 – 40 volume % with the instant claim, where the instant claim is being interpreted such that the hard metal material comprises greater than 15 to 50 volume % particles of the refractory metal. A *prima facie* case of

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obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 58, JP '479 teaches a cemented carbide comprising 0 to 40 (excluding 0) percent by volume of a cubic compound ([0015]), where the cubic compound is NbC as discussed above in claim 51. This overlaps from 5 – less than 30 volume % with the instant claim, where the instant claim is being interpreted such that the hard metal material comprises 5 to less than 30 volume % particles of the refractory metal. A *prima facie* case of obviousness exists when the instantly claimed range of refractory material particle volume % overlaps with the range disclosed by JP '479. See MPEP Section 2144.05.

Regarding claim 59, US '459 and JP '479 do not explicitly teach the weight percent of the particles of the refractory material relative to the total weight of the material. However, US '459 further in view of JP '479 teach the product of instant claim 1, including the volume percent of refractory material particles. It is expected that a hard metal material that has the required volume percent of refractory material particles would also have the required 12 to 33 weight percent of the particles because both volume percent and weight percent are related to how many particles are present in the host metal. A *prima facie* case of obviousness exists when the claimed and prior art products are identical or substantially identical in structure. See MPEP 2112.01I.

Regarding claim 60, US '459 and JP '479 do not explicitly teach the weight percent of the particles of the refractory material relative to the total weight of the material. However, US '459 further in view of JP '479 teach the product of instant claim 1, including the volume percent of refractory material particles. It is expected that a hard metal material that has the required volume percent of refractory material particles would also have the required 12 to 25 weight

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percent of the particles because both volume percent and weight percent are related to how many particles are present in the host metal. A *prima facie* case of obviousness exists when the claimed and prior art products are identical or substantially identical in structure. See MPEP 2112.01I.

17. Claim 65 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '459 (US 4119459) and further in view of JP '479 (JP2005068479 machine translation) as applied to claim 51 above, and further in view of US '936 (US PG Publication 20080226936).

Regarding claim 65, US '459 further in view of JP '479 is silent to the hard metal material including a non-uniform dispersion of particles of the refractory material in the host metal.

US '936 teaches a method of centrifugally casting an iron alloy with MC carbides in the matrix in order to form an outer layer that has more MC carbides dispersed ([0011]-[0014], [0019]-[0023], and Fig. 4(a)), where the MC particles preferentially gather along one edge of the casting due to the applied centrifugal force during casting.

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to perform the casting process of US '459 as a centrifugal casting process in order to create a non-uniform dispersion of refractory material particles because it creates a final product that has excellent wear resistance, surface roughening resistance, and seizure resistance without the problem of MC carbide segregation (US '936 [0010]).

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18. Claim 66 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '459 (US 4119459) further in view of JP '479 (JP2005068479 machine translation) as applied to claim 51 above, and further in view of US '548 (US PG Publication 2004-0028548).

Regarding claim 66, US '459 further in view of JP '479 is silent to the hard metal material being used as a pump impeller.

US '548 teaches a pump impeller with parts exposed to abrasive wear made of a carbide steel ([0081]), where a carbide steel is a hard metal material with carbide particles in a steel matrix.

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to make the pump impeller taught in US '548 out of the hard metal material of US '459 further in view of JP '479 because it is a specific type of carbide steel as it contains both carbide particles and a cast iron matrix as discussed above in claim 51.

19. Claim 67 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '459 (US 4119459) further in view of JP '479 (JP2005068479 machine translation) as applied to claim 51 above, and further in view of WO '511 (WO2009149511).

Regarding claim 67, US '459 further in view of JP '479 is silent to the hard metal material being used as a pump throatbush.

WO '511 teaches a pump with a throatbush (page 15 lines 23-24) that is made from a hard metal (page 39 lines 23-28).

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to use the hard metal material taught in US '459 further in view of

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JP '479 to make the pump throatbush in WO '511 because the hard metal material required in WO '511 needs to be wear resistant (page 39 lines 23-28) and the hard metal material of US '479 is wear resistant (column 1 lines 5-22).

20. Claim 68 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over US '459 (US 4119459) further in view of JP '479 (JP2005068479 machine translation) as applied to claim 51 above, and further in view of US '389 (US 5184389).

Regarding claim 68, US '459 further in view of JP '479 is silent to the hard metal material being used as a liner of a primary rock crusher.

US '389 teaches it is well known in the art to make liners of a primary rock crusher with a hard metal due to its abrasion resistance (column 1 lines 11-12, column 2 lines 67-68, column 3 lines 1-5).

It would have been obvious to one of ordinary skill in the art at the time the invention as instantly claimed was made to use the hard metal material taught in US '459 further in view of JP '479 as the material to make the rock crusher liner in US '389 because the rock crusher liner needs to be made out of an abrasion resistant hard metal, where the hard metal material of US '459 meets these limitations (column 1 lines 5-22), where wear resistant reads on abrasion resistance.

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Contact Information

Any inquiry concerning this communication or earlier communications from the examiner should be directed to **STEPHANI GULBRANDSEN** whose telephone number is (571)272-2523. The examiner can normally be reached on MON - THUR: 9:00AM-5:00PM EST.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Keith Walker can be reached on (571) 272-3458. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/S. G./

Examiner, Art Unit 1735

/KEITH WALKER/

Supervisory Patent Examiner, Art Unit 1735



Robson, Aidan John
Reddie & Grose LLP
16 Theobalds Road
London WC1X 8PL
ROYAUME UNI

**For any questions about
this communication:**

Tel.: +31 (0)70 340 45 00

Date

04.03.14

Reference P/68728.EP01	Application No./Patent No. 11739260.5 - 1362 / 2531630 PCT/AU2011000092
Applicant/Proprietor Weir Minerals Australia Ltd	

Communication

The extended European search report is enclosed.

The extended European search report includes, pursuant to Rule 62 EPC, the supplementary European search report (Art. 153(7) EPC) and the European search opinion.

Copies of documents cited in the European search report are attached.

0 additional set(s) of copies of such documents is (are) enclosed as well.

Refund of the search fee

If applicable under Article 9 Rules relating to fees, a separate communication from the Receiving Section on the refund of the search fee will be sent later.

Should you wish to further prosecute this application in the examination phase, your attention is drawn to the provisions of Rule 70a EPC. An invitation to respond to the extended European search report will be issued shortly (R. 70(2) EPC).



1 Application Documents

The examination is being carried out on the **following application documents**

Description, Pages

1-25 as published

Claims, Numbers

1-15 filed with entry into the regional phase before the EPO

Drawings, Sheets

1/2, 2/2 as published

2 Prior Art

Reference is made to the following documents; the numbering will be adhered to in the rest of the procedure.

D1 WO 94/11541 A1 (SHEFFIELD FORGEMASTERS [GB]; WRAGG DAVID [GB]; HEWITT PAUL HERBERT [GB] 26 May 1994 (1994-05-26)

D2 US 6 013 141 A (NYLEN BO TOMMY KAGE [SE] ET AL) 11 January 2000 (2000-01-11)

3 Amendments, Art. 123 (2) EPC

3.1 The amended claims 1 and 2 do not comply with Art. 123 (2) EPC, because the selection made ("any one or more than one of titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, and molybdenum" in claim 1 without tungsten, which is mentioned in claim 2) is not disclosed in the application.

3.2 Claims 3-15 comply with Art. 123 (2) EPC.

4 **Clarity, Art. 84 EPC**

The application does not meet the requirements of Article 84 EPC, because claims 5, 11 and 12-15 are not clear.

- 4.1 Claims 5, 11 and 12-15 have been drafted as separate independent claims. Under Article 84 in combination with Rule 43(2) EPC, an application may contain more than one independent claim in a particular category only if the subject-matter claimed falls within one or more of the exceptional situations set out in paragraph (a), (b) or (c) of Rule 43(2) EPC. This is not the case in the present application, however, because all these claims address different aspects of the method of claim 5.

5 **Novelty and Inventive Step, Art. 52, 54 and 56 EPC**

The present application does not meet the criteria of Article 52 EPC because the subject-matters of claims 1-4, 5-8 and 11-15 are not new in the sense of Art. 54 (1) (2) and the subject-matter of claims 9 and 10 does not involve an inventive step in the sense of Art. 56 EPC.

- 5.1 D1 (claims 18, 19, 24 and 30-33; descr. p. 2-15) discloses an engineering material made from a ferrous metal matrix comprising up to 20 vol% carbide particles selected from chromium, molybdenum, titanium, tungsten, niobium, vanadium or mixed carbides and therefore takes away the novelty of the subject-matter of claim 1.
- 5.2 D1 also takes away the novelty of the subject-matter of dependent claims 2-4.
- 5.3 The method of claims 5 and 6 is disclosed in D1, claim 1 with descr. p. 4, l. 1-3.
- 5.4 The features of dependent method claims 7 and 8 are disclosed in D1, claims 28 and 4, respectively.

5.5 The alternative method of forming a wear resistant hard metal material according to method claims 9 and 10 by allowing a melt to cool and thereby forming the solid particles is known from D2, claim 1. The subject-matter of claims 9 and 10 lacks therefore an inventive step over D2 in combination with D1.

5.6 The subject-matters of claims 11-15 are also disclosed in D1 (claims 18, 19, 24 and 30-33; descr. p. 2-15).

6 Procedure

6.1 The present set of claims is not allowable.

6.2 **At least some of the objections raised above are such that there appears to be no possibility of overcoming them by amendment. Refusal of the application under Article 97(2) EPC is therefore to be expected.**

6.3 Should the applicant nevertheless regard some particular matter as patentable, an independent claim should be filed taking account of Rule 43(1) EPC. The applicant should also indicate how the subject-matter of the new claim differs from the state of the art and the significance thereof.

6.4 When filing new claims the description should likewise be adapted properly.

6.5 To meet the requirements of Rule 42(1)(b) EPC, documents D1 and D3, which constitute the relevant prior art, should also be identified in the description and the relevant background art disclosed therein should be briefly discussed.

6.6 The attention of the applicant is drawn to the fact that the application may not be amended in such a way that it contains subject-matter which extends beyond the content of the application as filed (Art. 123(2) EPC).

6.7 In order to facilitate the examination of the conformity of the amended application with the requirements of Art. 123(2) EPC, the applicant should clearly identify the amendments carried out, irrespective of whether they concern amendments by addition, replacement or deletion, and to indicate the passages of the application as filed on which these amendments are based (see Guidelines 2013 H-III, 2.).

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 94/11541 A1 (SHEFFIELD FORGEMASTERS [GB]; WRAGG DAVID [GB]; HEWITT PAUL HERBERT [GB] 26 May 1994 (1994-05-26)	1-8, 11-15	INV. C22C29/02 C22C29/14 C22C29/16
Y	* p. 2-15; claims 1-36 *	9,10	
Y	----- US 6 013 141 A (NYLEN BO TOMMY KAGE [SE] ET AL) 11 January 2000 (2000-01-11) * claim 1 *	9,10	
E	----- WO 2011/091479 A1 (WEIR MINERALS AUSTRALIA LTD [AU]; DOLMAN KEVIN [AU]) 4 August 2011 (2011-08-04) * the whole document *	1-15	
A	----- DE 20 63 181 A1 (UDDEHOLMS AB) 22 July 1971 (1971-07-22) * the whole document *	1-15	
A	----- WO 2004/104253 A1 (WEIR WARMAN LTD [AU]; DOLMAN KEVIN FRANCIS [AU]) 2 December 2004 (2004-12-02) * the whole document *	1-15	
A	----- WO 01/88213 A1 (PROENCO AB [SE]; ANDERSSON CARL HAAKAN [SE]; NILSSON ANDERS [SE]; STA) 22 November 2001 (2001-11-22) * the whole document *	1-15	TECHNICAL FIELDS SEARCHED (IPC) C22C
The supplementary search report has been based on the last set of claims valid and available at the start of the search.			
Place of search Munich		Date of completion of the search 24 February 2014	Examiner Radeck, Stephanie
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 11 73 9260

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

24-02-2014

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
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			AU 5530494 A	08-06-1994
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			GB 2289288 A	15-11-1995
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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 11 73 9260

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

24-02-2014

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PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference P83238-PCT	FOR FURTHER ACTION	See Form PCT/IPEA/416
International application No. PCT/AU2011/000092	International filing date (<i>day/month/year</i>) 1 February 2011	Priority date (<i>day/month/year</i>) 5 February 2010
International Patent Classification (IPC) or national classification and IPC Int. Cl. C22C 29/02 (2006.01) C22C 29/14 (2006.01) C22C 29/16 (2006.01)		
Applicant WEIR MINERALS AUSTRALIA LTD et al		
<p>1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.</p> <p>2. This REPORT consists of a total of 5 sheets, including this cover sheet.</p> <p>3. This report is also accompanied by ANNEXES, comprising:</p> <p>a. <input checked="" type="checkbox"/> (<i>sent to the applicant and to the International Bureau</i>) a total of 8 sheets, as follows:</p> <p><input checked="" type="checkbox"/> sheets of the description, claims and/or drawings which have been amended and/or sheets containing rectifications authorized by this Authority, unless those sheets were superseded or cancelled, and any accompanying letters (see Rules 46.5, 66.8, 70.16, 91.2, and Section 607 of the Administrative Instructions).</p> <p><input type="checkbox"/> sheets containing rectifications not taken into account by this Authority because they were not available at the time when this Authority began to draw up this report, and any accompanying letters (Rules 66.4bis, 70.2(e), 70.16 and 91.2).</p> <p><input type="checkbox"/> Superseded sheets and any accompanying letters, where this Authority either considers that the superseding sheets contain an amendment that goes beyond the disclosure in the international application as filed, or the superseding sheets were not accompanied by a letter indicating the basis for the amendments in the application filed, as indicated in item 4 of Box No. I and the Supplemental Box (see Rule 70.16(b)).</p> <p>b. <input type="checkbox"/> (<i>sent to the International Bureau only</i>) a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing, in electronic form only, as indicated in the Supplemental Box Relating to Sequence Listing (see paragraph 3bis of Annex C of the Administrative Instructions).</p> <p>4. This report contains indications relating to the following items:</p> <p><input checked="" type="checkbox"/> Box No. I Basis of the report</p> <p><input type="checkbox"/> Box No. II Priority</p> <p><input type="checkbox"/> Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability</p> <p><input checked="" type="checkbox"/> Box No. IV Lack of unity of invention</p> <p><input checked="" type="checkbox"/> Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement</p> <p><input type="checkbox"/> Box No. VI Certain documents cited</p> <p><input type="checkbox"/> Box No. VII Certain defects in the international application</p> <p><input type="checkbox"/> Box No. VIII Certain observations on the international application</p>		
Date of submission of the demand 5 December 2011	Date of completion of this report 16 March 2012	
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRÁLIA E-mail address: pct@ipaustrialia.gov.au Facsimile No. +61 2 6283 7999	Authorized Officer VIJAYA MATHE AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. +61 2 6225 6162	

Box No. I Basis of the report

1. With regard to the **language**, this report is based on:
- The international application in the language in which it was filed
- A translation of the international application into _____, which is the language of a translation furnished for the purposes of:
- international search (under Rules 12.3(a) and 23.1 (b)).
- publication of the international application (under Rule 12.4(a)).
- international preliminary examination (Rules 55.2(a) and/or 55.3(a) and (b)).
2. With regard to the **elements** of the international application, this report is based on (*replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report*):
- the international application as originally filed/furnished
- the description:
- pages 1 – 25 as originally filed/furnished
- pages* received by this Authority on _____ with the letter of _____
- pages* received by this Authority on _____ with the letter of _____
- the claims:
- pages _____ as originally filed/furnished
- pages* _____ as amended (together with any statement) under Article 19
- pages* 26 – 30 received by this Authority on 5th March 2012 with the letter of 5th March 2012
- pages* received by this Authority on _____ with the letter of _____
- the drawings:
- pages 1/2 – 2/2 as originally filed/furnished
- pages* received by this Authority on _____ with the letter of _____
- pages* received by this Authority on _____ with the letter of _____
- a sequence listing - see Supplemental Box Relating to Sequence Listing.
3. The amendments have resulted in the cancellation of:
- the description, pages _____
- the claims, Nos. _____
- the drawings, sheets/figs _____
- the sequence listing (*specify*): _____
4. This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since either they are considered to go beyond the disclosure as filed, or they were not accompanied by a letter indicating the basis for the amendments in the application as filed, as indicated in the Supplemental Box (Rules 70.2(c) and (*c-bis*)):
- the description, pages _____
- the claims, Nos. _____
- the drawings, sheets/figs _____
- the sequence listing (*specify*): _____
5. This report has been established:
- taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rules 66.1(d-*bis*) and 70.2(e)).
- without taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rules 66.4*bis* and 70.2(e)).
6. Supplementary international search report(s) from Authority(ies) _____ has/have been received and taken into account in establishing this report (Rule 45bis.8(b) and (c)).

* If item 4 applies, some or all of those sheets may be marked "superseded."

Box No. IV Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has, within the applicable time limit:
- restricted the claims
 - paid additional fees
 - paid additional fees under protest and, where applicable, the protest fee
 - paid additional fees under protest but the applicable protest fee was not paid
 - neither restricted the claims nor paid additional fees
2. This Authority found that the requirement of unity of invention is not complied with and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is:

complied with.

not complied with for the following reasons:

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

In assessing whether there is more than one invention claimed, I have given consideration to those features which can be considered to potentially distinguish the claimed combination of features from the prior art.

This International Searching Authority has found that there are different inventions as follows:

- Claims 1 – 22, 28 – 29 are directed to a hard metal material comprising 5 - 50 vol % of refractory material particles dispersed in a host metal; and a method of manufacturing a component of said hard metal material comprising the step of forming slurry of refractory material particles in the liquid metal. It is considered that this group of claims define a first invention.
- Claims 23 – 27, 30 are directed to a method of casting a hard metal material having a dispersion of refractory material particles in a host metal which forms a matrix of the hard metal material comprising selecting the density of the refractory material particles in relation to the density of the host metal; and selectively controlling the dispersion of the refractory material particles in the solid casting ranging from a uniform dispersion to a non-uniform dispersion. It is considered that this group of claims define a second invention.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

None of the abovementioned groups of claims share any special technical feature. Because there is no common special technical feature it follows that there is no technical relationship between the identified inventions. Therefore the claims do not satisfy the requirement of unity of invention *a priori*.

4. Consequently, this report has been established in respect of the following parts of the international application:

all parts.

the parts relating to claims Nos.

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims 1 – 30	YES
	Claims NONE	NO
Inventive step (IS)	Claims 1 – 30	YES
	Claims NONE	NO
Industrial applicability (IA)	Claims 1 – 30	YES
	Claims NONE	NO

2. Citations and explanations (Rule 70.7)

The following document identified in the International Search Report has been considered for the purposes of this report:

D1: JP 60 – 169515 A

NOVELTY (N):

Claims 1 – 30 meet the criteria set forth in PCT Article 33(2) for novelty. The prior art published before the priority date does not disclose a hard metal material comprising 5 – 50 volume % particles of a refractory material dispersed in a host metal, wherein the refractory material comprises particles of carbides and/or nitrides and/or borides of any one or more of Ti, Zr, Hf, V, Nb, Ta, Cr, and Mo (OR) a method of forming a hard metal material comprising the defined combination of steps wherein a slurry of a hard metal material comprising 5 – 50 volume % particles of a refractory material dispersed in a liquid host metal is formed (OR) a method of forming a wear resistant hard metal material comprising the defined combination of steps wherein any one or more of the nine transition metals Ti, Zr, Hf, V, Nb, Ta, Cr, Mo and W are added to a melt of a host metal in a form that produces particles of carbides and/or nitrides and/or borides of any one or more of the nine transition metals in a range of 5 – 50 volume % of the hard metal material (OR) a method of forming a wear resistant hard metal material comprising the defined combination of steps wherein niobium or niobium and titanium is added to a melt containing a host metal in a form that produces particles of niobium carbide and/or particles of a chemical mixture of niobium carbide and titanium carbide in a range of 10 – 40 wt % of the total weight of the hard metal material in a microstructure of a solidified metal alloy (OR) a method of casting a hard metal material having a dispersion of refractory material particles of carbides and/or nitrides and/or borides of any one or more of the nine transition metals Ti, Zr, Hf, V, Nb, Ta, Cr, Mo and W in a host of metal which forms a matrix of the hard metal material in a solid casting, the method comprising the defined combination of steps wherein the density of the refractory material particles in relation to the density of the host metal is selected and the dispersion of the refractory material particles is selectively controlled in the matrix of a solid casting to range from a uniform dispersion to a non-uniform dispersion.

The closest prior art document D1 discloses a casting material with very high hardness and superior wear resistance wherein 15 – 75 vol % particles of tungsten carbide (WC) is dispersed in cast iron; manufacture of a casting with much superior wear resistance through inoculation of the molten cast iron in a melting furnace or during charging into a casting mould or in the casting mould with WC powder thereby causing uniform crystallization and dispersion of WC (of grain size 5 – 100 µm) in the matrix of casting (see abstract).

(continued in Supplemental Box)

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of: Box No. V

INVENTIVE STEP (IS):

Claims 1 – 30 meet the criteria set out in PCT Article 33(3) with regard to the requirement of Inventive Step because the prior art does not obviously suggest to a person skilled in the art a method of manufacturing a component of a hard metal material comprising the step of forming slurry of refractory material particles in the liquid metal (OR) a method of casting a hard metal material having a dispersion of refractory material particles in a host metal which forms a matrix of the hard metal material comprising the steps of selecting the density of the refractory material particles in relation to the density of the host metal; and selectively controlling the dispersion of the refractory material particles in the solid casting ranging from a uniform dispersion to a non-uniform dispersion (OR) a hard metal material comprising 5 – 50 volume % particles of a refractory material dispersed in a host metal, wherein the refractory material comprises particles of carbides and/or nitrides and/or oxides of any one or more of Ti, Zr, Hf, V, Nb, Ta, Cr, and Mo.

The claimed invention is not obvious in the light of the cited document nor is it disclosed in any obvious combination of it. It is also considered that it would not be obvious to a person skilled in the art in the light of common general knowledge either by itself or in combination with this document.

INDUSTRIAL APPLICABILITY (IA):

The invention defined in claims 1 – 30 is considered to meet the requirements of Industrial Applicability under Article 33(4) of the PCT because it can be made by, or used in, industry.

Claims:

1. A hard metal material comprising 5-50 volume % particles of a refractory material dispersed in a host metal, wherein the refractory material comprises particles of carbides and/or nitrides and/or borides of any one or more than one of titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, and molybdenum.
2. The hard metal material defined in claim 1 wherein the particles of the refractory material also comprise tungsten.
3. The hard metal material defined in claim 1 or claim 2 comprises 5-40 volume % particles of the refractory material dispersed in the host metal.
4. The hard metal material defined in any one of the preceding claims comprises greater than 10 volume % particles of the refractory material dispersed in the host metal.
5. The hard metal material defined in any one of the preceding claims comprises greater than 15 volume % particles of the refractory material dispersed in the host metal.
6. The hard metal material defined in any one of the preceding claims comprises less than 30 volume % particles of the refractory material dispersed in the host metal.
7. The hard metal material defined in any one of the preceding claims comprises less than 25 volume % particles of the refractory material dispersed in the host metal.
8. The hard metal material defined in any one of the preceding claims wherein the host metal comprises a ferrous alloy (such as a steel or a cast iron), a stainless steel, an austenitic-manganese steel, or an iron-based or a nickel-based or a cobalt-based superalloy.

9. A method of manufacturing a component of a hard metal material comprising:

- 5 (a) forming a slurry of a hard metal material comprising 5-50 volume % particles of a refractory material dispersed in a liquid host metal in an inert atmosphere, and
- 10 (b) pouring the slurry into a mould and forming a casting of the component, such as in an inert atmosphere.

10. The method defined in claim 9 comprises forming the
15 slurry and thereafter forming the casting of the component in a chamber under vacuum conditions which remove air from the chamber and supplying an inert gas, such as argon, into the chamber.

11. The method defined in claim 9 or claim 10 comprises
20 selecting the production parameters to form the slurry in step (a) with a required fluidity for processing in step (b).

12. The method defined in claim 11 wherein the production
25 parameters comprise any one or more of the particle size, shape, reactivity, density, and solubility of the refractory materials.

13. The method defined in any one of claims 9 to 12 wherein the refractory material is less than 400 microns particle size.

30 14. The method defined in any one of claims 9 to 13 wherein the refractory material is less than 150 microns particle size.

15. The method defined in any one of claims 9 to 14
35 comprises selecting the refractory material to have a smaller thermal contraction than the host metal.

16. The method defined in any one of claims 9 to 15 comprises selecting the density of the refractory material, compared to the density of the host metal in the liquid state to control the dispersion of the particles of the refractory material
5 in the host metal.

17. The method defined in any one of claims 9 to 16 comprises selecting the refractory material to have minimal solid solubility in the liquid host metal.

18. A method of forming a wear resistant hard metal material, the method comprising adding (a) niobium or (b) niobium and titanium to a melt containing a host metal in a form that produces particles of niobium carbide and/or particles of a
15 chemical mixture of niobium carbide and titanium carbide in a range of 10 to 40 wt% of the total weight of the hard metal material in a microstructure of a solidified metal alloy, and allowing the melt to solidify to form the solid hard metal material.

19. The method as defined in claim 18 comprising adding the niobium and/or the titanium to the melt to produce particles of niobium carbide and/or niobium/titanium carbides in a range of 12 wt% to 33 wt% niobium carbides and niobium/titanium carbides of
25 the total weight of the solidified hard metal material.

20. The method as defined in claim 18 or claim 19 wherein the particles of niobium/titanium carbides have a general formula $(\text{Nb}_x, \text{Ti}_y)\text{C}$.

21. The method as defined in any one of claims 18 to 20 comprising adding niobium and/or titanium to the melt in the form of particles of niobium carbide and/or niobium/titanium carbides.

22. The method as defined in claim 21 comprising forming a slurry of particles of niobium carbide and/or niobium/titanium

carbides suspended in the melt and allowing the melt to solidify to form the solidified hard metal material.

23. A method of casting a hard metal material having a dispersion of a chemical mixture of niobium carbides and titanium carbides in a host metal which forms a matrix of the hard metal material, the method comprising selecting the density of the niobium/titanium particles in relation to the density of the host metal and therefore selectively controlling the dispersion of the niobium/titanium particles in the matrix ranging from a uniform dispersion to a non-uniform dispersion.

24. A casting of the metal alloy made by the method defined in claim 23.

25. The casting defined in claim 24 comprising a uniform dispersion of niobium/titanium particles in the matrix.

26. The casting defined in claim 24 comprising a non-uniform dispersion of niobium/titanium particles in the matrix.

27. The casting defined in any one of claims 23 to 26 wherein the metal alloy is a ferrous alloy (such as a steel or a cast iron, such as a high chromium white cast iron), a stainless steel or an austenitic manganese steel (such as a Hadfield steel).

28. A method of forming a hard metal material comprising:

(a) forming a slurry of a hard metal material comprising 5-50 volume % particles of a refractory material dispersed in a liquid host metal, and

(b) allowing the slurry to solidify to form a solid hard metal material.

29. A method of forming a wear resistant hard metal material, the method comprising adding any one or more of the nine

transition metals titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum and tungsten to a melt of a host metal in a form that produces particles of carbides and/or nitrides and/or borides of any one or more of the nine transition metals in a range of 5 to 50 volume % of the total volume of the hard metal material, and allowing the melt to solidify to form the solid hard metal material.

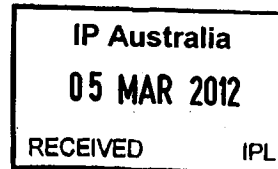
30 A method of casting a hard metal material having a
10 dispersion of refractory material particles of carbides and/or
nitrides and/or borides of any one or more of the nine transition
metals titanium, zirconium, hafnium, vanadium, niobium, tantalum,
chromium, molybdenum and tungsten in a host metal which forms a
matrix of the hard metal material in a solid casting, the method
15 comprising selecting the density of the refractory material
particles in relation to the density of the host metal and
therefore selectively controlling the dispersion of the refractory
material particles in the matrix of a solid casting ranging from a
uniform dispersion to a non-uniform dispersion.

20



PATENTS
TRADE MARKS
IP LAW

The Receiving Office



5 March 2012

Sir

**IN THE MATTER OF International (PCT) Patent Application No. PCT/AU2011/000092
in the name of Weir Minerals Australia Ltd
entitled WEAR RESISTANT METAL ALLOYS
Our Ref: GRM:BK:P83238.PCT**

We refer to the Written Opinion mailed to us on 6 February 2012 and we enclose the following.

1. Replacement claims page 26.
2. A copy of the current page 26 which we have marked up to include the amendments to the page.
3. English translation of D1 – JP 60-69515

We have amended claim 1 to include a significant part of the subject matter of claim 2. These amended claims read as follows:

Amended claim 1 – A hard metal material comprising 5-50 volume % particles of a refractory material dispersed in a host metal, wherein the refractory material comprises particles of carbides and/or nitrides and/or borides of any one or more than one of titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, and molybdenum.

Amended claim 2 – The hard metal material defined in claim 1 wherein the particles of the refractory material also comprise tungsten.

The Written Opinion indicates that claims 9-30 are novel and involve an inventive step and the remaining claims 1-8 are not novel and do not involve an inventive step. D1 is the basis for the opinion of the examiner on the lack of patentability of product claims 1-8.

Our reading of the translation is that D1 does not disclose the subject invention as defined in amended claim 1.

We set out below key passages from the translation that we believe highlight the disclosure in the translation:

3194620_1 (GHMatters) P83238.PCT

Melbourne Sydney Perth Brisbane

Level 10 161 Collins Street Melbourne VIC 3000 Australia

GPO Box 1285 Melbourne VIC 3001 Australia

T +61 3 9243 8300 F +61 3 9243 8333 griffithhack.com.au

ABN: 35 026 846 389 Associated with CPA Global Limited. Affiliated with Griffith Hack Lawyers.

GRIFFITH HACK

PATENTS, TRADE MARKS, IP LAW

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5 March 2012

- *"The wear-resistant materials envisaged by the present invention differ from these various kinds of materials of the prior art in providing high resistance to wear through the crystallisation (emphasis added by me) of large amounts of fine-grained massive tungsten carbide in the matrix."*
- **W: 25.0% - 80%**
W is the most important element for the formation of the castings envisaged by the current invention. At least 25% is required in order to bring about sufficient initial tungsten carbide crystallisation. On the other hand, if 80% is exceeded, the melting point becomes too high, and melting and casting become difficult.
- *"The inventors of the present invention conducted further research into this point, and as a result discovered that the inoculation (emphasis added) of the melt during casting with tungsten carbide grains was effective in uniformly disseminating the massive crystalline tungsten carbide."*
- *"In the present invention, ferrous alloys whose chemical composition has been so adjusted as to contain W, are inoculated (emphasis added) during casting with tungsten carbide grains. Moreover, they may be dispersed in the casting mould, or may be dispersed into the mould during casting."*
- *"If the grain diameter is less than 10 mm, the grains readily completely dissolve and disperse in the melt, and when dispersed, the inoculation effect is lost."*
- *".....there is no particular problem with the addition of large amounts of inoculum provided that the required fluidity of the melt is maintained. Excess tungsten carbide grains do not contribute to the nucleation action, but remain intact and contribute to increasing resistance to wear. At most, there is no increase in the effect if the amount added exceeds 2.0% and this is economically disadvantageous."*

The translation of D1 discloses the use of a small amount of tungsten carbide particles to inoculate a melt containing a larger amount of tungsten in solution, with the inoculated particles being provided to act as nucleation sites for tungsten carbide that precipitates from the melt as the melt solidifies.

More particularly, D1 discloses a method in which a ferrous alloy is heated up to the temperature range 1200-1700°C (depending of the tungsten content) in order to fully dissolve all elements in the alloy to form a single phase liquid. During casting, the liquid metal is inoculated with up to 2 wt% tungsten carbide particles which are either added to a liquid metal stream during pouring into a mould or added to the mould prior to pouring. The inoculated particles facilitate forming fine precipitates from solution in the resultant solidified material. The finely dispersed tungsten carbide particles in the final microstructure form during the solidification process by a process of nucleation and growth from solution. D1 teaches a casting process consisting of the formation of tungsten carbides by precipitation from a single phase liquid during solidification in a mould. On the other hand, the subject invention is a casting method that includes (a) forming a liquid metal that contains insoluble refractory particles in suspension in the liquid (i.e. forms a two phase slurry) and (b) pouring the slurry into a mould to produce a casting containing a fine dispersion of insoluble, hard particles in the microstructure.

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The disclosure in D1 is confined to precipitating tungsten carbide particles from a melt and the use of tungsten carbide particles to inoculate the melt.

There is no disclosure of the use of materials other than tungsten carbide in D1. In accordance with amended claim 1, the refractory particles dispersed in the claimed hard metal material do not include tungsten carbide particles. We submit that, on this basis alone, amended claim 1 is novel over the disclosure in D1.

In relation to amended claim 2, which defines that the particles of the refractory material also comprise tungsten, we submit that the claim is novel over the disclosure in D1 because the D1 disclosure does not extend beyond tungsten carbide.

We also submit that amended claim 1 involves an inventive step. In particular, there is no basis to conclude that the disclosure in D1, which is confined to precipitating tungsten carbide particles from a melt and the use of tungsten carbide particles to inoculate the melt, makes obvious a hard metal material that comprises 5-50 volume % particles of a refractory material dispersed in a host metal, wherein the refractory material comprises particles of carbides and/or nitrides and/or borides of any one or more than one of titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, and molybdenum as defined in amended claim 1.

We ask for favourable consideration.

Yours faithfully
GRIFFITH HACK

Greg Munt
Principal
greg.munt@griffithhack.com.au
61 03 9243 8314



Enc

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2011/000092

A. CLASSIFICATION OF SUBJECT MATTER
 Int. Cl.
C22C 29/02 (2006.01) **C22C 29/14** (2006.01) **C22C 29/16** (2006.01)
 According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
 WPI, EPODOC: IPC - C22C 29/00/-, C22C 32/00, C22C 33/04, C22C 33/08, C22C 35/00, C22C 37/00/-, C22C 38/00/-, C22C 19/00/-, C21D 10/00, C21C 1/00/-, C21C 3/00/-, C21C 5/00/-, C21C 7/00/- & Keywords (TRANSITION, METAL, CARBIDES, NITRIDES, BORIDES, PARTICLES, SLURRY, MELT, STEEL, IRON, CAST, NICKEL, COBALT, BASED, HARD, WEAR, RESISTANT) and like terms
 ESPACENET, USPTO, GOOGLE PATENTS & Keywords (HARD, WEAR, RESISTANT, MATERIAL, TRANSITION, METAL, CARBIDES, NITRIDES, BORIDES, PARTICLES, SLURRY, MELT, STEEL, IRON) and like terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 60 - 169515 A (KUBOTA LTD) 3 September 1985. English abstract retrieved from EPODOC database see abstract	1 - 8, 24
A	RU 2017578 C1 (OMSKIJ POLITEKHNI I [RU]) 15 August 1994. English abstract retrieved from EPODOC database see abstract	
A	US 6013141 A (NYLEN et al) 11 January 2000	
A	see abstract; column 3, lines 14 - 31; claims 1, 5, 11 - 13	

Further documents are listed in the continuation of Box C See patent family annex

* Special categories of cited documents:
 "A" document defining the general state of the art which is not considered to be of particular relevance "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
 "E" earlier application or patent but published on or after the international filing date "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
 "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
 "O" document referring to an oral disclosure, use, exhibition or other means "&" document member of the same patent family
 "P" document published prior to the international filing date but later than the priority date claimed

Date of the actual completion of the international search 28 February 2011	Date of mailing of the international search report - 3 MAR 2011
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Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaaustralia.gov.au Facsimile No. +61 2 6283 7999	Authorized officer VIJAYA MATHE AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : (02) 6225 6162
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2011/000092

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

- Claims 1 – 22, 28 – 29 are directed to a hard metal material comprising 5 - 50 vol% or 10 - 40 wt% of refractory material particles dispersed in a host metal; and a method of manufacturing a component of said hard metal material comprising the step of forming slurry of refractory material particles in the liquid metal. It is considered that this group of claims define a first invention.
- Claims 23 – 27, 30 are directed to a method of casting a hard metal material having a dispersion of refractory material particles in a host metal which forms a matrix of the hard metal material comprising selecting the density of the refractory material particles in relation to the density of the host metal; and selectively controlling the dispersion of the refractory material particles in the solid casting ranging from a uniform dispersion to a non-uniform dispersion. It is considered that this group of claims define a second invention.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

None of the abovementioned groups of claims share any special technical feature. Because there is no common special technical feature it follows that there is no technical relationship between the identified inventions. Therefore the claims do not satisfy the requirement of unity of invention *a priori*.

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2011/000092

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
JP	60169515	NONE					
RU	2017578	NONE					
US	6013141	AU	60924/96	BR	9609266	CA	2223785
		EP	0871784	MX	9709629	NZ	310183
		WO	9639544				
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.							
END OF ANNEX							

1 Application Documents

The examination is being carried out on the **following application documents**:

Main Request

Description, Pages

1, 2, 4-25	as published	
3, 3a	filed in electronic form on	19-11-2015

Claims, Numbers

1-12	filed in electronic form on	30-04-2018
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Drawings, Sheets

1/2, 2/2	as published	
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Auxiliary Request

Description, Pages

1-25	as published	
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Claims, Numbers

1-24	filed in electronic form on	30-04-2018
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Drawings, Sheets

1/2, 2/2	as published	
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2 Prior Art

Reference is made to the following documents already cited in the procedure:

D4	DE 20 63 181 A1 (UDDEHOLMS AB) 22 July 1971 (1971-07-22)
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D11 BERNIS H ET AL: "Wear behavior of ledeburitic Cr-steels with niobium and titanium", ZEITSCHRIFT FUER WERKSTOFFTECHNIK - JOURNAL OF MATERIALSTECHNOLOGY. MATERIALS TECHNOLOGY AND TEST, VCH, WEINHEIM, DE, vol. 14, no. 11, 1 November 1983, pp. 382-389, XP008083489, ISSN: 0049-8688

3 **Clarity, Article 84 EPC**

The clarity objections are overcome by claim 1 of the main and also by claim 1 of the auxiliary request.

4 **Novelty and Inventive Step, Art. 52, 54 and 56 EPC**

4.1 **Main Request**

Novelty of the hard metal material defined in claim 1 is taken away by **D4** (Fig. 2 with p. 7: "Fig. 2"), which discloses a steel containing 20% of titanium carbide.

On p. 11, 2nd paragraph, **D4** points the skilled person to a hard metal material with 10% niobium carbide instead of titanium carbide, thereby also disclosing the feature "*selected from (a) niobium carbide containing refractory particles*" of dependent claim 3.

However, a hard metal material in accordance with option "*(b) particles of a chemical mixture of niobium carbide and titanium carbide*" of dependent claim 3 is not disclosed in **D4**.

Since **D4** merely points at mixing different types of "pure" carbides, inventive step is also acknowledged for option (b).

An independent claim 1 based on claim 1 with feature (b) of claim 3 presently on file would therefore appear to fulfill the requirements of novelty and inventive step of the EPC.

Such a hard metal material would also be considered novel and inventive over **D11** (p. 384: "Tabelle 1") because although **D11** discloses mixed (Nb,Ti) carbides, the employed amounts are significantly lower, i.e. 5% and below in view of the 10% as indicated in claim 1.

4.2 **Auxiliary Request**

The hard metal material defined in claim 1 lacks an inventive step over **D4** (p. 11, 2nd paragraph), which points the skilled person to a hard metal material with 10% niobium carbide instead of titanium carbide, thereby disclosing the feature "*(a) particles of niobium carbide that are insoluble in the host metal at the casting temperature*" defined in claim 1.

5 **Procedure**

5.1 The present set of claims is not allowable.

5.2 **The applicant is invited to file a new (independent) claim which takes account of the above comments.**

5.3 When filing new claims the description should likewise be adapted properly.

5.4 **Amendments should be made by filing replacement pages.** Unnecessary recasting of the description should be avoided. An amended abstract is not required. The applicant should also take account of the requirements of Rule 50(1) EPC. According to Rule 50(1) in conjunction with Rule 49(8) EPC, amendments shall be typed or printed. Handwritten amendments may only be made in documents other than those replacing application documents (Rule 50(2) EPC); they may, for example, be used to fulfil the requirements of Rule 137(4) EPC (identifying amendments and indicating basis for them).

5.5 The attention of the applicant is drawn to the fact that the application may not be amended in such a way that it contains subject-matter which extends beyond the content of the application as filed (Art. 123(2) EPC).

5.6 In order to facilitate the examination of the conformity of the amended application with the requirements of Art. 123(2) EPC, the applicant should clearly identify the amendments carried out, irrespective of whether they concern amendments by addition, replacement or deletion, and to indicate the passages of the application as filed on which these amendments are based (see Guidelines H-III, 2.).



European Patent Office
80298 MUNICH
GERMANY
Tel: +49 89 2399 0
Fax: +49 89 2399 4465



Robson, Aidan John
Reddie & Grose LLP
The White Chapel Building
10 Whitechapel High Street
London E1 8QS
ROYAUME-UNI

Formalities Officer
Name: Rousseau-Jäger, N
Tel: +49 89 2399 - 7597
or call
+31 (0)70 340 45 00

Substantive Examiner
Name: Radeck, Stephanie
Tel: +49 89 2399 - 8443

Application No. 11 739 260.5 - 1108	Ref. P/68728.EP01	Date 16.05.2019
Applicant Weir Minerals Australia Ltd		

Communication pursuant to Article 94(3) EPC

The examination of the above-identified application has revealed that it does not meet the requirements of the European Patent Convention for the reasons enclosed herewith. If the deficiencies indicated are not rectified the application may be refused pursuant to Article 97(2) EPC.

You are invited to file your observations and insofar as the deficiencies are such as to be rectifiable, to correct the indicated deficiencies within a period

of 4 months

from the notification of this communication, this period being computed in accordance with Rules 126(2) and 131(2) and (4) EPC. One set of amendments to the description, claims and drawings is to be filed within the said period on separate sheets (R. 50(1) EPC).

If filing amendments, you must identify them and indicate the basis for them in the application as filed. Failure to meet either requirement may lead to a communication from the Examining Division requesting that you correct this deficiency (R. 137(4) EPC).

Failure to comply with this invitation in due time will result in the application being deemed to be withdrawn (Art. 94(4) EPC).



Radeck, Stephanie
Primary Examiner
For the Examining Division

Enclosure(s): 3 page/s reasons (Form 2906)

1 Application Documents

The examination is being carried out on the **following application documents**:

Description, Pages

1, 2, 4-25	as published	
3, 3a	filed in electronic form on	19-11-2015

Claims, Numbers

1-25	filed in electronic form on	02-08-2016
------	-----------------------------	------------

Drawings, Sheets

1/2, 2/2	as published	
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2 Prior Art

The following documents are cited by the Examiner. A copy of the documents is annexed to the communication and the numbering will be adhered to in the rest of the procedure.

- D10 SPIEKERMANN P: "LEGIERUNGEN - EIN BESONDERES PATENT-RECHTLICHES PROBLEM? - LEGIERUNGSPRÜFUNG IM EUROPÄISCHEN PATENTAMT", MITTEILUNGEN DER DEUTSCHEN PATENTANWÄLTE, HEYMANN, KÖLN, DE, 1993, p. 178-190, XP000961882, ISSN: 0026-6884
- D11 BERNIS H ET AL: "Wear behavior of ledeburitic Cr-steels with niobium and titanium", ZEITSCHRIFT FÜR WERKSTOFFTECHNIK - JOURNAL OF MATERIALSTECHNOLOGY. MATERIALS TECHNOLOGY AND TEST, VCH, WEINHEIM, DE, vol. 14, no. 11, November 1983, p. 382-389, XP008083489, ISSN: 0049-8688

3 Amendments, Article 123 (2) EPC

The filed claims amended as indicated by the applicant comply with Article 123 (2) EPC.

4 **Clarity, Article 84 EPC**

In view of the reply of the applicant dated 2 August 2016 and the new set of claims, the following clarity objection must be raised:

Claim 1 has been phrased in an "open-list" manner which allows the addition of additional elements in unspecified amounts by using the wording "... *in the form of a casting including a host metal and a dispersion of 5-50 volume % of particles of a refractory material...*". By employing the term "*including*", the presence of additional refractory material is not excluded. Accordingly, dependent claim 2 lists further optional elements, namely carbides and/or and nitrides and/or borides of tungsten.

In view of dependent claim 2, this "open list" phrasing is - contrary to the argument of the applicant - not overcome by the amendment in claim 1, "*wherein the refractory material particles consist of (a) particles of niobium carbide that are insoluble in the host metal at the casting temperature and/or (b) refractory particles of a chemical mixture of niobium carbide and titanium carbide that are insoluble in the host metal at the casting temperature*".

To overcome this deficiency, all possible different alloying elements should be incorporated into the single independent alloy claim, whereby elements which are not essential for obtaining the scope of the present invention may be included as optional alloying elements.

In addition, to fulfill the requirements of Article 84 EPC, it must be indicated that the "hard metal material in the form of a casting" consists "of a host material and a dispersion of ..."

Detailed information on the drafting of claims relating to an alloy can be found in document D10.

5 **Novelty and Inventive Step, Art. 52, 54 and 56 EPC**

- 5.1 In his reply, the applicant does not address the objections made in the communication dated 2 March 2016 in view of document D4, nor are these overcome by the latest set of claims, because according to claim 1 presently on file the presence of tungsten carbides cannot be excluded.

The objections made with the communication dated 2 March 2016 are therefore upheld accordingly in view of the current set of claims.

5.2 But even under the assumption - as put forward by the applicant - that claim 1 would be drafted in a manner that it excludes all other refractory particle material besides niobium carbide or (niobium, titanium) carbide, novelty of such a subject-matter would be taken away not only by **D4** (claims 1, 4), but also by document **D11** (table on p. 605: "Alloy 2"), which was found during TopUp search.

5.3 **In view of documents D4 and D11**, a set of claims directed at a hard metal material in the form of a casting consisting exclusively of "*a host metal and 5-50 volume % of particles of a chemical mixture of niobium carbide and titanium carbide*" as refractory particles **appears to meet the requirements of novelty and inventive step.**

In addition, the optional presence of tungsten carbides and/or nitride and/or borides appears to be allowable.

In both cases, to avoid clarity objections and to ensure that the claim specification truly reflects in an unambiguous manner the presence of both titanium and niobium in the carbide, the "*Nb/Ti ratio*" in the "*(Nb,Ti)C chemical compound*" should be specified as disclosed on p. 9, l. 35ff of the A1 pamphlet.

6 Procedure

6.1 The present set of claims is not allowable.

6.2 **The applicant is invited to file a new (independent) claim which takes account of the above comments.**

6.3 When filing new claims the description should likewise be adapted properly.

6.4 **Amendments should be made by filing replacement pages. Unnecessary recasting of the description should be avoided. An amended abstract is not required. The applicant should also take account of the requirements of Rule 50(1) EPC. According to Rule 50(1) in conjunction with Rule 49(8) EPC, amendments shall be typed or printed. Handwritten amendments may only be made in documents other than those**

replacing application documents (Rule 50(2) EPC); they may, for example, be used to fulfil the requirements of Rule 137(4) EPC (identifying amendments and indicating basis for them).

- 6.5 The attention of the applicant is drawn to the fact that the application may not be amended in such a way that it contains subject-matter which extends beyond the content of the application as filed (Art. 123(2) EPC).
- 6.6 In order to facilitate the examination of the conformity of the amended application with the requirements of Art. 123(2) EPC, the applicant should clearly identify the amendments carried out, irrespective of whether they concern amendments by addition, replacement or deletion, and to indicate the passages of the application as filed on which these amendments are based (see Guidelines H-III, 2.).



European Patent Office
80298 MUNICH
GERMANY
Tel: +49 89 2399 0
Fax: +49 89 2399 4465



Robson, Aidan John
Reddie & Grose LLP
The White Chapel Building
10 Whitechapel High Street
London E1 8QS
ROYAUME-UNI

Formalities Officer
Name: Zurkinden, Jolanda
Tel: +49 89 2399 - 4668
or call
+31 (0)70 340 45 00

Substantive Examiner
Name: Radeck, Stephanie
Tel: +49 89 2399 - 8443

Application No. 11 739 260.5 - 1362	Ref. P/68728.EP01	Date 18.10.2017
Applicant Weir Minerals Australia Ltd		

Communication pursuant to Article 94(3) EPC

The examination of the above-identified application has revealed that it does not meet the requirements of the European Patent Convention for the reasons enclosed herewith. If the deficiencies indicated are not rectified the application may be refused pursuant to Article 97(2) EPC.

You are invited to file your observations and insofar as the deficiencies are such as to be rectifiable, to correct the indicated deficiencies within a period

of 4 months

from the notification of this communication, this period being computed in accordance with Rules 126(2) and 131(2) and (4) EPC. One set of amendments to the description, claims and drawings is to be filed within the said period on separate sheets (R. 50(1) EPC).

If filing amendments, you must identify them and indicate the basis for them in the application as filed. Failure to meet either requirement may lead to a communication from the Examining Division requesting that you correct this deficiency (R. 137(4) EPC).

Failure to comply with this invitation in due time will result in the application being deemed to be withdrawn (Art. 94(4) EPC).



Radeck, Stephanie
Primary Examiner
For the Examining Division

Enclosure(s): 4 page/s reasons (Form 2906)
XP000961882, XP008083489

1 Application Documents

The examination is being carried out on the **following application documents**

Description, Pages

1, 2, 4-25 as published

3, 3a filed in electronic form on 19-11-2015

Claims, Numbers

1-25 filed in electronic form on 19-11-2015

Drawings, Sheets

1/2, 2/2 as published

2 Amendments, Article 123(2) EPC

In support of the amended claim 1 the applicant has brought forward that the objected feature combination can be found on p. 11, l. 5-13 and on p. 4, l. 21-23 and 35-36.

Amended claim 1 therefor fulfills the requirements of Art. 123(2) EPC.

3 Novelty and Inventive Step, Articles 52, 54 and 56 EPC

However, the present application does not meet the criteria of Art. 52 EPC because at least the subject-matters of claims 1, 3-13 and 17-19 are not new in the sense of Art. 54(1), (2) EPC and the subject-matters of claims 2, 14-16 and 20-25 lack an inventive step in the sense of Art. 56 EPC.

- 3.1 Subject-matter of claim 1 is a
*"hard metal material in the form of a casting including a host metal and a dispersion of 5-50 volume % of particles of a refractory material selected from:
(a) refractory particles of niobium carbide that are insoluble in the host metal at the casting temperature, and*

*(b) refractory particles of a chemical mixture of niobium carbide and titanium carbide that are insoluble in the host metal at the casting temperature, and the host metal is selected from a group comprising:
a ferrous alloy (including a steel or a cast iron, such as a high chromium white iron),
a stainless steel (including duplex, ferritic, austenitic and martensitic),
an austenitic-manganese steel (including a Hadfield steel),
and an iron-based or a nickel-based or a cobalt-based superalloy."*

Such a casted material is however known from **D4** (claims 1, 3 and 4), because a TiC content of 35 respectively 17 wt% as indicated in claims 1 and 3 of **D4** must inevitably falls within the 5-50 volume% of claim 1 of the present application (see p. 5, l. 33-35 with p. 12, l. 8-10 of the description and claim 1 as filed).

- 3.2 In a similar manner, **D4** takes away the novelty of the subject-matter of dependent claims 3-10.
- 3.3 The subject-matter of dependent claim 2 lacks an inventive step over **D4** (p. 11), which discloses additional carbides and suitable upper limits thereof.
- 3.4 Novelty of the subject-matter of dependent claims 10-13 is taken away by **D4** (p. 15, 2nd paragraph).
- 3.5 The subject-matters of claims 14-16 lack an inventive step, because **D4** (p. 29, 1st paragraph) discloses the high wear resistance of the respective casted hard materials.
- 3.6 The novelty objection based on **D4** (p. 13: table with claims 1-11) against claims 17 and 18 (former claims 19 and 22) is upheld.
- 3.7 The objections based on document **D5** are also upheld:
- 3.7.1 **D5** (claims 1-11) takes away the novelty of claims 17 and 18 because the following amounts [wt%] of carbide forming elements are employed (disclosed endpoints): Cr: 12 , Mo: 2, Ti: 2, Zr: 2, Nb: 2, B: 2, V: 2 and W: 2, which results in a total of more than 26 wt% of carbides.

3.7.2 **D5** (ibid) also takes away the novelty of the subject-matter of dependent claim 19, because the feature of claim 19 describes the inevitable result of a process where a melt of a ferrous alloy comprising Ti, Nb and C is solidified.

3.7.3 Dependent claims 20-25 refer to the adding of ferro-niobium, which is a practice customary carried out by the skilled person without requiring an inventive step over **D5** (ibid).

3.8 Because the wording of claim 1 ("open definition") "hard metal material ... including..." allows for the presence of other hard particles besides the specified niobium carbide and/or particles of a chemical mixture of niobium carbide and titanium carbide, **D5** (ibid) in addition takes away the novelty at least of the subject-matter of claims 1-10.

3.9 **A set of claims directed at a hard metal material in the form of a casting in accordance with claim 1 but containing exclusively "*particles of a chemical mixture of niobium carbide and titanium carbide*" as refractory particles appears to meet the requirements of novelty and inventive step.**

4 **Procedure**

4.1 The present set of claims is not allowable.

4.2 **The applicant is invited to file a new (independent) claim which takes account of the above comments.**

4.3 When filing new claims the description should likewise be adapted properly.

4.4 To meet the requirements of Rule 42(1)(b) EPC, documents **D1, D4 and D5**, which constitute the relevant prior art, should also be identified in the description and the relevant background art disclosed therein should be briefly discussed.

4.5 **Amendments should be made by filing replacement pages. Unnecessary recasting of the description should be avoided. An amended abstract is not required. The applicant should also take account of the requirements of Rule 50(1) EPC. According to Rule 50(1) in conjunction with Rule 49(8) EPC, amendments shall be typed or printed. Handwritten amendments**

may only be made in documents other than those replacing application documents (Rule 50(2) EPC); they may, for example, be used to fulfil the requirements of Rule 137(4) EPC (identifying amendments and indicating basis for them).

- 4.6 The attention of the applicant is drawn to the fact that the application may not be amended in such a way that it contains subject-matter which extends beyond the content of the application as filed (Art. 123(2) EPC).
- 4.7 In order to facilitate the examination of the conformity of the amended application with the requirements of Art. 123(2) EPC, the applicant should clearly identify the amendments carried out, irrespective of whether they concern amendments by addition, replacement or deletion, and to indicate the passages of the application as filed on which these amendments are based (see Guidelines H-III, 2.).



European Patent Office
80298 MUNICH
GERMANY
Tel: +49 89 2399 0
Fax: +49 89 2399 4465



Robson, Aidan John
Reddie & Grose LLP
16 Theobalds Road
London WC1X 8PL
ROYAUME-UNI

Formalities Officer
Name: Boesenberg-Chouet, A
Tel: +49 89 2399 - 2512
or call
+31 (0)70 340 45 00

Substantive Examiner
Name: Radeck, Stephanie
Tel: +49 89 2399 - 8443

Application No. 11 739 260.5 - 1362	Ref. P/68728.EP01	Date 02.03.2016
Applicant Weir Minerals Australia Ltd		

Communication pursuant to Article 94(3) EPC

The examination of the above-identified application has revealed that it does not meet the requirements of the European Patent Convention for the reasons enclosed herewith. If the deficiencies indicated are not rectified the application may be refused pursuant to Article 97(2) EPC.

You are invited to file your observations and insofar as the deficiencies are such as to be rectifiable, to correct the indicated deficiencies within a period

of 4 months

from the notification of this communication, this period being computed in accordance with Rules 126(2) and 131(2) and (4) EPC. One set of amendments to the description, claims and drawings is to be filed within the said period on separate sheets (R. 50(1) EPC).

If filing amendments, you must identify them and indicate the basis for them in the application as filed. Failure to meet either requirement may lead to a communication from the Examining Division requesting that you correct this deficiency (R. 137(4) EPC).

Failure to comply with this invitation in due time will result in the application being deemed to be withdrawn (Art. 94(4) EPC).



Radeck, Stephanie
Primary Examiner
For the Examining Division

Enclosure(s): 4 page/s reasons (Form 2906)

1 Application Documents

The examination is being carried out on the **following application documents**

Description, Pages

1-25 as published

Claims, Numbers

1-29 filed in electronic form on 30-09-2014

Drawings, Sheets

1/2, 2/2 as published

2 Prior Art

Reference is made to the following documents; the numbering will be adhered to in the rest of the procedure.

D1 WO 94/11541 A1 (SHEFFIELD FORGEMASTERS [GB]; WRAGG DAVID [GB]; HEWITT PAUL HERBERT [GB] 26 May 1994

D5 WO 2004/104253 A1 (WEIR WARMAN LTD [AU]; DOLMAN KEVIN FRANCIS [AU]) 2 December 2004

3 Amendments, Article 123 (2) EPC

The filed amendments do not comply with Art. 123(2) EPC, because at least the subject-matters of claims 1 and 16-18 introduce subject-matter which **extends** beyond the content of the application as filed:

3.1 Subject-matter of amended claim 1 is a

"hard metal material in the form of a casting

including a host metal

*and a dispersion of **5-50 volume % of particles of a refractory material***

selected from

(a) niobium carbide containing refractory particles that are insoluble in the host metal at the casting temperature

and

(b) particles of a chemical mixture of niobium carbide and titanium carbide that are insoluble in the host metal at the casting temperature, and the host metal is selected from a group comprising a ferrous alloy, a stainless steel, an austenitic-manganese steel and an iron-based or a nickel-based or a cobalt-based superalloy"

- 3.1.1 Disclosed in the originally filed description (p. 5, l. 33-35 with p. 12, l. 8-10 and claim 1 as originally filed) is merely

"forming a slurry of a hard metal material comprising 5-50 volume % particles of a refractory material dispersed in a liquid host metal",

"wherein the refractory material comprises particles of carbides and/or nitrides and/or borides of any one or more than one of the nine transition metals titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum and tungsten"

"adding (a) niobium or (b) niobium and titanium to a melt containing a host metal in a form that produces particles of niobium carbide and/or particles of a chemical mixture of niobium carbide and titanium carbide in a range of 10 to 40 wt% of the total weight of the hard metal material"

and not a 5-50 vol% content of niobium carbide and particles of a chemical mixture of niobium carbide and titanium carbide.

- 3.1.2 In addition, originally disclosed is merely the selection of **either one** of "a) niobium carbide" **or** " b) particles of a chemical mixture of niobium carbide and titanium carbide", as it is also reflected in the description, see e.g. p. 15, l. 12-16 or amended claim 19. The compulsory presence of both components a) **and** b) is not disclosed in the application as originally filed.

- 3.2 Neither a "pump impeller" nor a "pump throatbush" nor a "liner of a primary rock crusher" as specified in amended claims 16-18 is disclosed in the application as originally filed.

4 **Clarity, Article 84 EPC**

The application in addition does not meet the requirements of Art. 84 EPC, because claims 14 and 15 are not clear.

There is no quantitative range or degree of tolerance associated with the terms "uniform dispersion" respectively "non-uniform dispersion" employed in said claims, thereby leaving the reader in doubt about the exact meaning of the claimed subject-matter.

5 **Novelty and Inventive Step, Articles 52, 54 and 56 EPC**

The above mentioned objections notwithstanding, the present application does not meet the criteria of Art. 52 EPC because at least the subject-matter of claims 19-23 is not new in the sense of Art. 54(1), (2) EPC.

5.1 Subject-matter of amended claim 19 is a

"method of casting a wear resistant hard metal material, the method comprising adding

(a) niobium

or

(b) niobium and titanium to a melt containing a host metal in a form that produces particles of niobium carbide and/or particles of a chemical mixture of niobium carbide and titanium carbide in a range of 10 to 40 wt % of the total weight of the hard metal material in a solidified casting, forming a casting of the melt, and allowing the casting to solidify to form a solid hard metal material casting, with the host metal being selected from a group comprising a ferrous alloy, a stainless steel, an austenitic-manganese steel, and an iron-based or a nickel-based or a cobalt-based superalloy".

A method falling under claim 19 is however disclosed in document **D4** (p. 13: table with claims 1-11), because the 3-35 wt% titanium carbide powder employed according to **D4** is also a "form that produces particles of niobium carbide and/or particles of a chemical mixture of niobium carbide and titanium carbide in a range of 10 to 40 wt% of the total weight of the hard metal material in a solidified casting".

- 5.2 For the same reasons **D4** (ibid) takes away the novelty of the subject-matter of dependent claims 20-22.
- 5.3 **D5** (claims 1-11) is another document which takes away the novelty of claims 19-22, because the following amounts [wt%] of carbide forming elements are employed: Cr: 12 , Mo: 2, Ti: 2, Zr: 2, Nb: 2, B: 2, V: 2 and W: 2, which results in above 26 wt% of carbides.
- 5.4 **D5** (ibid) also takes away the novelty of the subject-matter of dependent claim 23, because the feature of claim 23 describes the inevitable result of a process where a melt of a ferrous alloy comprising Ti, Nb and C is solidified.
- 5.5 Dependent claims 24-28 refer to the adding of ferro-niobium, which is a practice customary carried out by the skilled person without requiring an inventive step over **D5** (ibid).

6 Procedure

- 6.1 The present set of claims is not allowable.
- 6.2 **At least some of the objections raised above are such that there appears to be no possibility of overcoming them by amendment. Refusal of the application under Article 97(2) EPC is therefore to be expected.**
- 6.3 **WARNING: Since the objections against the set of claims as originally filed were not overcome by the amendment and because the examining procedure should be brought to a conclusion in as few actions as possible, the Examining Division will only admit one more amendment under Rule 137(3) (see H-II, 2.3):**
- 6.4 **Should the applicant regard some particular matter as patentable, an independent claim should be filed taking account of Rule 43(1) EPC and the above mentioned warning. The applicant should also indicate how the subject-matter of the new claim differs from the state of the art and the significance thereof.**
- 6.5 When filing new claims the description should likewise be adapted properly.

- 6.6 To meet the requirements of Rule 42(1)(b) EPC, documents **D1, D4 and D5**, which constitute the relevant prior art, should also be identified in the description and the relevant background art disclosed therein should be briefly discussed.
- 6.7 **Amendments should be made by filing replacement pages. Unnecessary recasting of the description should be avoided. An amended abstract is not required. The applicant should also take account of the requirements of Rule 50(1) EPC. According to Rule 50(1) in conjunction with Rule 49(8) EPC, amendments shall be typed or printed. Handwritten amendments may only be made in documents other than those replacing application documents (Rule 50(2) EPC); they may, for example, be used to fulfil the requirements of Rule 137(4) EPC (identifying amendments and indicating basis for them).**
- 6.8 The attention of the applicant is drawn to the fact that the application may not be amended in such a way that it contains subject-matter which extends beyond the content of the application as filed (Art. 123(2) EPC).
- 6.9 In order to facilitate the examination of the conformity of the amended application with the requirements of Art. 123(2) EPC, the applicant should clearly identify the amendments carried out, irrespective of whether they concern amendments by addition, replacement or deletion, and to indicate the passages of the application as filed on which these amendments are based (see Guidelines H-III, 2.).



European Patent Office
80298 MUNICH
GERMANY
Tel: +49 89 2399 0
Fax: +49 89 2399 4465



Robson, Aidan John
Reddie & Grose LLP
16 Theobalds Road
London WC1X 8PL
ROYAUME-UNI

Formalities Officer
Name: Galatioto, Maruska
Tel: +49 89 2399 - 7849
or call
+31 (0)70 340 45 00

Substantive Examiner
Name: Radeck, Stephanie
Tel: +49 89 2399 - 8443

Application No. 11 739 260.5 - 1362	Ref. P/68728.EP01	Date 15.05.2015
Applicant Weir Minerals Australia Ltd		

Communication pursuant to Article 94(3) EPC

The examination of the above-identified application has revealed that it does not meet the requirements of the European Patent Convention for the reasons enclosed herewith. If the deficiencies indicated are not rectified the application may be refused pursuant to Article 97(2) EPC.

You are invited to file your observations and insofar as the deficiencies are such as to be rectifiable, to correct the indicated deficiencies within a period

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from the notification of this communication, this period being computed in accordance with Rules 126(2) and 131(2) and (4) EPC. One set of amendments to the description, claims and drawings is to be filed within the said period on separate sheets (R. 50(1) EPC).

If filing amendments, you must identify them and indicate the basis for them in the application as filed. Failure to meet either requirement may lead to a communication from the Examining Division requesting that you correct this deficiency (R. 137(4) EPC).

Failure to comply with this invitation in due time will result in the application being deemed to be withdrawn (Art. 94(4) EPC).



Radeck, Stephanie
Primary Examiner
For the Examining Division

Enclosure(s): 5 page/s reasons (Form 2906)

1 Application Documents

The examination is being carried out on the **following application documents**

Description, Pages

1-25 as published

Claims, Numbers

1-15 filed with entry into the regional phase before the EPO

Drawings, Sheets

1/2, 2/2 as published

2 Prior Art

Reference is made to the following documents; the numbering will be adhered to in the rest of the procedure.

D1 WO 94/11541 A1 (SHEFFIELD FORGEMASTERS [GB]; WRAGG DAVID [GB]; HEWITT PAUL HERBERT [GB] 26 May 1994 (1994-05-26)

D2 US 6 013 141 A (NYLEN BO TOMMY KAGE [SE] ET AL) 11 January 2000 (2000-01-11)

3 Amendments, Art. 123 (2) EPC

3.1 The amended claims 1 and 2 do not comply with Art. 123 (2) EPC, because the selection made ("any one or more than one of titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, and molybdenum" in claim 1 without tungsten, which is mentioned in claim 2) is not disclosed in the application.

3.2 Claims 3-15 comply with Art. 123 (2) EPC.

4 **Clarity, Art. 84 EPC**

The application does not meet the requirements of Article 84 EPC, because claims 5, 11 and 12-15 are not clear.

- 4.1 Claims 5, 11 and 12-15 have been drafted as separate independent claims. Under Article 84 in combination with Rule 43(2) EPC, an application may contain more than one independent claim in a particular category only if the subject-matter claimed falls within one or more of the exceptional situations set out in paragraph (a), (b) or (c) of Rule 43(2) EPC. This is not the case in the present application, however, because all these claims address different aspects of the method of claim 5.

5 **Novelty and Inventive Step, Art. 52, 54 and 56 EPC**

The present application does not meet the criteria of Article 52 EPC because the subject-matters of claims 1-4, 5-8 and 11-15 are not new in the sense of Art. 54 (1) (2) and the subject-matter of claims 9 and 10 does not involve an inventive step in the sense of Art. 56 EPC.

- 5.1 D1 (claims 18, 19, 24 and 30-33; descr. p. 2-15) discloses an engineering material made from a ferrous metal matrix comprising up to 20 vol% carbide particles selected from chromium, molybdenum, titanium, tungsten, niobium, vanadium or mixed carbides and therefore takes away the novelty of the subject-matter of claim 1.
- 5.2 D1 also takes away the novelty of the subject-matter of dependent claims 2-4.
- 5.3 The method of claims 5 and 6 is disclosed in D1, claim 1 with descr. p. 4, l. 1-3.
- 5.4 The features of dependent method claims 7 and 8 are disclosed in D1, claims 28 and 4, respectively.

5.5 The alternative method of forming a wear resistant hard metal material according to method claims 9 and 10 by allowing a melt to cool and thereby forming the solid particles is known from D2, claim 1. The subject-matter of claims 9 and 10 lacks therefore an inventive step over D2 in combination with D1.

5.6 The subject-matters of claims 11-15 are also disclosed in D1 (claims 18, 19, 24 and 30-33; descr. p. 2-15).

6 Procedure

6.1 The present set of claims is not allowable.

6.2 **At least some of the objections raised above are such that there appears to be no possibility of overcoming them by amendment. Refusal of the application under Article 97(2) EPC is therefore to be expected.**

6.3 Should the applicant nevertheless regard some particular matter as patentable, an independent claim should be filed taking account of Rule 43(1) EPC. The applicant should also indicate how the subject-matter of the new claim differs from the state of the art and the significance thereof.

6.4 When filing new claims the description should likewise be adapted properly.

6.5 To meet the requirements of Rule 42(1)(b) EPC, documents D1 and D3, which constitute the relevant prior art, should also be identified in the description and the relevant background art disclosed therein should be briefly discussed.

6.6 The attention of the applicant is drawn to the fact that the application may not be amended in such a way that it contains subject-matter which extends beyond the content of the application as filed (Art. 123(2) EPC).

6.7 In order to facilitate the examination of the conformity of the amended application with the requirements of Art. 123(2) EPC, the applicant should clearly identify the amendments carried out, irrespective of whether they concern amendments by addition, replacement or deletion, and to indicate the passages of the application as filed on which these amendments are based (see Guidelines 2013 H-III, 2.).

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 94/11541 A1 (SHEFFIELD FORGEMASTERS [GB]; WRAGG DAVID [GB]; HEWITT PAUL HERBERT [GB] 26 May 1994 (1994-05-26)	1-8, 11-15	INV. C22C29/02 C22C29/14 C22C29/16
Y	* p. 2-15; claims 1-36 *	9,10	
Y	----- US 6 013 141 A (NYLEN BO TOMMY KAGE [SE] ET AL) 11 January 2000 (2000-01-11) * claim 1 *	9,10	
E	----- WO 2011/091479 A1 (WEIR MINERALS AUSTRALIA LTD [AU]; DOLMAN KEVIN [AU]) 4 August 2011 (2011-08-04) * the whole document *	1-15	
A	----- DE 20 63 181 A1 (UDDEHOLMS AB) 22 July 1971 (1971-07-22) * the whole document *	1-15	
A	----- WO 2004/104253 A1 (WEIR WARMAN LTD [AU]; DOLMAN KEVIN FRANCIS [AU]) 2 December 2004 (2004-12-02) * the whole document *	1-15	
A	----- WO 01/88213 A1 (PROENCO AB [SE]; ANDERSSON CARL HAAKAN [SE]; NILSSON ANDERS [SE]; STA) 22 November 2001 (2001-11-22) * the whole document *	1-15	TECHNICAL FIELDS SEARCHED (IPC) C22C
The supplementary search report has been based on the last set of claims valid and available at the start of the search.			
Place of search Munich		Date of completion of the search 24 February 2014	Examiner Radeck, Stephanie
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document	

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 11 73 9260

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

24-02-2014

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<p>(30) Prioridad(es): 05/02/2010 AU 2010900457 01/10/2010 AU 2010904416</p> <p>(71) Solicitante: WEIR MINERALS AUSTRALIA LTD 1 Marden Street 2064 Artarmon New South Wales AU</p> <p>(72) Inventor(es): KEVIN DOLMAN 29 Chester Street Epping New South Wales 2121 AU</p> <p>(74) Representante: MANUEL MARTIN SOTO GUTIERREZ Hamburgo No. 260 Distrito Federal 06600 MX</p>	
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(54) Título: **MATERIALES DE METAL DURO.**

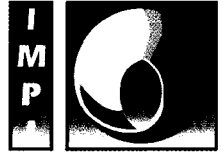
(54) Title: **HARD METAL MATERIALS.**

(57) Resumen

Se dan a conocer un material de metal duro y un método de fabricación de un componente del material de metal duro. El material de metal duro comprende el 5-50% en volumen de partículas de un material refractario dispersadas en un metal huésped. El método comprende formar una suspensión del 5-50% en volumen de partículas del material refractario dispersadas en un metal huésped líquido en una atmósfera inerte y verter la suspensión en un molde y formar una pieza colada del componente.

(57) Abstract

A hard metal material and a method of manufacturing a component of the hard metal material are disclosed. The hard metal material comprises 5-50 volume % particles of a refractory material dispersed in a host metal. The method comprises forming a slurry of 5-50 volume % particles of the refractory material dispersed in a liquid host metal in an inert atmosphere and pouring the slurry into a mould and forming a casting of the component.



TÍTULO DE PATENTE NO. 345311

Titular(es): WEIR MINERALS AUSTRALIA LTD
Domicilio: 1 Marden Street, Artarmon, New South Wales, 2064, AUSTRALIA
Denominación: MATERIALES DE METAL DURO.
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Inventor(es): KEVIN DOLMAN

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La patente de referencia se otorga con fundamento en los artículos 1º, 2º fracción V, 6º fracción III, y 59 de la Ley de la Propiedad Industrial.

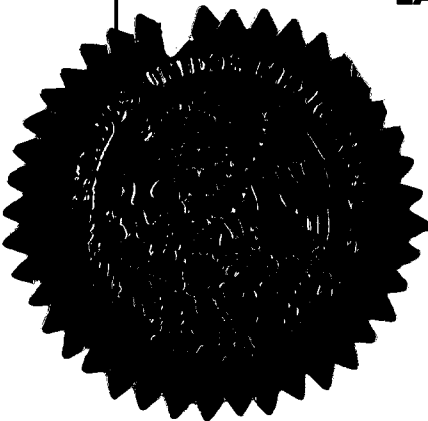
De conformidad con el artículo 23 de la Ley de la Propiedad Industrial, la presente patente tiene una vigencia de veinte años improrrogables, contada a partir de la fecha de presentación de la solicitud internacional y estará sujeta al pago de la tarifa para mantener vigentes los derechos.

Quien suscribe el presente título lo hace con fundamento en lo dispuesto por los artículos 6º fracciones III y 7º bis 2 de la Ley de la Propiedad Industrial (Diario Oficial de la Federación (D.O.F.) 27/06/1991, reformada el 02/08/1994, 20/10/1996, 26/12/1997, 17/05/1999, 26/01/2004, 16/06/2005, 25/01/2006, 06/05/2009, 06/01/2010, 18/06/2010, 28/06/2010, 27/01/2012 y 09/04/2012); artículos 1º, 3º fracción V inciso a), 4º y 12º fracciones I y III del Reglamento del Instituto Mexicano de la Propiedad Industrial (D.O.F. 14/12/1999, reformado el 01/07/2002, 15/07/2004, 28/07/2004 y 7/09/2007); artículos 1º, 3º, 4º, 5º fracción V inciso a), 16 fracciones I y III y 30 del Estatuto Orgánico del Instituto Mexicano de la Propiedad Industrial (D.O.F. 27/12/1999, reformado el 10/10/2002, 29/07/2004, 04/08/2004 y 13/09/2007); 1º, 3º y 5º inciso a) del Acuerdo que delega facultades en los Directores Generales Adjuntos, Coordinador, Directores Divisionales, Titulares de las Oficinas Regionales, Subdirectores Divisionales, Coordinadores Departamentales y otros subalternos del Instituto Mexicano de la Propiedad Industrial. (D.O.F. 15/12/1999, reformado el 04/02/2000, 29/07/2004, 04/08/2004 y 13/09/2007).

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LA DIRECTORA DIVISIONAL DE PATENTES

NAHANNY CANAL REYES



MATERIALES DE METAL DURO

Campo de la Invención

La presente invención se refiere en términos generales a
5 materiales de metal duro que comprenden partículas de material
refractario, tal como se describe en el presente documento,
dispersadas en un metal huésped o aleación de metal.

El Diccionario de Ingeniería de Materiales ASM ("*ASM
Materials Engineering Dictionary*") define el término "metal
10 duro" como un término colectivo para un material sinterizado
con alta dureza, solidez y resistencia al desgaste.

La presente invención también proporciona componentes
fabricados a partir de los materiales de metal duro. La
presente invención se refiere particularmente, aunque de
15 ningún modo exclusivamente, a componentes grandes que pesan
más de 100 kg y normalmente más de 1 tonelada.

La presente invención también proporciona un método de
fabricación de los componentes a partir de los materiales de
metal duro.

20 En términos más particulares, aunque de ningún modo
términos exclusivos, la presente invención se refiere a
materiales de metal duro que son útiles para aplicaciones que
requieren resistencia al desgaste.

Antecedentes de la Invención

25 Se sabe usar la pulvimetalurgia para fabricar

componentes pequeños a partir de materiales de metal duro que comprenden partículas refractarias dispersadas en un metal huésped (término que se entiende en el presente documento que incluye una aleación de metal).

5 Los procesos de pulvimetalurgia implican sinterizar mecánicamente polvos refractarios mezclados a temperaturas elevadas bajo presión, habitualmente en una atmósfera inerte.

"Sinterizar" comprende unir materiales en polvo, habitualmente bajo presión, mediante reacciones en estado
10 sólido a temperaturas inferiores a la requerida para la formación de una fase líquida. Durante un proceso de sinterización, a temperaturas por debajo del punto de fusión de los aglutinantes metálicos, los polvos de la fase de aglutinante metálico y las partículas refractarias se sueldan
15 entre sí mediante presión y calor. La sinterización se usa tradicionalmente para fabricar componentes cerámicos y también ha encontrado usos en campos tales como pulvimetalurgia para la fabricación de productos que contienen materiales con un punto de fusión muy alto.

20 La pulvimetalurgia es un procedimiento útil para fabricar componentes relativamente pequeños, de forma sencilla, resistentes al desgaste tales como brocas de carburo de tungsteno. Sin embargo, la pulvimetalurgia no es un procedimiento práctico para fabricar componentes más
25 grandes, de forma compleja, de metal duro, resistentes al

desgaste tales como propulsores de bombas y piezas de
desgaste de trituradoras que pesan más de 100 kg y
normalmente más de 1 tonelada a partir de materiales de metal
duro. Esto es un problema, particularmente en aplicaciones en
5 minería e industrias de procesamiento de minerales en las que
se requieren a menudo componentes grandes con alta
resistencia al desgaste.

Se sabe usar aleaciones de metales resistentes al
desgaste, tales como hierros colados blancos con alto
10 contenido en cromo, en la fabricación de componentes usados
en aplicaciones en minería e industrias de procesamiento de
minerales, tales como aplicaciones que implican transportar
materiales sólidos. Por ejemplo, se forman aleaciones de
superficie endurecida en las bandejas de camiones basculantes
15 que transportan el mineral extraído desde el sitio de la mina
hasta una planta de procesamiento de minerales. En otro
ejemplo, se usan piezas coladas de aleaciones resistentes al
desgaste para formar bombas para transportar suspensiones de
partículas de mineral suspendidas en agua a través de fases
20 de procesamiento en circuitos de flotación en una planta de
procesamiento de minerales.

Los requisitos de tenacidad a la fractura y resistencia
a la corrosión para la aleación resistente al desgaste en
cada uno de los ejemplos anteriores son diferentes y, por
25 consiguiente, las composiciones de la aleación resistente al

desgaste son diferentes. El factor común entre ambas es, sin embargo, la necesidad de proporcionar resistencia al desgaste además de otras propiedades.

En términos generales, puede lograrse una resistencia al desgaste superior a través del control de la composición de la aleación, aunque hay una compensación frente a otras propiedades.

Para cualquier circunstancia dada en la que la resistencia al desgaste sea una propiedad importante, es deseable proporcionar materiales con propiedades deseables y resistencia al desgaste mejorada comprometiendo menos el equilibrio de estas propiedades.

Cabe señalar que la descripción incluye referencias a porcentaje en peso (% en peso) y porcentaje en volumen (% en volumen). En el contexto de las referencias a NbC en la descripción, en la que NbC tiene una densidad similar a un metal huésped, estos términos son intercambiables.

Sumario de la Invención

El solicitante ha encontrado en el transcurso de una extensa investigación y trabajo de desarrollo que un metal huésped líquido, que contiene una dispersión, normalmente una dispersión del 5-50% en volumen de partículas finas de un material refractario que es insoluble en el metal huésped, y que se describe en el presente documento como una suspensión de metal líquido, tiene una fluidez muy buena durante el



vertido en una fundición y la suspensión fluye fácilmente llenando moldes de arena para producir piezas ~~coladas firmes~~ del material de metal duro.

El término "insoluble" se entiende en el presente documento que significa que para todos los propósitos y fines el material refractario no es soluble en el metal huésped. Puede haber una solubilidad limitada. Sin embargo, las partículas refractarias son esencialmente distintas del metal huésped porque hay un reparto insignificante de los metales de transición en las partículas de material refractario con respecto al metal huésped.

El solicitante ha encontrado también que el mezclado y la dispersión de las partículas refractarias insolubles en el metal huésped pueden llevarse a cabo de un modo eficaz en el estado líquido en una atmósfera inerte, tal como en un horno al vacío, para minimizar la oxidación de los elementos reactivos en las partículas de material refractario.

La presente invención es una desviación de la práctica de fundición convencional conocida por el solicitante que implica la fusión completa de todas las adiciones de aleación contenidas en una pieza colada para formar un líquido de una única fase para garantizar una fluidez máxima durante el vertido en un molde.

El solicitante ha encontrado también que la fluidez de las suspensiones de metal líquido, cuando se cuelean dentro de

determinados parámetros de producción según la presente invención, es suficiente para producir una familia de piezas coladas de material de metal duro firmes que oscilan entre carcasas pequeñas y grandes con resistencia al desgaste, tenacidad a la fractura y resistencia a la corrosión específicas que se adecuan a un amplio intervalo de condiciones de funcionamiento en servicio.

Los parámetros de producción pueden comprender uno cualquiera o más del tamaño de partícula, reactividad, expansión o contracción térmica, densidad y solubilidad del material refractario, tal como se trata adicionalmente a continuación.

En términos amplios, la presente invención proporciona un material de metal duro que comprende el 5-50% en volumen de partículas de un material refractario dispersadas en un metal huésped.

En el contexto de la presente invención, el término "material de metal duro" se entiende que comprende partículas de carburos y/o nitruros y/o boruros de alto punto de fusión de uno cualquiera o más de uno de los nueve metales de transición titanio, zirconio, hafnio, vanadio, niobio, tantalio, cromo, molibdeno y tungsteno dispersadas en un metal huésped tenaz, que actúa como fase aglutinante. Normalmente, el metal huésped es una aleación de metal ferroso. Cada una de estas partículas es una partícula de un

material refractario y se denomina en el presente documento
"material refractario".

Las partículas del material refractario pueden ser
carburos y/o boruros y/o nitruros de un metal de transición,
5 tales como NbC. Las partículas del material refractario
pueden ser carburos y/o boruros y/o nitruros de más de un
metal de transición en el que las partículas son una mezcla
química (en contraposición a una mezcla física) de los
carburos y/o boruros y/o nitruros de los metales de
10 transición. En otras palabras, en el caso de carburos, las
partículas del material refractario pueden ser del tipo
descrito como $(M_1, M_2)C$, donde "M" es un metal de transición.
Un ejemplo que se trata adicionalmente en el presente
documento es $(Nb, Ti)C$.

15 El material de metal duro puede comprender el 5-40% en
volumen de partículas del material refractario dispersadas en
el metal huésped.

El material de metal duro puede comprender más del 10%
en volumen de partículas del material refractario dispersadas
20 en el metal huésped.

El material de metal duro puede comprender más del 15%
en volumen de partículas del material refractario dispersadas
en el metal huésped.

El material de metal duro puede comprender menos del 30%
25 en volumen de partículas del material refractario dispersadas

en el metal huésped.

El material de metal duro puede comprender menos del 25% en volumen de partículas del material refractario dispersadas en el metal huésped.

5 El metal huésped puede ser una aleación ferrosa (tal como un acero o un hierro colado), un acero inoxidable, un acero austenítico al manganeso tal como un acero Hadfield o una superaleación a base de hierro o a base de níquel o a base de cobalto.

10 La presente invención también proporciona un método de formación de un material de metal duro que comprende:

(a) formar una suspensión de un material de metal duro que comprende el 5-50% en volumen de partículas de un material refractario dispersadas en un metal huésped líquido, 15 por ejemplo en una atmósfera inerte, y

(b) dejar que la suspensión solidifique para formar un material de metal duro sólido.

La presente invención también proporciona un método de fabricación de un componente de un material de metal duro que 20 comprende:

(a) formar una suspensión de un material de metal duro que comprende el 5-50% en volumen partículas de un material refractario dispersadas en un metal huésped líquido en una atmósfera inerte, y

25 (b) verter la suspensión en un molde y formar una pieza

colada del componente en una atmósfera inerte.

El método puede comprender formar la suspensión y después de eso formar la pieza colada del componente en una cámara en condiciones al vacío que eliminan el aire de la cámara y suministrar un gas inerte, tal como argón, a la cámara. A modo de ejemplo, el método puede llevarse a cabo en un horno de fusión al vacío.

El método puede comprender seleccionar los parámetros de producción para formar la suspensión en la etapa (a) que tiene una fluidez requerida para el procesamiento en la etapa (b). En cualquier situación dada, un experto podrá determinar la fluidez requerida para la etapa de procesamiento (b) teniendo en cuenta consideraciones de la práctica de fundición convencional tales como el tamaño y la forma del componente que va a formarse y la dispersión requerida (uniforme o segregada) para proporcionar la microestructura requerida para el componente.

Los parámetros de producción pueden comprender uno cualquiera o más del tamaño de partícula, reactividad, densidad y solubilidad de los materiales refractarios, tal como se trata adicionalmente a continuación.

Tamaño de partícula del material refractario

El material refractario puede tener un tamaño de partícula fino. Puede requerirse un tamaño de partícula del material refractario fino para garantizar una dispersión

homogénea en el metal huésped. Los puntos de fusión de la
mayoría de los materiales refractarios de metales de
transición superan los 1800°C y los materiales refractarios
son generalmente insolubles en metales líquidos huésped. El
5 solicitante ha encontrado que polvos refractarios con tamaños
de partícula inferiores a 500 micrómetros, normalmente
inferiores a 150 micrómetros de diámetro proporcionan
características de flujo óptimas en suspensiones de metal
líquido y producen una dispersión uniforme deseable de los
10 materiales particulados refractarios en las microestructuras
de las piezas coladas de metal duro.

El material refractario puede tener menos de 400
micrómetros de tamaño de partícula.

El material refractario puede tener menos de 200
15 micrómetros de tamaño de partícula.

El material refractario puede tener menos de 150
micrómetros de tamaño de partícula.

El material refractario puede añadirse al metal líquido
huésped tal como sigue.

20 (a) Como un polvo fino con una distribución de tamaño de
partícula seleccionada. Por ejemplo, un 15% en peso de
partículas de un material refractario en forma de carburo de
niobio (NbC) (menos de 50 micrómetros de diámetro) añadidas a
un metal huésped líquido en forma de un metal huésped de
25 hierro colado blanco con alto contenido en cromo. NbC

presenta una dureza Vickers de 24 GPa, un punto de fusión de 3600°C y una solubilidad muy baja en el metal líquido huésped a una temperatura de colada de aproximadamente 1500°C. La suspensión de metal líquido comprende una suspensión de partículas de NbC insolubles (menos de 50 micrómetros de diámetro) en el metal líquido huésped. Al solidificarse, la microestructura presenta una dispersión del 15% en volumen de partículas de NbC finas (menos de 50 micrómetros de diámetro) en una matriz de hierro colado blanco con alto contenido en cromo que contiene una cantidad insignificante (inferior al 0,3% en peso) de niobio en disolución en la matriz.

(b) Los metales de transición mencionados anteriormente o ferroaleaciones de los mismos metales de transición pueden añadirse a una amplia variedad de metales huésped que contienen todas las combinaciones y permutaciones de los elementos carbono, boro y nitrógeno.

Por ejemplo, tal como se describe en más detalle a continuación, el solicitante ha encontrado que Fe-Nb se disuelve fácilmente en el metal líquido huésped a 1500°C e inmediatamente el niobio se combina con el carbono en el metal líquido huésped para formar carburos de niobio *in situ* con tamaños de partícula inferiores a 50 micrómetros de diámetro.

Materiales refractarios reactivos

La mayoría de los materiales refractarios de metales de

transición descritos anteriormente se clasifican como "elementos reactivos", es decir, los elementos metálicos individuales y/o sus formas de compuestos de carburo, nitruro o boruro reaccionan fácilmente con aire a temperaturas de colada del metal de aproximadamente 1500°C para formar óxidos de metales indeseables y/o cantidades copiosas de gases tales como CO₂, lo que puede dar como resultado una porosidad grave en las piezas coladas. Los problemas de oxidación y porosidad en piezas coladas de metal duro, producidas mediante una suspensión de metal líquido, y asociados con reacciones químicas de los materiales refractarios reactivos en aire a temperaturas elevadas se superan fundiendo y vertiendo la suspensión de metal líquido en una atmósfera inerte.

Selección de partículas de material refractario que tienen expansión o contracción térmica inferior que el metal huésped

Se ha notificado de manera diversa una mala unión entre partículas refractarias y el metal huésped en materiales de metal duro en la bibliografía. El solicitante no ha encontrado pruebas de una mala unión entre las partículas refractarias y una amplia variedad de los metales huésped evaluados por el solicitante. Sin querer restringirse a la teoría mediante el siguiente comentario, la excelente unión observada la atribuye el solicitante en gran parte al uso de una atmósfera inerte durante la colada de los materiales de

metal duro y a que la contracción térmica de las partículas
refractarias de metales de transición es mucho menor, de
manera normal aproximadamente un 50% inferior, que la
contracción térmica de los metales huésped durante el
5 enfriamiento del sólido hasta temperatura ambiente, lo que
genera fuerzas compresivas sobre las partículas de material
refractario que sujetan firmemente las partículas en los
metales huésped al solidificarse. Se encontró que todas las
partículas refractarias en las piezas coladas de material de
10 metal duro producidas por el solicitante en una atmósfera
inerte estaban bajo una carga compresiva que garantizaba un
contacto íntimo y una buena unión con los metales huésped.

Densidad de materiales refractarios

La densidad del material refractario de las partículas,
15 en comparación con la densidad del metal huésped en el estado
líquido, es un parámetro que debe considerarse durante el
método de la presente invención para controlar la dispersión
de partículas refractarias en el metal huésped caliente. En
algunas situaciones, puede ser importante evitar la
20 segregación de partículas de material refractario en el metal
huésped líquido. En otras situaciones, la segregación puede
ser deseable. Por ejemplo, la densidad nominal de un metal
líquido ferroso a 1400°C es de 6.9 gramos/cc. Cuando se
añaden partículas de carburo de tungsteno, con una densidad
25 de 15.7 gramos/cc, a un metal ferroso huésped, las partículas

de WC se hundirán en el fondo del molde antes de la
solidificación del metal huésped. Cuando se añaden partículas
de carburo de titanio, con una densidad de 4.8 gramos/cc, al
mismo metal ferroso huésped, las partículas de TiC flotarán en
5 la parte superior de la cuchara o molde. El carburo de niobio,
con una densidad de 7.7 gramos/cc a 1400°C, está bastante
próximo a la densidad del metal líquido huésped a 6.9 gramos/cc
y es menos propenso a la segregación en el metal huésped
líquido que TiC o WC. Sin embargo, el solicitante ha observado
10 que se segregarán partículas de NbC al fondo de piezas coladas
de hierro blanco de sección grande durante el procedimiento de
la presente invención cuando los tiempos de solidificación son
del orden de 30 minutos o más. Tal como se describe en más
detalle a continuación, el carburo de niobio y carburo de
15 titanio tienen estructuras cristalinas similares y son
isomorfos. La selección de la razón de Nb/Ti requerida en un
compuesto químico (Nb,Ti)C produce un material refractario con
cualquier densidad requerida en el intervalo de 4.8 - 7.7
gramos/cc a la temperatura de colada. La coincidencia de la
20 densidad de las partículas refractarias sólidas y el metal
huésped líquido a la temperatura de colada elimina la
segregación de los materiales particulados en la masa fundida
durante el procedimiento de la presente invención.

Solubilidad de materiales refractarios

25 La adición de partículas de material refractario que son

para todos los propósitos y fines insolubles, ~~es decir, que~~
tienen una solubilidad sólida mínima en el metal líquido
huésped, para producir una pieza colada según el método de la
presente invención, produce un material de metal duro que
5 presenta propiedades físicas y químicas que son muy similares
al metal huésped con resistencia al desgaste sustancialmente
mejorada debido a la presencia de una dispersión controlada
de un % en volumen alto de partículas de material refractario
en la microestructura.

10 Por ejemplo, la solubilidad de un material refractario
en forma de (Nb,Ti)C en metales huésped líquidos en forma
de (a) acero Hadfield líquido y (b) acero inoxidable 316
líquido y (c) hierro colado blanco con alto contenido en
cromo líquido a temperaturas elevadas es insignificante
15 (<0,3% en peso). La adición de un 15% en peso de (Nb,Ti)C
con las densidades requeridas a estas tres aleaciones de
metal, seguido por un procedimiento de tratamiento térmico
convencional para cada metal huésped produce
microestructuras que consisten en una dispersión uniforme
20 del 15% en volumen de carburos de niobio-titanio primarios
en los metales huésped que están sustancialmente libres de
niobio y titanio, es decir, hay un reparto insignificante
de los metales de transición en las partículas de la
suspensión de material refractario con respecto al metal
25 huésped líquido.

En consecuencia, hay una influencia insignificante de los materiales refractarios de las partículas sobre la química y la respuesta al tratamiento térmico del metal huésped.

5 Los tres materiales de metal duro producidos mediante el método de la presente invención presentan las propiedades físicas y químicas conocidas de (a) acero Hadfield, (b) acero inoxidable 316 y (c) hierro colado blanco con alto contenido en cromo respectivamente con una resistencia al desgaste
10 aumentada debido a la presencia de una dispersión del 15% en volumen de carburos de niobio-titanio primarios en las microestructuras.

Además de lo anterior, en particular el solicitante ha encontrado que dotar a un material de metal duro de una
15 microestructura que incluye partículas de carburo de niobio y/o partículas de una mezcla química (en contraposición a física) de carburo de niobio y carburo de titanio dispersadas en una matriz de un metal huésped mejora considerablemente la resistencia al desgaste del material de metal duro sin
20 afectar perjudicialmente a la contribución que otros elementos de aleación tienen sobre otras propiedades del material de metal duro.

Además, en particular el solicitante ha encontrado que es posible ajustar la densidad de partículas de una mezcla
25 química de carburo de niobio y carburo de titanio en un grado

suficiente en relación con la densidad de un metal huésped,
que forma una matriz del material de metal duro, para hacer
posible controlar selectivamente la dispersión de las
partículas en la matriz desde una dispersión uniforme hasta
5 una dispersión no uniforme de las partículas. Esta
oportunidad para el control de la densidad es un hallazgo
importante en relación a piezas coladas del material de metal
duro. En particular, en virtud de este hallazgo, ahora es
posible producir piezas coladas del material de metal duro
10 con segregación controlada de las partículas en partes de las
piezas coladas. Esto es importante para algunas aplicaciones
de uso final para piezas coladas, tal como cuando es deseable
tener una concentración de partículas con alta resistencia al
desgaste casi en la superficie de una pieza colada de un
15 material de metal duro. Igualmente, en otras aplicaciones de
uso final para piezas coladas, es deseable tener una
dispersión uniforme de las partículas en la matriz de la
pieza colada.

Además, el solicitante ha encontrado que la formación de
20 un material de metal duro y piezas coladas del material para
que incluyan partículas de carburo de niobio y/o partículas
de una mezcla química de carburo de niobio y carburo de
titanio en un intervalo del 10 al 25% en peso, o incluso
hasta el 33% en peso o superior, dispersadas en un metal
25 huésped, que forma una matriz del material de metal duro, no

tiene un impacto negativo significativo sobre la resistencia
a la corrosión y tenacidad del material ferroso en el metal
huésped. Por tanto, la presente invención hace posible lograr
una alta resistencia al desgaste de un material de metal duro
5 sin la pérdida de otras propiedades deseables del material.

Por consiguiente, se proporciona un método de formación
de un material de metal duro resistente al desgaste,
comprendiendo el método añadir (a) niobio o (b) niobio y
titanio a una masa fundida que contiene un metal huésped en
10 una forma que produce partículas de carburo de niobio y/o
partículas de una mezcla química de carburo de niobio y
carburo de titanio en un intervalo del 10 al 40% en peso del
peso total del material de metal duro, y dejar que la masa
fundida solidifique para formar el material de metal duro
15 sólido.

Los términos "una mezcla química de carburo de niobio y
carburo de titanio" y "carburos de niobio/titanio" se
entiende a continuación en el presente documento que son
sinónimos. Además, el término "mezcla química" se entiende en
20 este contexto que significa que los carburos de niobio y los
carburos de titanio no están presentes como partículas
separadas en la mezcla sino que están presentes como
partículas de carburos de niobio/titanio.

Los carburos de niobio y carburos de titanio tienen cada
25 uno una dureza Vickers (HV, por sus siglas en inglés) de

aproximadamente 2500, que está aproximadamente ~~1000 HV por~~
encima de la dureza de carburos de cromo. Por consiguiente,
materiales de metal duro que tienen una microestructura que
contiene del 10 al 40% en peso de partículas de carburo de
5 niobio y/o carburos de niobio/titanio tienen excelentes
propiedades de resistencia al desgaste. Sin embargo, un
aspecto significativo del trabajo del solicitante ha
reconocido que los carburos de niobio y carburos de titanio y
carburos de niobio/titanio son sustancialmente inertes
10 químicamente con respecto a otros constituyentes en el
material de metal duro de modo que esos constituyentes dotan
al material de metal duro de las propiedades para las que se
seleccionaron. Por ejemplo, el cromo añadido a aleaciones de
hierro colado produce todavía carburos de cromo y proporciona
15 resistencia a la corrosión.

La masa fundida puede estar en forma de un baño de
fusión de la soldadura en un procedimiento de endurecimiento
de superficie. En estas circunstancias, el niobio y/o el
titanio pueden añadirse al baño de fusión de la soldadura en
20 una aleación de alambre con el fin de dosificar la adición de
niobio y/o titanio.

La masa fundida puede estar en forma de una masa fundida
para formar una pieza colada.

El niobio y el titanio pueden añadirse a la masa fundida
25 en cualquier forma adecuada, teniendo en cuenta el requisito

de formación de partículas de carburos de niobio y/o carburos de niobio/titanio en el material de metal duro sólido.

Por ejemplo, el método puede comprender añadir el niobio a la masa fundida en forma de ferro-niobio, por ejemplo 5 partículas de ferro-niobio. En esta situación, el ferro-niobio se disuelve en la masa fundida y el niobio libre resultante y el carbono en la masa fundida forman carburos de niobio en la masa fundida.

El método también puede comprender añadir el niobio a la 10 masa fundida como niobio elemental.

El método también puede comprender añadir el niobio y el titanio a la masa fundida como ferro-niobio-titanio.

El método también puede comprender añadir el niobio a la masa fundida en forma de partículas de carburo de niobio. El 15 método también puede comprender añadir el niobio y el titanio a la masa fundida en forma de partículas de carburos de niobio/titanio. En ambos casos, la aleación de metal solidificada puede estar formada por una suspensión de partículas de carburo de niobio y/o carburos de 20 niobio/titanio suspendidas en la masa fundida. Se espera que si la fracción en peso de estos carburos en la suspensión de la masa fundida es demasiado alta, las propiedades de flujo de la suspensión pueden verse afectadas de manera adversa con el resultado de que pueden producirse piezas coladas 25 defectuosas de la masa fundida. No obstante, la colada de una

suspensión contrasta con el procedimiento de funcionamiento convencional en fundiciones que implica colar masas fundidas líquidas transparentes (de una única fase), es decir, en el que la masa fundida está por encima de la temperatura líquida del constituyente de punto de fusión más alto de la masa fundida.

Las partículas de carburos de niobio/titanio pueden ser cualquier mezcla química adecuada de una fórmula general $(\text{Nb}_x, \text{Ti}_y)\text{C}$. A modo de ejemplo, los carburos de niobio/titanio pueden ser $(\text{Nb}_{0,5}, \text{Ti}_{0,5})\text{C}$ o $(\text{Nb}_{0,25}, \text{Ti}_{0,75})\text{C}$ o $(\text{Nb}_{0,75}, \text{Ti}_{0,25})\text{C}$.

El niobio y/o el titanio pueden añadirse a la masa fundida para producir partículas de carburo de niobio y/o carburos de niobio/titanio en un intervalo del 12% en peso al 33% en peso de carburos de niobio y carburos de niobio/titanio del peso total del material de metal duro solidificado.

El niobio y/o el titanio pueden añadirse a la masa fundida para producir partículas de carburo de niobio y/o carburos de niobio/titanio en un intervalo del 12% en peso al 25% en peso de carburos de niobio y carburos de niobio/titanio del peso total del material de metal duro solidificado.

La cantidad de partículas de carburo de niobio y/o carburos de niobio/titanio en la microestructura del material de metal duro solidificado puede depender del sistema.

El solicitante se interesa particularmente por materiales de metal duro sólidos que incluyen metales huésped en forma de aleaciones ferrosas, tales como aleaciones ferrosas descritas como hierros colados blancos con alto contenido en cromo, aceros inoxidable y aceros austeníticos al manganeso (tales como aceros Hadfield). Para las aleaciones ferrosas, la cantidad de partículas de carburo de niobio y/o carburos de niobio/titanio en la microestructura final puede estar en un intervalo del 10 al 33% en peso o en un intervalo del 12 al 25% en peso del peso total del material de metal duro solidificado.

El tamaño de partícula de carburo de niobio y/o carburo de niobio/titanio puede estar en un intervalo de 1 a 150 μm de diámetro.

El método puede comprender agitar la masa fundida con un gas inerte o inducción magnética o cualquier otro medio adecuado con el fin de dispersar partículas de carburo de niobio y/o carburos de niobio/titanio en la masa fundida.

El método puede comprender añadir partículas de carburo de niobio y/o partículas de carburos de niobio/titanio a la masa fundida en condiciones inertes, tales como un manto de argón, para reducir el grado en el que el carburo de niobio y/o el carburo de titanio se oxidan mientras que se añaden a la masa fundida.

El método puede comprender añadir partículas de ferro-

niobio y/o ferro-titanio y/o ferro-niobio-titanio a la masa fundida en condiciones inertes, tales como un manto de argón, para reducir el grado en el que el niobio y/o titanio se oxidan mientras que se añaden a la masa fundida.

5 En una situación en la que se requieren partículas de carburos de niobio/titanio en el material de metal duro solidificado, el método puede comprender fundir previamente ferro-niobio y ferro-titanio y/o ferro-niobio-titanio en condiciones inertes y formar una fase líquida que es una
10 mezcla química homogénea de hierro, niobio y titanio y solidificar esta mezcla química. La mezcla química puede procesarse entonces según se requiera, por ejemplo mediante trituración hasta un tamaño de partícula requerido, y añadirse entonces a la masa fundida (que contiene carbono) en
15 condiciones inertes. El hierro, niobio y titanio se disuelven en la masa fundida y el niobio y titanio y carbono en la masa fundida forman carburos de niobio/carburos de titanio en la masa fundida.

20 El método puede comprender formar el material de metal duro solidificado colando la masa fundida para dar un producto colado, tal como un impulsor de bomba o un buje de garganta de bomba.

25 El producto colado puede someterse a tratamiento térmico posterior para ajustar la microestructura para lograr las propiedades de aleación deseadas.

También se proporciona un material de metal duro formado según el método descrito anteriormente.

También se proporciona un método de colada del material de metal duro descrito anteriormente con una dispersión de partículas de una mezcla química de carburos de niobio y carburos de titanio en un metal huésped, que forma una matriz de la pieza colada que comprende seleccionar la densidad de las partículas de niobio/titanio en relación con la densidad del material de matriz y por tanto controlar selectivamente la dispersión de las partículas de niobio/titanio en la matriz que oscila desde una dispersión uniforme hasta una dispersión no uniforme.

También se proporciona una pieza colada del material de metal duro descrito anteriormente fabricada mediante el método descrito anteriormente.

La pieza colada puede comprender una dispersión uniforme de las partículas de carburo de niobio/titanio en la matriz. Por ejemplo, la pieza colada puede ser un impulsor de bomba.

La pieza colada puede comprender una dispersión no uniforme de las partículas de carburo de niobio/titanio en la matriz. Por ejemplo, la pieza colada puede ser un buje de garganta de bomba.

El metal huésped puede ser una aleación ferrosa, tal como un hierro colado blanco con alto contenido en cromo, un acero inoxidable, o un acero austenítico al manganeso (tal

como un acero Hadfield).

Breve Descripción de las Figuras

Se describirán ahora modalidades de la invención, a modo de ejemplo únicamente, con referencia a las figuras adjuntas, en las que:

La figura 1 es una micrografía de una aleación de hierro colado blanco con alto contenido en cromo que incluye un 27% en peso de cromo y un 15% en peso de carburos de niobio.

La figura 2 es una micrografía de acero inoxidable martensítico (grado 420C) que incluye un 15% en peso de carburos de niobio.

Descripción Detallada de la Invención

El solicitante llevó a cabo una extensa serie de ensayos de fusión en laboratorio sobre la adición del 10 al 30% en peso de partículas de NbC y Nb/TiC a una amplia selección de aleaciones ferrosas incluyendo hierros blancos con alto contenido en cromo, aceros austeníticos al manganeso (incluyendo aceros Hadfield), superaleaciones, aceros inoxidables (incluyendo dúplex, ferrítico, austenítico y martensítico) y depósitos de soldadura de superficie endurecida.

El solicitante ha llevado a cabo un extenso trabajo adicional revisando los datos recopilados por el solicitante directamente y en otras fuentes en relación a carburos, boruros y nitruros de metales de transición, y combinaciones

químicas de carburos, boruros y nitruros de ~~estos metales~~, y ha establecido que los hallazgos del trabajo de laboratorio notificados en el presente documento son igualmente aplicables a estos carburos, boruros y nitruros de metales de transición y combinaciones de elementos en metales huésped ferrosos.

Se muestra en la figura 1 un ejemplo de una microestructura de una aleación de hierro colado blanco con alto contenido en cromo que incluye un 15% en peso de NbC. La aleación se produjo colando un lingote de 50 g a partir de una masa fundida producida en un horno de fusión por arco eléctrico bajo una presión parcial de argón en un crisol de cobre enfriado con agua, es decir, el lingote se coló en coquilla. Se añadió el NbC a la masa fundida del horno como partículas diferenciadas que tenían un intervalo de tamaño de partícula de 2 a 20 μm de diámetro.

En modalidades adicionales, el solicitante ha examinado el uso de otros diversos intervalos de tamaño de partícula de NbC, incluyendo $<45 \mu\text{m}$ de diámetro, de 45 a 75 μm de diámetro, de 75 a 150 μm de diámetro y $<100 \mu\text{m}$ de diámetro.

Las aleaciones de hierro colado blanco con alto contenido en cromo se basan convencionalmente en el alto contenido en cromo para producir un volumen significativo de carburos de cromo duros que dotan a las piezas coladas de una alta resistencia al desgaste. Además, las aleaciones de

hierro colado blanco con alto contenido en Cromo se basan
convencionalmente en que queda algo de cromo en la matriz
ferrosa y dota a las aleaciones de resistencia a la
corrosión.

5 La microestructura en la figura 1 presenta una matriz
ferrosa que contiene una dispersión fina de carburos M_7C_3
eutécticos (que se aproxima al 30% en volumen) y una
dispersión de partículas de NbC al 15% en peso que aparecen
como una fase de esferoides de color blanco en la figura.

10 La microestructura formada en la figura 2 es una forma
de acero inoxidable martensítico de grado 420C que se produjo
mediante el mismo procedimiento descrito anteriormente para
el hierro colado blanco con alto contenido en cromo mostrado
en la figura 1.

15 En cambio, las partículas de NbC (de color blanco en la
figura 2) no son esferoides regulares como en el hierro
colado blanco con alto contenido en cromo, sino más bien una
forma de carburo de NbC irregular que parece ser típica para
diversos grados de acero inoxidable que se han aleado con
20 NbC.

 El trabajo experimental notificado anteriormente y otro
trabajo experimental llevado a cabo por el solicitante
indican que aleaciones producidas con partículas de carburo
de niobio en el intervalo del 10-30% en peso de NbC en un
25 metal huésped ferroso muestran microestructuras,

características de soldadura y características de colada en fundición muy prometedoras. Las indicaciones son que la adición de alto contenido en NbC a estos materiales aumenta sustancialmente la resistencia al desgaste sin afectar de manera adversa a la colabilidad, soldabilidad, respuesta al tratamiento térmico y a las propiedades mecánicas del material ferroso original.

Las microestructuras de las coladas de prueba en la figura 1 y otras coladas de prueba producidas por el solicitante muestran que todas las partículas de NbC añadidas a las aleaciones ferrosas son carburos primarios en suspensión en el metal líquido. La analogía es que todas las coladas convencionales por encima de la temperatura líquida (aproximadamente 1300-1400°C) son "líquidos transparentes", es decir, líquidos de una única fase. Sin embargo, cuando se añaden partículas de carburo de niobio, por ejemplo un 20% en peso, las partículas permanecen en suspensión de modo que el metal líquido y las partículas de NbC se aproximan a una "suspensión" (2 fases) con buena fluidez, lo que es un requisito obligatorio para producir piezas coladas firmes. El trabajo experimental encontró un resultado similar cuando se añadieron partículas de carburo de niobio/titanio a una masa fundida líquida.

Se apreciará, sin embargo, que pueden formarse carburos de niobio como partículas sólidas en una masa fundida, en vez

de añadirse a la masa fundida, añadiendo ferro-niobio a la
masa fundida. En tales casos, la masa fundida contiene
carbono, y el % en peso de carbono es mayor que un octavo del
% en peso de niobio. En el caso de adiciones de ferro-niobio,
5 el hierro y el niobio se separan en la masa fundida. El
niobio, que tiene una alta afinidad por el carbono, se
combina químicamente con el carbono de la masa fundida
líquida para formar partículas de carburo de niobio
dispersadas en la masa fundida líquida. Con la colada, la
10 masa fundida se cuele como una "suspensión" que consiste en
partículas de carburo de niobio sólidas suspendidas en la
masa fundida líquida. Con la solidificación, la pieza colada
tendrá una microestructura que incluye carburos de niobio
dispersados en una matriz ferrosa. Se logra una
15 microestructura similar con partículas de carburo de
niobio/titanio.

Las ventajas de añadir un 10-30% en peso de partículas
de NbC a materiales ferrosos se resumen a continuación.

(a) La dureza de NbC es de aprox. 2500 HV que se
20 compara con una dureza de 1500 HV para carburos M_7C_3 presentes
en aleaciones de hierro colado blanco con alto contenido en
cromo.

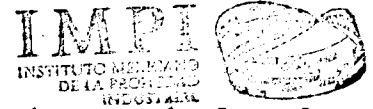
(b) El niobio es un formador de carburo muy fuerte y
puede añadirse como ferro-niobio o polvo de NbC a la masa
25 fundida ferrosa.

(c) El punto de fusión de NbC es de 3600°C, ~~es decir,~~ aproximadamente 2000°C por encima de la temperatura de la masa fundida ferrosa de aceros, hierros colados y depósitos de soldadura de superficie endurecida. Adicionalmente, las
5 partículas de NbC finas (por ejemplo de 2 a 20 μm de diámetro) no crecen de tamaño o coalescen en la masa fundida durante el procedimiento de colada. Esto es importante en cuanto a la colabilidad de la masa fundida y la resistencia al desgaste resultante del producto colado. La resistencia al
10 desgaste del producto colado se optimiza cuando se distribuye uniformemente una dispersión de partículas de NbC finas por toda la microestructura.

(d) Otros elementos, por ejemplo Cr, Mn y Fe, no se disuelven en las partículas de NbC de alto punto de fusión.
15 Por consiguiente, la composición química de las partículas de NbC no se ve alterada y conservarán sus propiedades físicas durante la preparación de la masa fundida y tras colar.

(e) La solubilidad de NbC en la matriz ferrosa es insignificante (<0,3% en peso), lo que sugiere que la adición
20 de NbC a materiales ferrosos no dará como resultado efectos observables sobre la respuesta al tratamiento térmico o cambios en las propiedades del material de la matriz ferrosa.

(f) La densidad de NbC es de 7,82 gramos/cc a temperatura ambiente. Esto está muy cerca de las densidades
25 de materiales ferrosos que son de aproximadamente 7,5



gramos/cc. Esto significa que no se segregarán partículas de NbC en la masa fundida líquida por hundimiento (en comparación con carburo de tungsteno, por ejemplo, que tiene una densidad de 15,8 gramos/cc) o por flotación (en 5 comparación con carburo de titanio, por ejemplo, que tiene una densidad de 4,93 gramos/cc).

(g) La presencia de una fracción en volumen alta de partículas de NbC en la microestructura dará como resultado un tamaño de grano de matriz ferrosa más fino durante la 10 colada y el tratamiento térmico. Esto mejora las propiedades mecánicas de las piezas coladas.

(h) Se estima que la adición de un 20% en peso de NbC a la familia existente de aleaciones de hierro colado blanco con alto contenido en cromo resistentes al desgaste mejorará 15 la resistencia al desgaste de estos materiales, en algunos casos posiblemente en un orden de magnitud.

(i) Observando las microestructuras resultantes, se considera que la adición de un 10-25% en peso de NbC a diversos aceros inoxidables, por ejemplo martensítico, 20 austenítico, ferrítico y dúplex, aumentará sustancialmente la vida útil con reducción insignificante en tenacidad, resistencia a la corrosión y propiedades mecánicas para los diversos grados.

(j) La adición de un 20% en peso de NbC a acero 25 Hadfield (que se usa normalmente en revestimientos de

tritadoras de rocas primarias, tales como trituradoras de mandíbulas y giratorias, en las que se requiere una alta tenacidad al impacto) producirá un material con una vida útil mucho mayor que el acero Hadfield original sin disminuir la excepcional tenacidad y capacidad de endurecimiento por deformación que es inherente en este acero.

(k) La adición de un 20% en peso de NbC a acero para herramientas mejorará enormemente la vida útil de la herramienta mientras que se mantienen las propiedades del material original.

El carburo de niobio puede añadirse a aleaciones ferrosas, tales como hierros colados blancos con alto contenido en cromo de dos modos distintos, tal como sigue.

1. Como partículas de carburo de niobio finas (2-100 micrómetros de diámetro) a una masa fundida, según el trabajo de laboratorio mencionado anteriormente.

2. Como polvo de ferro-niobio fino (menos de 1 mm de diámetro) en presencia de la cantidad estequiométrica requerida de carbono previamente disuelto en la masa fundida.

La densidad de NbC es de 7,8 gramos/cc a temperatura ambiente y esto está cerca de la densidad del hierro colado blanco con alto contenido en cromo (7,5 gramos/cc). La presencia de fases con densidades similares ayuda a lograr una dispersión uniforme de partículas de NbC en el metal líquido durante un procedimiento de colada.

Sin embargo, una prueba de laboratorio llevada a cabo por el solicitante mostró que se producía segregación de NbC en una aleación de hierro colado blanco con alto contenido en cromo + 5% en peso de NbC por sedimentación de las partículas de NbC finas en el fondo del lingote cuando la masa fundida se dejaba reposar durante 15 minutos a aproximadamente 150°C por debajo de la temperatura líquida del metal huésped.

La diferencia de densidad entre el hierro colado blanco con alto contenido en cromo y NbC aumenta con la temperatura. El coeficiente de expansión térmica del hierro colado blanco con alto contenido en cromo es el doble que el de NbC. Además, el hierro colado blanco con alto contenido en cromo experimenta un aumento escalonado de volumen en el cambio de fase de sólido a líquido a aproximadamente 1260°C.

Como consecuencia, la densidad del hierro colado blanco con alto contenido en cromo en el estado líquido a 1400°C es de 6,9 gramos/cc mientras que la densidad de NbC a 1400°C es de aproximadamente 7,7 gramos/cc. El solicitante ha encontrado que esta diferencia de densidad es suficiente para provocar la segregación de partículas de NbC en hierro colado blanco con alto contenido en cromo líquido a temperaturas de colada en fundición de 1300°C o mayores.

El carburo de titanio es similar en muchas características a NbC. Las estructuras cristalinas son las mismas, con un número de grupo de 225. El parámetro de

estructura reticular de NbC es de 4,47 Angstroms y el parámetro de estructura reticular de TiC es de 4,32 Angstroms. TiC y NbC son isomorfos, es decir, los átomos de Nb se sustituirán fácilmente por átomos de Ti en NbC. La dureza de TiC es similar a NbC. El punto de fusión de TiC es de 3160°C, que es similar al punto de fusión de NbC (3600°C).

Sin embargo, la densidad de TiC es de 4,9 gramos/cc a temperatura ambiente, y esto es muy inferior a la densidad de NbC. Puesto que TiC y NbC son isomorfos, es posible lograr cualquier valor de densidad para el carburo mezclado en un intervalo de 4,9-7,8 gramos/cc seleccionando la composición química correspondiente con la fórmula general $(\text{Nb}_x, \text{Ti}_y)\text{C}$. A modo de ejemplo, los carburos de niobio/titanio pueden ser $(\text{Nb}_{0,5}, \text{Ti}_{0,5})\text{C}$ o $(\text{Nb}_{0,25}, \text{Ti}_{0,75})\text{C}$ o $(\text{Nb}_{0,75}, \text{Ti}_{0,25})\text{C}$. Esta diferencia de densidad es la base de un método rentable de reducción de la segregación de carburos sólidos, duros en metal líquido a temperaturas de colada en fundición habituales. Especialmente, es posible ajustar selectivamente la densidad de los carburos de niobio/titanio dentro del intervalo de 4.9-7.8 gramos/cc y controlar si las partículas formarán una dispersión uniforme o se segregarán en una pieza colada de una aleación de metal, tal como un hierro blanco con alto contenido en cromo, que incluye las partículas. Esta selección puede ser deseable para algunas piezas coladas en las que es deseable una resistencia al desgaste uniforme a

través de las piezas coladas y para otras piezas coladas en las que es deseable tener una concentración de partículas resistentes al desgaste en una sección, tal como una superficie, de las piezas coladas.

5 La descripción se refiere a las microestructuras de materiales de metal duro de la presente invención en % en volumen en vez del % en peso de productos químicos a gran escala habitual. La tabla expuesta a continuación se proporciona para explicar el motivo de esta selección de
10 nomenclatura.

En los primeros 2 casos en la tabla, la química del metal huésped es idéntica y es esencialmente un hierro colado blanco con alto contenido en cromo, con una química = Fe-27Cr-2,7C-2Mn-0,5Si. Es intuitivamente sencillo visualizar
15 las microestructuras de los dos materiales de metal duro (concretamente el 10 y el 20% en volumen de NbC) en el mismo metal huésped. Sin embargo, las químicas a gran escala de los dos materiales de metal duro (tal como se determina mediante la técnica de análisis espectrográfico en fundición habitual)
20 no expresan claramente la diferencia sencilla entre estos dos materiales de metal duro.

En los casos tercero y cuarto en la tabla, el ejercicio se repite para el 10 y el 20% en volumen de NbC en acero Hadfield. La química del metal huésped es idéntica y es
25 esencialmente Fe-12Mn-1,2C-2Mn-0,5Si. De nuevo, las químicas

a gran escala de estos dos materiales de metal duro son ampliamente diferentes y no son descriptivas de las microestructuras.

Microestructura = 90% en volumen de hierro colado blanco +

5 10% en volumen de NbC

Carga de horno		Volumen						Composición (% en peso)					
Desc.	(%)	Cr	C	Mn	Si	Nb	Fe	Cr	C	Mn	Si	Nb	Fe
NbC	10		11,4			88,6	0,00						
Metal huésped	90	27,0	2,7	2,0	0,5		67,80						
Química a gran escala	100	24,3	3,57	1,80	0,45	8,86	61,02						

Microestructura = 80% en volumen de hierro colado blanco +

15 20% en volumen de NbC

Carga de horno		Volumen						Composición (% en peso)					
Desc.	(%)	Cr	C	Mn	Si	Nb	Fe	Cr	C	Mn	Si	Nb	Fe
NbC	20		11,4			88,6	0,00						
Metal huésped	80	27,0	2,7	2,0	0,5		67,80						
Química a gran escala	100	21,6	4,44	1,60	0,40	17,72	54,24						

Microestructura = 90% en volumen de acero Hadfield + 10% en

volumen de NbC

5

Carga de Volumen horno		Composición (% en peso)					
Desc.	(%)	Cr	C	Mn	Si	Nb	Fe
NbC	10		11,4			88,6	0,00
Metal huésped	90		1,2	12,0	0,5		86,30
Química a gran escala	100		2,22	10,80	0,45	8,86	77,67

10

Microestructura = 80% en volumen de acero Hadfield + 20% en

volumen de NbC

15

Carga de Volumen horno		Composición (% en peso)					
Desc.	(%)	Cr	C	Mn	Si	Nb	Fe
NbC	20		11,4			88,6	0,00
Metal huésped	80		1,2	12,0	0,5		86,30
Química a gran escala	100		3,24	9,60	0,40	17,72	69,04

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En todo el trabajo llevado a cabo por el solicitante en relación a la presente invención, el solicitante ha encontrado que la química a gran escala final de cada uno de los materiales de metal duro es una función compleja de la microestructura seleccionada y la química a gran escala real

25

no es un medio útil de descripción de las características

requeridas de los materiales de metal duro. Las características requeridas del material de metal duro de la presente invención son (a) química del metal huésped y (b) % en volumen de las partículas refractarias seleccionadas.

5 Cabe señalar que la química a gran escala es incluso más complicada cuando se incluyen carburos y/o nitruros y/o boruros de dos o más metales de transición en los materiales de metal duro.

10 Cabe señalar que el material de metal duro de la presente invención puede colarse como una forma de producto final y puede formarse como un material sólido que posteriormente se trabaja en caliente en una operación de procesamiento posterior para formar una forma de producto final. Por ejemplo, el material de metal duro de la presente
15 invención puede formarse como un lingote y posteriormente trabajarse en caliente mediante laminación o forjado según se requiera para dar un producto final tal como una barra o una placa.

20 Pueden realizarse muchas modificaciones a las modalidades de la presente invención tal como se describió anteriormente sin apartarse del espíritu y alcance de la presente invención.

25 Se entenderá que el término "comprende" o sus variantes gramaticales tal como se usan en esta descripción y reivindicaciones es equivalente al término "incluye" y no

pretende tomarse como excluyente de la presencia de otras características o elementos.

Se hace constar que con relación a esta fecha, el mejor método conocido por la solicitante para llevar a la práctica la citada invención, es el que resulta claro de la presente descripción de la invención.

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REIVINDICACIONES

Habiéndose descrito la invención como antecede, se reclama como propiedad lo contenido en las siguientes reivindicaciones:

1. Una colada de un material de metal duro que incluye un metal huésped y una dispersión de 5 a 50% en volumen de partículas de material refractario que consisten de: (a) carburo de niobio que contiene partículas refractarias que son insolubles en el metal huésped a la temperatura de colada y/o (b) partículas de una mezcla química de carburo de niobio y carburo de titanio que son insolubles en el metal huésped a la temperatura de colada, y el metal huésped se selecciona de un grupo que se selecciona de un grupo de una aleación ferrosa (que incluye un acero o un hierro colado), un acero inoxidable (que incluye duplex, ferrítico, austenítico y martensítico), un acero austenítico-manganeso (que incluye un acero Hadfield) y una superaleación basada en hierro o una basada en níquel o una basada en cobalto.

2. La colada de material de metal duro de conformidad con la reivindicación 1, caracterizada porque las partículas de material refractario también comprenden tungsteno.

3. La colada de material de ~~metal duro de~~ conformidad con la reivindicación 1 o la reivindicación 2, caracterizada porque la mezcla química de carburo de niobio y partículas de carburo de titanio tiene a fórmula general
5 (Nb_xTi_y).

4. La colada de material de metal duro de conformidad con la reivindicación 1 o la reivindicación 2, caracterizada porque la mezcla química de partículas de carburo de niobio y de carburo de titanio incluye partículas
10 de (Nb_{0.5}, Ti_{0.5})C o (Nb_{0.25}, Ti_{0.75})C o (Nb_{0.75}, Ti_{0.25})C.

5. La colada de material de metal duro de conformidad con cualquiera de las reivindicaciones precedentes, caracterizada porque incluye 5-40% en volumen de partículas del material refractario dispersadas en el metal
15 huésped.

6. La colada de material de metal duro de conformidad con cualquiera de las reivindicaciones precedentes, caracterizada porque incluye más de 10% en volumen de partículas del material refractario dispersadas en
20 el metal huésped.

7. La colada de material de metal duro de conformidad con cualquiera de las reivindicaciones precedentes, caracterizada porque incluye más de 15% en volumen de partículas del material refractario dispersadas en
25 el metal huésped.

8. La colada de material de metal duro de conformidad con cualquiera de las reivindicaciones precedentes, caracterizada porque incluye menos de 30% en volumen de partículas del material refractario dispersadas en el metal huésped.

9. La colada de material de metal duro de conformidad con cualquiera de las reivindicaciones precedentes, caracterizada porque incluye las partículas del material refractario en un intervalo de 12% en peso a 33% en peso del peso total del material.

10. La colada de material de metal duro de conformidad con cualquiera de las reivindicaciones precedentes, caracterizada porque incluye las partículas del material refractario en un intervalo de 12% en peso a 25% en peso del peso total del material.

11. La colada de material de metal duro de conformidad con cualquiera de las reivindicaciones precedentes, caracterizada porque el tamaño de las partículas del material refractario está en el intervalo de 1 a 150 μm de diámetro.

12. La colada de material de metal duro de conformidad con cualquiera de las reivindicaciones 1 a 10, caracterizada porque el tamaño de las partículas del material refractario es menor de 500 μm de diámetro.

13. La colada de material de metal duro de

conformidad con la reivindicación 12, caracterizada porque el
tamaño de las partículas del material refractario es menor de
200 μm de diámetro.

14. La colada de material de metal duro de
5 conformidad con la reivindicación 1, caracterizada porque
incluye una dispersión uniforme de las partículas del
material refractario en el metal huésped.

15. La colada de material de metal duro de
conformidad con cualquiera de las reivindicaciones
10 precedentes, caracterizada porque incluye una dispersión no
uniforme de las partículas del material refractario en el
metal huésped.

16. Un método de colado de un material de metal
duro resistente al desgaste, caracterizado porque comprende
15 agregar: (a) niobio o (b) niobio y titanio a un fundido que
contiene un metal huésped en una forma que produce una
dispersión de partículas refractarias que consisten de
partículas de carburo de niobio y/o partículas de una mezcla
química de carburo de niobio y carburo de titanio en un
20 intervalo de 10 a 40% en peso del peso total del material del
metal duro en una colada solidificada, conformar una colada
del fundido y permitir que la colada solidifique para formar
una colada de material de metal duro sólido en donde el metal
huésped se selecciona de una aleación ferrosa (que incluye un
25 acero o un hierro colado), un acero inoxidable (que incluye



duplex, ferrítico, austenítico y martensítico), y un acero austenítico-manganeso (que incluye un acero Hadfield) y una superaleación basada en hierro o una basada en níquel o una basada en cobalto.

- 5 17. El método de conformidad con la reivindicación 16, caracterizado porque el fundido está forma de una lechada de partículas de carburo de niobio o partículas de una mezcla química de carburo de niobio y carburo de titanio en el fundido.
- 10 18. El método de conformidad con la reivindicación 16, caracterizado porque comprende formar una lechada de partículas de carburo de niobio o partículas de la mezcla química de carburo de niobio y carburo de titanio suspendidas en el fundido.
- 15 19. El método de conformidad con cualquiera de las reivindicaciones 16-18, caracterizado porque comprende agregar niobio o niobio y titanio al fundido y producir partículas de carburo de niobio o partículas de la mezcla química de carburo de niobio y carburo de titanio en un
- 20 intervalo de 12% en peso a 33% en peso del peso total del material de metal duro solidificado.
- 25 20. El método de conformidad con cualquiera de las reivindicaciones 16 a 19, caracterizado porque las partículas de la mezcla química de carburo de niobio y carburo de titanio producidas en el fundido tienen una fórmula general

(Nb_xTi_y)C.

21. El método de conformidad con cualquiera de las reivindicaciones 16 a 19, caracterizado porque comprende agregar niobio al fundido en forma de particular de ferro-
5 niobio, en donde las partículas de ferro-niobio se disuelven en el fundido y el niobio libre resultante y el carbono en el fundido forman carburos de niobio en el fundido.

22. El método de conformidad con cualquiera de las reivindicaciones 16 a 19, caracterizado porque comprende
10 agregar niobio y titanio al fundido en la forma de ferroniobio-titanio, por lo que las partículas de ferro-niobio-titanio se disuelven en el fundido y el niobio libre y el titanio libre resultantes y el carbono en el fundido forman la mezcla química de carburo de niobio y carburo de
15 titanio en el fundido.

23. El método de conformidad con la reivindicación 21 ó la reivindicación 22, caracterizado porque comprende agregar ferro-niobio o ferro-niobio-titanio al fundido bajo condiciones inertes.

20 24. El método de conformidad con la reivindicación 16, caracterizado porque comprende agregar niobio al fundido en forma de particular de carburo de ferro-niobio.

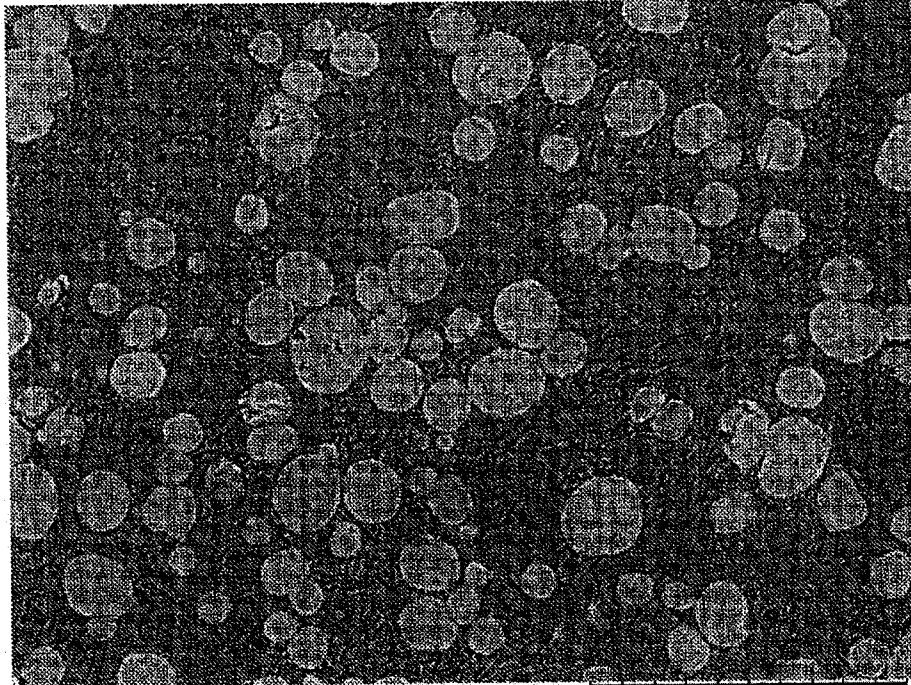
25 25. El método de conformidad con la reivindicación 16, caracterizado porque comprende agregar

niobio y titanio al fundido en forma e partículas de una mezcla química de carburo de ferro-niobio-titanio.

26. El método de conformidad con la reivindicación 24 ó la reivindicación 25, caracterizado 5 porque comprende agregar partículas de carburo ferro-niobio o carburo de ferro-niobio-titanio al fundido bajo condiciones inertes.

RESUMEN DE LA INVENCION

Se dan a conocer un material de metal duro y un método de fabricación de componente del material de metal duro. El material de metal duro comprende el 5-50% en volumen de partículas de un material refractario dispersadas en un metal huésped. El método comprende formar una suspensión del 5-50% en volumen de partículas del material refractario dispersadas en un metal huésped líquido en una atmósfera inerte y verter la suspensión en un molde y formar una pieza colada del componente.

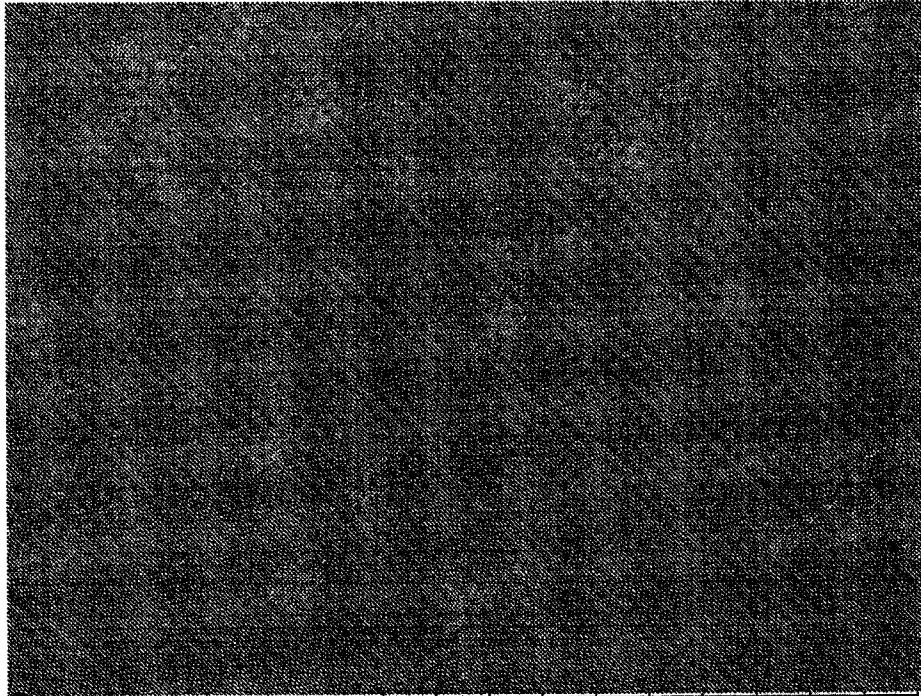


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Figura 1



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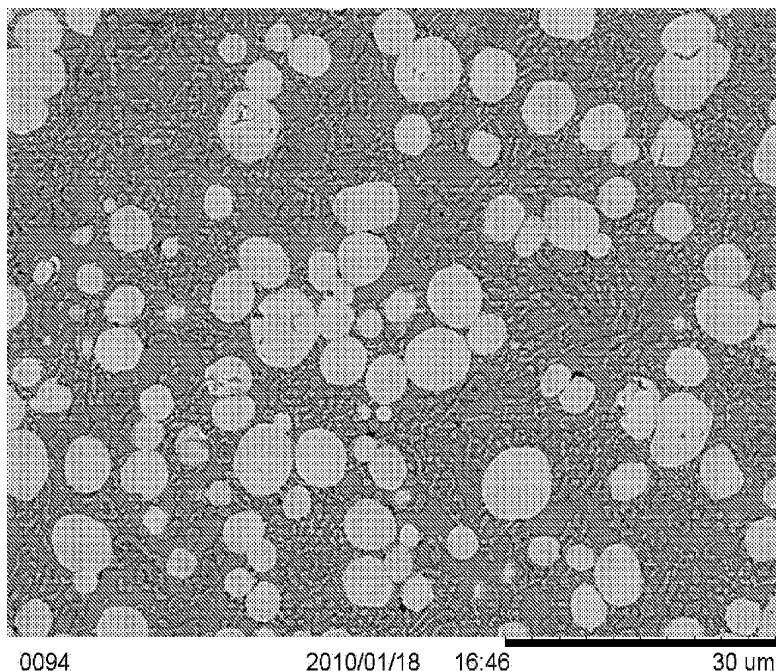
Figura 2



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(72) Inventeur/Inventor:
DOLMAN, KEVIN, AU
(73) Propriétaire/Owner:
WEIR MINERALS AUSTRALIA LTD, AU
(74) Agent: SMART & BIGGAR

(54) Titre : **MATERIAUX A BASE DE METAL DUR**
(54) Title: **HARD METAL MATERIALS**



(57) **Abrégé/Abstract:**

A hard metal material and a method of manufacturing a component of the hard metal material are disclosed. The hard metal material comprises 5-50 volume % particles of a refractory material dispersed in a host metal. The method comprises forming a slurry of 5-50 volume % particles of the refractory material dispersed in a liquid host metal in an inert atmosphere and pouring the slurry into a mould and forming a casting of the component.

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(72) Inventor; and

(75) Inventor/Applicant (for US only): **DOLMAN, Kevin** [AU/AU]; 29 Chester Street, Epping, New South Wales 2121 (AU).(74) Agent: **GRIFFITH HACK**; Level 3, 509 St Kilda Road, Melbourne, Victoria 3004 (AU).

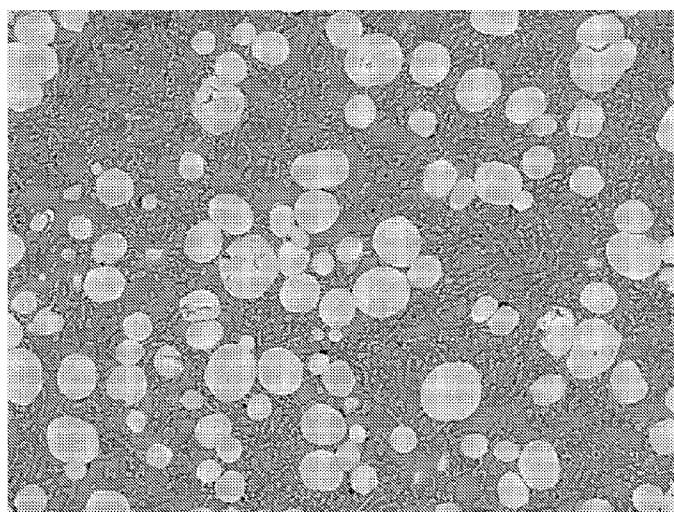
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Figure 1

(57) Abstract: A hard metal material and a method of manufacturing a component of the hard metal material are disclosed. The hard metal material comprises 5-50 volume % particles of a refractory material dispersed in a host metal. The method comprises forming a slurry of 5-50 volume % particles of the refractory material dispersed in a liquid host metal in an inert atmosphere and pouring the slurry into a mould and forming a casting of the component.

HARD METAL MATERIALSField of the invention

5 The present invention relates in general terms to hard metal materials comprising refractory material particles, as described herein, dispersed in a host metal or metal alloy.

10 The ASM Materials Engineering Dictionary defines the term "hard metal" as a collective term for a sintered material with high hardness, strength and wear resistance.

15 The present invention also provides components manufactured from the hard metal materials. The present invention relates particularly, although by no means exclusively, to large components weighing more than 100kgs and typically more than 1 tonne.

20 The present invention also provides a method of manufacturing the components from the hard metal materials.

In more particular terms, although by no means exclusive terms, the present invention relates to hard metal materials that are useful for applications requiring wear resistance.

25

Background

30 It is known to use powder metallurgy to manufacture small components from hard metal materials comprising refractory particles dispersed in a host metal (which term is understood herein to include metal alloy).

35 Powder metallurgy processes involve sintering mechanically mixed refractory powders at elevated temperatures under pressure, usually in an inert atmosphere.

"Sintering" comprises bonding powdered materials, usually under pressure, by solid-state reactions at temperatures lower than that required for the formation of a liquid phase. During a sintering process, at temperatures below the melting point of the metallic binders, powders of metallic binder phase and refractory particles are welded together by pressure and heat. Sintering is traditionally used for manufacturing ceramic components and has also found uses in such fields as powder metallurgy for the manufacture of products containing very high melting point materials.

Powder metallurgy is a useful process for manufacturing relatively small, simple-shaped, wear resistant components such as tungsten carbide tool bits. However, powder metallurgy is not a practical process for manufacturing larger, complex-shaped, hard metal, wear resistant components such as pump impellers and crusher wear parts weighing more than 100kgs and typically more than 1 tonne from hard metal materials. This is an issue, particularly in applications in the mining and minerals processing industries where large high wear resistant components are often required.

It is known to use wear resistant metal alloys, such as high chromium white cast irons, in the manufacture of components used in applications in the mining and minerals processing industries, such as applications involving transporting solid materials. For example, hard-facing alloys are formed on the trays of dump trucks that transport mined ore from a mine site to a minerals processing plant. In another example, castings of wear resistant alloys are used to form pumps for transporting slurries of ore particles suspended in water through processing stages in flotation circuits in a minerals processing plant.

The fracture toughness and corrosion resistance requirements for the wear resistant alloy in each of the above examples are different and, accordingly, the wear resistant alloy compositions are different. The common factor between both, however, is a need to provide wear resistance in addition to other properties.

Generally speaking, higher wear resistance can be achieved through controlling the alloy composition, but there is a trade-off against other properties.

5 For any given circumstance where wear resistance is an important property, it is desirable to provide materials with desirable properties and improved wear resistance by compromising less on the balance of these properties.

10 It is noted that the specification includes references to weight percent (wt.%) and volume percent (vol.%). In the context of the references to NbC in the specification, where NbC has a density similar to a host metal, these terms are interchangeable.

15 Summary of the disclosure

The applicant has found in the course of extensive research and development work that a liquid host metal, containing a dispersion, typically a dispersion, of 5-50 volume % fine
20 particles of a refractory material that is insoluble in the host metal, and is described herein as a liquid metal slurry, has very good fluidity during pouring in a foundry and the slurry readily flows to fill sand moulds to produce sound castings of the hard metal material.

25 The term "insoluble" is understood herein to mean that for all intents and purposes the refractory material is not soluble in the host metal. There may be limited solubility. However, the refractory particles are essentially distinct from the host metal
30 in that there is negligible partitioning of the transition metals in the refractory material particles to the host metal.

The applicant has also found that mixing and dispersing the insoluble refractory particles in the host metal may be carried
35 out in an effective way in the liquid state in an inert atmosphere, such as in a vacuum furnace, to minimise oxidation of the reactive elements in the refractory material particles.

The present invention is a departure from standard foundry practice known to the applicant that involves the complete melting of all alloying additions contained in a casting to form a single
5 phase liquid to ensure maximum fluidity during pouring into a mould.

The applicant has also found that the fluidity of liquid metal slurries, when cast within certain production parameters in
10 accordance with the present invention, is sufficient to produce a family of sound hard metal material castings ranging from small to large casings with specific wear resistance, fracture toughness and corrosion resistance that suit a wide range of operating conditions in service.

15 The production parameters may comprise any one or more of the particle size, reactivity, thermal expansion or contraction, density, and solubility of the refractory material, as discussed further below.

20 In broad terms, the present invention provides a hard metal material comprising 5-50 volume % particles of a refractory material dispersed in a host metal.

25 In the context of the present invention, the term "hard metal material" is understood to comprise particles of high melting point carbides and/or nitrides and/or borides of any one or more than one of the nine transition metals titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum and
30 tungsten dispersed in a tough host metal, which acts as a binder phase. Typically the host metal is a ferrous metal alloy. Each of these particles is a particle of a refractory material and is referred to herein as a "refractory material".

35 The particles of the refractory material may be carbides and/or borides and/or nitrides of one transition metal, such as NbC.

The particles of the refractory material may be carbides and/or borides and/or nitrides of more than one transition metal where the particles are a chemical mixture (as opposed to a physical mixture) of the carbides and/or borides and/or nitrides of the transition metals. In other words, in the case of carbides, the particles of the refractory material may be of the type described as $(M_1, M_2) C$, where "M" is a transition metal. One example that is discussed further herein is $(Nb, Ti)C$.

The hard metal material may comprise 5-40 volume % particles of the refractory material dispersed in the host metal.

The hard metal material may comprise greater than 10 volume % particles of the refractory material dispersed in the host metal.

The hard metal material may comprise greater than 15 volume % particles of the refractory material dispersed in the host metal.

The hard metal material may comprise less than 30 volume % particles of the refractory material dispersed in the host metal.

The hard metal material may comprise less than 25 volume % particles of the refractory material dispersed in the host metal.

The host metal may be a ferrous alloy (such as a steel or a cast iron), a stainless steel, an austenitic-manganese steel such as a Hadfield steel, or a iron-based or nickel-based or cobalt-based superalloy.

In one aspect, the present invention provides a hard metal material comprising 5-50 volume % particles of a refractory material with particle sizes less than 500 microns dispersed in a host metal, wherein the refractory material comprises

5 particles of carbides and/or nitrides and/or borides of any one or more than one of titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, and molybdenum that are insoluble in the host metal at the casting temperature.

In another aspect, the present invention provides a method of

10 manufacturing a component of a hard metal material comprising:

(a) forming a slurry of a hard metal material comprising 5-50 volume % particles of a refractory material with particle sizes less than 500 microns dispersed in a liquid host metal in an inert atmosphere, with the particles being insoluble in the

15 liquid host metal; and (b) pouring the slurry into a mould and forming a casting of the component.

In another aspect, the present invention provides a method of forming a wear resistant hard metal material, the method comprising adding (a) niobium or (b) niobium and titanium to a

20 melt containing a host metal in a form that produces particles of niobium carbide and/or particles of a chemical mixture of niobium carbide and titanium carbide with particle sizes less than 500 microns that are insoluble in the host metal of the melt in a range of 10 to 40 wt% of the total weight of the hard

25 metal material in a microstructure of a solidified metal alloy, and allowing the melt to solidify to form the solid hard metal material.

In another aspect, the present invention provides a method of casting a hard metal material having a dispersion of a chemical

mixture of niobium carbides and titanium carbides with particle sizes less than 500 microns in a host metal which forms a matrix of the hard metal material, with the niobium/titanium particles being insoluble in the host metal, the method

5 comprising selecting the density of the niobium/titanium particles in relation to the density of the host metal and therefore selectively controlling the dispersion of the niobium/titanium particles in the matrix ranging from a uniform dispersion to a non-uniform dispersion.

- 10 In another aspect, the present invention provides a casting of the metal alloy made by the method defined herein.

In another aspect, the present invention provides a method of forming a hard metal material comprising: (a) forming a slurry of a hard metal material comprising 5-50 volume % particles of

15 a refractory material with particle sizes less than 500 microns dispersed in a liquid host metal, with the particles being insoluble in the liquid host metal, and (b) allowing the slurry to solidify to form a solid hard metal material.

In another one aspect, the present invention provides a method

20 of forming a wear resistant hard metal material, the method comprising adding any one or more of the nine transition metals titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum and tungsten to a melt of a host metal in a form that produces particles of carbides and/or nitrides

25 and/or borides of any one or more of the nine transition metals in a range of 5 to 50 volume % of the total volume of the hard metal material, and allowing the melt to solidify to form the solid hard metal material.

- In another aspect, the present invention provides a method of casting a hard metal material having a dispersion of refractory material particles of carbides and/or nitrides and/or borides of any one or more of the nine transition metals titanium,
- 5 zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum and tungsten with particle sizes less than 500 microns in a host metal, with the particles being insoluble in the host metal, and with the host metal forming a matrix of the hard metal material in a solid casting, the method
- 10 comprising selecting the density of the refractory material particles in relation to the density of the host metal and therefore selectively controlling the dispersion of the refractory material particles in the matrix of a solid casting ranging from a uniform dispersion to a non-uniform dispersion.
- 15 In another aspect, the present invention provides a hard metal material in the form of a casting including a host metal and a dispersion of 5-50 volume % of particles of a refractory material selected from (a) niobium carbide containing refractory particles with particle sizes less than 500 microns
- 20 that are insoluble in the host metal at the casting temperature and (b) particles of a chemical mixture of niobium carbide and titanium carbide with particle sizes less than 500 microns that are insoluble in the host metal at the casting temperature, and the host metal is selected from a group comprising a ferrous
- 25 alloy, a stainless steel, an austenitic-manganese steel, and an iron-based or a nickel-based or a cobalt-based superalloy.

In another aspect, the present invention provides a pump impeller in the form of a casting of hard metal material defined herein.

In another aspect, the present invention provides a pump throatbush in the form of a casting of hard metal material defined herein.

In another aspect, the present invention provides a liner of a
5 primary rock crusher in the form of a casting of hard metal material defined herein.

In another aspect, the present invention provides a method of casting a wear resistant hard metal material, the method comprising adding (a) niobium or (b) niobium and titanium to a
10 melt containing a host metal in a form that produces particles of niobium carbide and/or particles of a chemical mixture of niobium carbide and titanium carbide with particle sizes less than 500 microns in a range of 10 to 40 wt% of the total weight of the hard metal material in a solidified casting, with the
15 particles being insoluble in the host metal at the casting temperature, forming a casting of the melt, and allowing the casting to solidify to form a solid hard metal material casting, with the host metal being selected from a group comprising a ferrous alloy, a stainless steel an austenitic-
20 manganese steel, and an iron-based or a nickel-based or a cobalt-based superalloy.

The present invention also provides a method of forming a hard metal material comprising:

(a) forming a slurry of a hard metal material
25 comprising 5-50 volume % particles of a refractory material dispersed in a liquid host metal, for example in an inert atmosphere, and

- (b) allowing the slurry to solidify to form a solid hard metal material.

The present invention also provides a method of manufacturing a component of a hard metal material comprising:

- (a) forming a slurry of a hard metal material comprising 5-50 volume % particles of a refractory material dispersed in a liquid host metal in an inert atmosphere, and
- (b) pouring the slurry into a mould and forming a casting of the component in an inert atmosphere.

The method may comprise forming the slurry and thereafter forming the casting of the component in a chamber under vacuum conditions which remove air from the chamber and supplying an inert gas, such as argon, into the chamber. By way of example, the method may be carried out in a vacuum melting furnace.

The method may comprise selecting the production parameters to form the slurry in step (a) that has a required fluidity for processing in step (b). In any given situation, a skilled person will be able to determine a required fluidity for processing step (b) having regard to standard foundry practice considerations such as the size and shape of the component to be formed and the required dispersion (uniform or segregated) to provide the required microstructure for the component.

The production parameters may comprise any one or more of the particle size, reactivity, density, and solubility of the refractory materials, as discussed further below.

Refractory material particle size

The refractory material may be a fine particle size. A fine refractory material particle size may be required to ensure a

homogeneous dispersion in the host metal. The melting points of the majority of the transition metal refractory materials are in excess of 1800°C and the refractory materials are generally insoluble in host liquid metals. The applicant has found that refractory powders with particle sizes less than 500 microns, typically less than 150 microns, in diameter provide optimum flow characteristics in liquid metal slurries and yield a desirable uniform dispersion of the refractory particulates in the microstructures of the Hard Metal castings.

The refractory material may be less than 400 microns particle size.

The refractory material may be less than 200 microns particle size.

The refractory material may be less than 150 microns particle size.

The refractory material may be added to the host liquid metal as follows.

(a) As a fine powder with a selected particle size distribution. For example, 15 wt.% of particles of a refractory material in the form of niobium carbide (NbC) (minus 50 microns in diameter) added to a liquid host metal in the form of a high chromium white cast iron host metal. NbC exhibits a Vickers Hardness of 24 GPa, a melting point of 3600°C, and a very low solubility in the host liquid metal at a casting temperature of about 1500°C. The liquid metal slurry comprises a suspension of insoluble NbC particles (minus 50 microns in diameter) in the host liquid metal. On solidification, the microstructure exhibits a dispersion of 15 volume% fine NbC particles (minus 50 microns in diameter) in a high chromium white cast iron matrix containing a negligible amount (less than 0.3 wt.%) of niobium in solution in the matrix.

(b) The transition metals mentioned above or ferro-alloys of the same transition metals can be added to a wide range of host metals containing all the combinations and permutations of the elements carbon, boron and nitrogen.

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For example, as is described in more detail below, the applicant has found that Fe-Nb readily dissolves in the host liquid metal at 1500°C and niobium immediately combines with carbon in the host liquid metal to form niobium carbides in situ with particle sizes less than 50 microns in diameter.

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Reactive refractory materials

Most of the transition metal refractory materials described above are classed as "reactive elements", i.e. the individual metal elements and/or their carbide, nitride or boride compound forms react readily with air at metal casting temperatures about 1500°C to form undesirable metal oxides and/or copious quantities of gases such as CO₂ which can result in severe porosity in the castings. The problems of oxidation and porosity in hard metal castings, produced by a liquid metal slurry, and associated with chemical reactions of the reactive refractory materials in air at elevated temperatures are overcome by melting and pouring the liquid metal slurry in an inert atmosphere.

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Selection of refractory material particles having lower thermal expansion or contraction than the host metal

Poor bonding between refractory particles and the host metal in hard metal materials have been variously reported in the literature. The applicant found no evidence of poor bonding between the refractory particles and a wide range of the host metals evaluated by the applicant. Whilst not wishing to be bound by the following comment, the observed excellent bonding is attributed by the applicant in large part to the use of an inert atmosphere during casting of the hard metal materials and the thermal contraction of the transition metal refractory particles

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being much less, typically about 50% lower, than the thermal contraction of the host metals during cooling from the solidus to ambient temperature generating compressive forces on the refractory material particles that firmly held the particles in the host metals on solidification. All refractory particles in hard metal material castings produced by the applicant in an inert atmosphere were found to be under compressive loading ensuring intimate contact and good bonding with the host metals.

Density of refractory materials

The density of the refractory material of the particles, compared to the density of the host metal in the liquid state, is a parameter to consider during the method of the present invention to control the dispersion of refractory particles in the hot host metal. In some situations it may be important to avoid segregation of refractory material particles in the liquid host metal. In other situations, segregation may be desirable. For example, the nominal density of a host ferrous liquid metal at 1400 °C is 6.9 grams/cc. When tungsten carbide particles, with a density of 15.7 grams/cc, are added to a host ferrous metal, the WC particles will sink to the bottom of the mould prior to solidification of the host metal. When titanium carbide particles, with a density of 4.8 grams/cc, are added to the same host ferrous metal, the TiC particles will float to the top of the ladle or mould. Niobium carbide, with a density of 7.7 grams/cc at 1400 C, is fairly close to the density of the host liquid metal at 6.9 grams/cc and is less prone to segregation in the liquid host metal than TiC or WC. However, the applicant has observed that NbC particles will segregate to the bottom of large section white iron castings during the process of the present invention when solidification times are in the order of 30 minutes or more. As described in more detail below, niobium carbide and titanium carbide have similar crystal structures and are isomorphous. Selecting the required Nb/Ti ratio in a (Nb,Ti)C chemical compound yields a refractory material with any required density in the range 4.8 - 7.7 grams/cc at the casting temperature. Matching the

density of the solid refractory particles and the liquid host metal at the casting temperature eliminates segregation of the particulates in the melt during the process of the present invention.

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Solubility of refractory materials

The addition of refractory material particles that are for all intents and purposes insoluble, i.e. having minimal solid solubility in the host liquid metal, to produce a casting in accordance with the method of the present invention, produces a hard metal material that displays physical and chemical properties that are very similar to the host metal with substantially improved wear resistance due to the presence of a controlled dispersion of a high volume % of hard refractory material particles in the microstructure.

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For example, the solubility of a refractory material in the form of (Nb,Ti)C in liquid host metals in the form of (a) liquid Hadfield steel and (b) liquid 316 stainless steel and (c) liquid high chromium white cast iron at elevated temperatures is negligible (<0.3 weight%). The addition of 15 weight% (Nb,Ti)C with the required densities to these three metal alloys, followed by standard heat treatment procedure for each host metal produces microstructures consisting of a uniform dispersion of 15 volume% primary niobium-titanium carbides in the host metals which are substantially free of niobium and titanium, i.e. there is negligible partitioning of the transition metals in the refractory material slurry particles to the liquid host metal.

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Consequently, there is a negligible influence of the refractory materials of the particles on the chemistry and response to heat treatment of the host metal.

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The three hard metal materials produced by the method of the present invention display the known physical and chemical properties of (a) Hadfield steel, (b) 316 stainless steel and (c)

high chromium white cast iron respectively with an increased wear resistance due to the presence of a dispersion of 15 volume% of primary niobium-titanium carbides in the microstructures.

5 In addition to the above, in particular the applicant has found that providing a hard metal material with a microstructure that includes particles of niobium carbide and/or particles of a chemical (as opposed to a physical) mixture of niobium carbide and titanium carbide dispersed in a matrix of a host metal
10 considerably improves wear resistance of the hard metal material without detrimentally affecting the contribution that other alloying elements have on other properties of the hard metal material.

15 In addition, in particular the applicant has found that it is possible to adjust the density of particles of a chemical mixture of niobium carbide and titanium carbide to a sufficient extent in relation to the density of a host metal, which forms a matrix of the hard metal material, to make it possible to selectively
20 control the dispersion of the particles in the matrix from a uniform dispersion to a non-uniform dispersion of the particles. This opportunity for density control is an important finding in relation to castings of the hard metal material. In particular, by virtue of this finding it is now possible to produce castings
25 of the hard metal material with controlled segregation of the particles in parts of the castings. This is important for some end-use applications for castings, such as where it is desirable to have a concentration of high wear resistant particles near a surface of a casting of a hard metal material. Equally, in other
30 end-use applications for castings it is desirable to have a uniform dispersion of the particles in the matrix of the casting.

In addition, the applicant has found that forming a hard metal material and castings of the material to include particles of
35 niobium carbide and/or particles of a chemical mixture of niobium carbide and titanium carbide in a range of 10 to 25 wt%, or even up to 33 wt% or higher, dispersed in a host metal, which forms a

matrix of the hard metal material, does not have a significant negative impact on corrosion resistance and toughness of ferrous material in the host metal. Hence, the present invention makes it possible to achieve high wear resistance of a hard metal material without a loss of other desirable material properties.

Accordingly, there is provided a method of forming a wear resistant hard metal material, the method comprising adding (a) niobium or (b) niobium and titanium to a melt containing a host metal in a form that produces particles of niobium carbide and/or particles of a chemical mixture of niobium carbide and titanium carbide in a range of 10 to 40 wt% of the total weight of the hard metal material, and allowing the melt to solidify to form the solid hard metal material.

The terms "a chemical mixture of niobium carbide and titanium carbide" and "niobium/titanium carbides" are hereinafter understood to be synonyms. In addition, the term "chemical mixture" is understood in this context to mean that the niobium carbides and the titanium carbides are not present as separate particles in the mixture but are present as particles of niobium/titanium carbides.

Niobium carbides and titanium carbides each have a Vickers hardness (HV) around 2500, which is about 1000 HV above the hardness of chromium carbides. Accordingly, hard metal materials having a microstructure containing 10 to 40 wt% particles of niobium carbide and/or niobium/titanium carbides have excellent wear resistance properties. However, a significant aspect of the applicant's work has recognised that niobium carbides and titanium carbides and niobium/titanium carbides are substantially inert chemically with respect to other constituents in the hard metal material so those constituents provide the hard metal material with the properties for which they were selected. For example, chromium added to cast iron alloys still produces chromium carbides and provides corrosion resistance.

The melt may be in the form of a weld pool in a hard-facing process. In these circumstances, the niobium and/or the titanium may be added to the weld pool in a wire alloy in order to meter the addition of niobium and/or titanium.

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The melt may be in the form of a melt for forming a casting.

The niobium and the titanium may be added to the melt in any suitable form, bearing in mind the requirement of forming particles of niobium carbides and/or niobium/titanium carbides in the solid hard metal material.

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For example, the method may comprise adding the niobium to the melt in the form of ferro-niobium, for example particles of ferro-niobium. In this situation, the ferro-niobium dissolves in the melt and the resultant free niobium and carbon in the melt form niobium carbides in the melt.

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The method may also comprise adding the niobium to the melt as elemental niobium.

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The method may also comprise adding the niobium and the titanium to the melt as ferro-niobium-titanium.

The method may also comprise adding the niobium to the melt in the form of particles of niobium carbide. The method may also comprise adding the niobium and the titanium to the melt in the form of particles of niobium/titanium carbides. In both cases, the solidified metal alloy may be formed from a slurry of particles of niobium carbide and/or niobium/titanium carbides suspended in the melt. It is anticipated that if the weight fraction of these carbides in the melt slurry is too high, the flow properties of the slurry may be adversely affected with the result that unsound castings of the melt may be produced. Nevertheless, casting a slurry contrasts with the standard operating procedure in foundries which involves casting clear (single phase) liquid

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melts, i.e. where the melt is above the liquidus temperature of the highest melting point constituent of the melt.

5 The particles of niobium/titanium carbides may be any suitable chemical mixture of a general formula $(\text{Nb}_x, \text{Ti}_y)\text{C}$. By way of example, the niobium/titanium carbides may be $(\text{Nb}_{0.5}, \text{Ti}_{0.5})\text{C}$ or $(\text{Nb}_{0.25}, \text{Ti}_{0.75})\text{C}$ or $(\text{Nb}_{0.75}, \text{Ti}_{0.25})\text{C}$.

10 The niobium and/or the titanium may be added to the melt to produce particles of niobium carbide and/or niobium/titanium carbides in a range of 12 wt% to 33 wt% niobium carbides and niobium/titanium carbides of the total weight of the solidified hard metal material.

15 The niobium and/or the titanium may be added to the melt to produce particles of niobium carbide and/or niobium/titanium carbides in a range of 12 wt% to 25 wt% niobium carbides and niobium/titanium carbides of the total weight of the solidified hard metal material.

20 The quantity of particles of niobium carbide and/or niobium/titanium carbides in the microstructure of the solidified hard metal material may depend on the system.

25 The applicant is concerned particularly with solid hard metal materials that include host metals in the form of ferrous alloys, such as ferrous alloys described as high chromium white cast irons, stainless steels, and austenitic manganese steels (such as Hadfield steels). For ferrous alloys the quantity of particles of niobium carbide and/or niobium/titanium carbides in the final
30 microstructure may be in a range of 10 to 33 wt% or in a range of 12 to 25 wt% of the total weight of the solidified hard metal material.

35 The particle size of niobium carbide and/or niobium/titanium carbide may be in a range of 1 to 150 μm in diameter.

The method may comprise stirring the melt with an inert gas or magnetic induction or any other suitable means in order to disperse particles of niobium carbide and/or niobium/titanium carbides in the melt.

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The method may comprise adding particles of niobium carbide and/or particles of niobium/titanium carbides to the melt under inert conditions, such as an argon blanket, to reduce the extent to which niobium carbide and/or titanium carbide oxidize while being added to the melt.

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The method may comprise adding particles of ferro-niobium and/or ferro-titanium and/or ferro-niobium-titanium to the melt under inert conditions, such as an argon blanket, to reduce the extent to which niobium and/or titanium oxidize while being added to the melt.

15

In a situation where particles of niobium/titanium carbides are required in the solidified hard metal material, the method may comprise pre-melting ferro-niobium and ferro-titanium and/or ferro-niobium-titanium under inert conditions and forming a liquid phase that is a homogeneous chemical mixture of iron, niobium and titanium and solidifying this chemical mixture. The chemical mixture can then be processed as required, for example by crushing to a required particle size, and then added to the melt (containing carbon) under inert conditions. The iron, niobium and titanium dissolve in the melt and the niobium and titanium and carbon in the melt form niobium/titanium carbides in the melt.

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The method may comprise forming the solidified hard metal material by casting the melt into a cast product, such as a pump impeller or a pump throatbush.

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The cast product may be subject to subsequent thermal treatment for adjusting the microstructure to achieve desired alloy properties.

There is also provided a hard metal material formed according to the method described above.

5 There is also provided a method of casting the above-described hard metal material with a dispersion of particles of a chemical mixture of niobium carbides and titanium carbides in a host metal, which forms a matrix of the casting that comprises selecting the density of the niobium/titanium particles in relation to the density of the matrix material and therefore selectively
10 controlling the dispersion of the niobium/titanium particles in the matrix ranging from a uniform dispersion to a non-uniform dispersion.

15 There is also provided a casting of the above-described hard metal material made by the above-described method.

The casting may comprise a uniform dispersion of the niobium/titanium carbide particles in the matrix. For example, the casting may be a pump impeller.

20 The casting may comprise a non-uniform dispersion of the niobium/titanium carbide particles in the matrix. For example, the casting may be a pump throatbush.

25 The host metal may be a ferrous alloy, such as a high chromium white cast iron, a stainless steel, or an austenite manganese steel (such as a Hadfield steel).

Brief description of the drawings

30 Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

35 Figure 1 is a micrograph of a high chromium white cast iron alloy including 27 wt% chromium and 15 wt% niobium carbides.

Figure 2 is a micrograph of martensitic stainless steel (grade 420C) including 15 wt% niobium carbides.

Detailed description

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The applicant carried out an extensive series of laboratory melting trials on the addition of 10 to 30 wt% NbC and Nb/TiC particles to a wide selection of ferrous alloys including high chromium white irons, austenitic-manganese steels (including Hadfield steels), superalloys, stainless steels (including duplex, ferritic, austenitic and martensitic) and hard-facing weld deposits

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The applicant has carried out further extensive work reviewing data compiled by the applicant directly and in other sources in relation to carbides, borides, and nitrides of transition metals, and chemical combinations of carbides, borides, and nitrides of these metals, and has established that the findings of the laboratory work reported herein are equally applicable to these carbides, borides, and nitrides of transition metals and combinations of elements in ferrous host metals.

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An example of a microstructure of a high chromium white cast iron alloy including 15 wt% NbC is shown in Figure 1. The alloy was produced by casting a 50g ingot from a melt produced in an electric arc melting furnace under a partial pressure of argon in a water cooled copper hearth, i.e. the ingot was chill cast. The NbC was added to the furnace melt as discrete particles which had a particle size range of 2 to 20 μm in diameter.

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In further embodiments the applicant has examined the use of various other particle size ranges of NbC, including <45 μm in diameter, 45 to 75 μm in diameter, 75 to 150 μm in diameter and <100 μm in diameter.

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High chromium white cast iron alloys conventionally rely on the high chromium content to produce a significant volume of hard

chromium carbides that provide castings with high wear resistance. In addition, high chromium white cast iron alloys conventionally rely on some chromium remaining in the ferrous matrix and provides alloys with corrosion resistance.

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The microstructure in Figure 1 exhibits a ferrous matrix containing a fine dispersion of eutectic M_7C_3 carbides (approximating 30 volume%) and a dispersion of 15 wt% NbC particles which appear as a phase of white coloured spheroids in the Figure.

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The microstructure shown in Figure 2 is a form of 420C grade martensitic stainless steel that was produced by the same process described above for the high chromium white cast iron shown in Figure 1.

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In contrast, NbC particles (white coloured in Figure 2) are not regular spheroids as in the high chromium white cast iron, but rather an irregular NbC carbide shape that appears to be typical for various stainless steel grades that have been alloyed with NbC.

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The experimental work reported above and other experimental work carried out by the applicant indicates that alloys produced with niobium carbide particles in the range of 10-30 wt% NbC in a ferrous host metal show very promising microstructures, welding characteristics and foundry casting characteristics. The indications are that the addition of high NbC contents to these materials substantially increases wear resistance without adversely affecting castability, weldability, response to heat treatment and the mechanical properties of the original ferrous materials.

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The microstructures of the test castings in Figure 1 and other test castings produced by the applicant show that all the NbC particles added to the ferrous alloys are primary carbides in suspension in the liquid metal. The analogy is that all

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conventional castings above the liquidus temperature (approximately 1300-1400°C) are "clear liquids", i.e. single phase liquids. However, when niobium carbide particles were added, for example 20 wt%, the particles remained in suspension so the liquid metal and NbC particles approximate a "slurry" (2 phases) with good fluidity, which is a mandatory requirement for producing sound castings. The experimental work found a similar outcome when niobium/titanium carbide particles were added to a liquid melt.

It will be appreciated, however, that niobium carbides can form as solid particles in a melt, rather than added to the melt, by adding ferro-niobium to the melt. In such cases, the melt contains carbon, and the weight% carbon is greater than one eighth of the weight% of niobium. In the case of ferro-niobium additions, the iron and niobium separate in the melt. The niobium, which has a high affinity for carbon, chemically combines with carbon from the liquid melt to form solid niobium carbide particles dispersed in the liquid melt. Upon casting, the melt is cast as a "slurry" consisting of solid niobium carbide particles suspended in the liquid melt. Upon solidification, the casting will have a microstructure that includes niobium carbides dispersed in a ferrous matrix. A similar microstructure is achieved with niobium/titanium carbide particles.

The advantages of adding 10-30 wt% NbC particles to ferrous materials are summarised below.

- (a) Hardness of NbC is approx 2500 HV which compares to a hardness of 1500 HV for M_7C_3 carbides present in high chromium white cast iron alloys.
- (b) Niobium is a very strong carbide former and can be added as ferro niobium or NbC powder to the ferrous melt.
- (c) The melting point of NbC is 3600°C, i.e. about 2000°C above the temperature of the ferrous melt of steels, cast irons and

hard-facing weld deposits. Additionally, fine NbC particles (e.g. 2 to 20 μm in diameter) do not grow in size or coalesce in the melt during the casting process. This is important in terms of the castability of the melt and the resultant wear resistance of the cast product. The wear resistance of the cast product is optimised when a dispersion of fine NbC particles is evenly distributed throughout the microstructure.

- (d) Other elements, e.g. Cr, Mn and Fe, do not dissolve in the high melting point NbC particles. Accordingly, the chemical composition of the NbC particles is not altered and they will retain their physical properties during preparation of the melt and after casting.
- (e) The solubility of NbC in the ferrous matrix is negligible (<0.3 wt%) which suggests that the addition of NbC to ferrous materials will result in no observable effect on the response to heat treatment or change in material properties of the ferrous matrix.
- (f) The density of NbC is 7.82 grams/cc at room temperature. This is very close to the densities of ferrous materials which are approximately 7.5 grams/cc. This means that NbC particles will not segregate in the liquid melt by sinking (compared with tungsten carbide, for example, which has a density of 15.8 grams/cc) or by floating (compared with titanium carbide, for example, which has a density of 4.93 grams/cc).
- (g) The presence of a high volume fraction of NbC particles in the microstructure will result in a finer ferrous matrix grain size during casting and heat treatment. This improves mechanical properties of the castings.
- (h) It is estimated that 20 wt% addition of NbC to the existing family of wear resistant high chromium white cast iron alloys, will improve the wear resistance of these materials, in some cases possibly by an order of magnitude.

5 (i) By observing the resultant microstructures is it considered that the addition of 10-25 weight% NbC to various stainless steels, for example martensitic, austenitic, ferritic and duplex, will substantially increase wear life with negligible reduction in toughness, corrosion resistance and mechanical properties for the various grades.

10 (j) The addition of 20 wt% NbC to Hadfield steel (which is normally used in liners of primary rock crushers, such as jaw and gyratory crushers, where high impact toughness is required) will produce a material with a much greater wear life than the original Hadfield steel without diminishing the exceptional toughness and work hardening capacity which is
15 inherent in this steel.

(k) The addition of 20 wt% NbC to tool steels will greatly improve tool wear life while maintaining the original material
20 properties.

Niobium carbide can be added to ferrous alloys, such as high chromium white cast irons in two distinct ways, as follows.

25 1. As fine niobium carbide particles (2-100 microns in diameter) to a melt, as per the above-mentioned laboratory work.

30 2. As fine ferro-niobium powder (minus 1 mm diameter) in the presence of the required stoichiometric amount of carbon previously dissolved in the melt.

The density of NbC is 7.8 grams/cc at room temperature and this is close to the density of high chromium white cast iron (7.5 grams/cc). The presence of phases with similar densities assists in achieving a uniform dispersion of NbC particles in the liquid
35 metal during a casting process.

However, a laboratory test carried out by the applicant showed

that segregation of NbC occurred in a high chromium white cast iron + 5wt% NbC alloy by settling of the fine NbC particles to the bottom of the ingot when the melt was allowed to stand for 15 minutes at about 150°C below the liquidus temperature of the host metal.

The density difference between high chromium white cast iron and NbC increases with temperature. The coefficient of thermal expansion of high chromium white cast iron is double that of NbC. In addition, high chromium white cast iron undergoes a step increase in volume at the solid to liquid phase change at approximately 1260°C.

As a consequence, the density of high chromium white cast iron in the liquid state at 1400°C is 6.9 grams/cc whereas the density of NbC at 1400°C is about 7.7 grams/cc. The applicant has found that this density difference is sufficient to cause segregation of NbC particles in liquid high chromium white cast iron at foundry casting temperatures of 1300°C or greater.

Titanium carbide is similar in many characteristics to NbC. The crystal structures are the same, with group number 225. The lattice parameter of NbC is 4.47 Angstroms and the lattice parameter of TiC is 4.32 Angstroms. TiC and NbC are isomorphous, i.e. Ti atoms will readily substitute for Nb atoms in NbC. The hardness of TiC is similar to NbC. The melting point of TiC is 3160°C, which is similar to the melting point of NbC (3600°C).

However, the density of TiC is 4.9 grams/cc at room temperature, and this is much less than the density of NbC. Since TiC and NbC are isomorphous, it is possible to achieve any density value for the mixed carbide in a range 4.9-7.8 grams/cc by selecting the corresponding chemical composition with the general formula $(\text{Nb}_x, \text{Ti}_y)\text{C}$. By way of example, the niobium/titanium carbides may be $(\text{Nb}_{0.5}, \text{Ti}_{0.5})\text{C}$ or $(\text{Nb}_{0.25}, \text{Ti}_{0.75})\text{C}$ or $(\text{Nb}_{0.75}, \text{Ti}_{0.25})\text{C}$. This density difference is the basis of a cost effective method of reducing the segregation of hard, solid carbides in liquid metal at usual

foundry casting temperatures. Specially, it is possible to selectively adjust the density of the niobium/titanium carbides within the range of 4.9-7.8 grams/cc and control whether the particles will form a uniform dispersion in or segregate in a casting of a metal alloy, such as a high chromium white iron, which includes the particles. This selection may be desirable for some castings where uniform wear resistance through the castings is desirable and for other castings where it is desirable to have a concentration of wear resistant particles in one section, such as a surface, of the castings.

The specification refers to the microstructures of hard metal materials of the present invention by volume % rather than the usual bulk chemical weight %. The table set out below is provided to explain the reason for this selection of nomenclature.

In the first 2 cases in the table, the chemistry of the host metal is identical and is essentially a high chrome white chromium cast iron, with a chemistry = Fe-27Cr-2.7C-2Mn-0.5Si. It is intuitively simple to visualize the microstructures of the two hard metal materials (namely 10 and 20 volume % NbC) in the same host metal. However, the bulk chemistries of the two hard metal materials (as determined by the usual foundry spectrographic analysis technique) do not clearly convey the simple difference between these two hard metal materials.

The third and fourth cases in the table, the exercise is repeated for 10 and 20 volume % NbC in Hadfield steel. The chemistry of the host metal is identical and is essentially Fe-12Mn-1.2C-2 Mn-0.5Si. Again, the bulk chemistries of these two hard metal materials are widely different and are not descriptive of the microstructures.

Microstructure = 90 volume% white cast iron + 10 volume% NbC

Furnace Charge	Volume	Composition (Wt%)					
Desc	(%)	Cr	C	Mn	Si	Nb	Fe
NbC	10		11.4			88.6	0.00
Host metal	90	27.0	2.7	2.0	0.5		67.80
Bulk Chemistry	100	24.3	3.57	1.80	0.45	8.86	61.02

Microstructure = 80 volume% white cast iron + 20 volume% NbC

Furnace Charge	Volume	Composition (Wt%)					
Desc	(%)	Cr	C	Mn	Si	Nb	Fe
NbC	20		11.4			88.6	0.00
Host metal	80	27.0	2.7	2.0	0.5		67.80
Bulk Chemistry	100	21.6	4.44	1.60	0.40	17.72	54.24

Microstructure = 90 volume% Hadfield Steel + 10 volume % NbC

Furnace Charge	Volume	Composition (Wt%)					
Desc	(%)	Cr	C	Mn	Si	Nb	Fe
NbC	10		11.4			88.6	0.00
Host metal	90		1.2	12.0	0.5		86.30
Bulk Chemistry	100		2.22	10.80	0.45	8.86	77.67

Microstructure = 80 volume% Hadfield Steel + 20 volume % NbC

Furnace Charge	Volume	Composition (Wt%)					
Desc	(%)	Cr	C	Mn	Si	Nb	Fe
NbC	20		11.4			88.6	0.00
Host metal	80		1.2	12.0	0.5		86.30
Bulk Chemistry	100		3.24	9.60	0.40	17.72	69.04

In all of the work carried out by the applicant in relation to the present invention the applicant has found that the final bulk chemistry of each of the hard metal materials is a complex function of the selected microstructure and the actual bulk chemistry is not a useful means of describing the required features of the hard metal materials. The required features of the hard metal material of the present invention are (a) host metal chemistry and (b) volume % of the selected refractory particles.

It is noted that the bulk chemistry is even more complicated when carbides and/or nitrides and/or borides of two or more transition metals are included in the hard metal materials.

5

It is noted that the hard metal material of the present invention may be cast as a final product shape and may be formed as a solid material that is subsequently hot worked in a downstream processing operation to form a final product shape. For example, the hard metal material of the present invention may be formed as an ingot and subsequently hot worked by rolling or forging as required into a final product such as a bar or a plate.

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Many modifications may be made to the embodiments of the present invention as described above without departing from the spirit and scope of the present invention.

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It will be understood that the term "comprises" or its grammatical variants as used in this specification and claims is equivalent to the term "includes" and is not to be taken as excluding the presence of other features or elements.

CLAIMS:

1. A hard metal material comprising 5-50 volume % particles of a refractory material with particle sizes less than 500 microns dispersed in a host metal, wherein the refractory material comprises particles of carbides and/or nitrides and/or borides of any one or more than one of titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, and molybdenum that are insoluble in the host metal at the casting temperature.
2. The hard metal material defined in claim 1 in the form of a casting.
3. The hard metal material defined in claim 1 or claim 2 wherein the particles of the refractory material are selected from (a) niobium carbide containing refractory particles and (b) particles of a chemical mixture of niobium carbide and titanium carbide.
4. The hard metal material defined in any one of claims 1 to 3 wherein the particles of the refractory material also comprise tungsten.
5. The hard metal material defined in any one of claims 1 to 4 comprises 5-40 volume % particles of the refractory material dispersed in the host metal.
6. The hard metal material defined in any one of claims 1 to 4 comprises greater than 10 volume % and no more than 50 volume % particles of the refractory material dispersed in the host metal.

7. The hard metal material defined in claim 6 comprises greater than 15 volume % and no more than 50 volume % particles of the refractory material dispersed in the host metal.

8. The hard metal material defined in claim 7 comprises
5 less than 30 volume % and greater than 15 volume % particles of the refractory material dispersed in the host metal.

9. The hard metal material defined in claim 8 comprises less than 25 volume % and greater than 15 volume % particles of the refractory material dispersed in the host metal.

10 10. The hard metal material defined in claim 5 comprises greater than 10 volume % and no more than 40 volume % particles of the refractory material dispersed in the host metal.

11. The hard metal material defined in claim 10 comprises
15 greater than 15 volume % and no more than 40 volume % particles of the refractory material dispersed in the host metal.

12. The hard metal material defined in any one of claims 1 to 11 wherein the host metal comprises a ferrous alloy, a stainless steel, an austenitic-manganese steel, or an iron-based or a nickel-based or a cobalt-based superalloy.

20 13. The hard metal material defined in claim 12, wherein the ferrous alloy is a steel or a cast iron.

14. A method of manufacturing a component of a hard metal material comprising:

(a) forming a slurry of a hard metal material
25 comprising 5-50 volume % particles of a

refractory material with particle sizes less than 500 microns dispersed in a liquid host metal in an inert atmosphere, with the particles being insoluble in the liquid host metal; and

5 (b) pouring the slurry into a mould and forming a casting of the component.

15. The method defined in claim 14 comprises forming the slurry and thereafter forming the casting of the component in a chamber under vacuum conditions which remove air from the
10 chamber and supplying an inert gas into the chamber.

16. The method defined in claim 14 or claim 15 comprises selecting the production parameters to form the slurry in step (a) with a required fluidity for processing in step (b).

17. The method defined in claim 16 wherein the production
15 parameters comprise any one or more of the particle size, shape, reactivity, density, and solubility of the refractory materials.

18. The method defined in any one of claims 14 to 17 wherein the refractory material is less than 400 microns
20 particle size.

19. The method defined in any one of claims 14 to 18 wherein the refractory material is less than 150 microns particle size.

20. The method defined in any one of claims 14 to 19
25 comprises selecting the refractory material to have a smaller thermal contraction than the host metal.

21. The method defined in any one of claims 14 to 20 comprises selecting the density of the refractory material, compared to the density of the host metal in the liquid state to control the dispersion of the particles of the refractory material in the host metal.

22. The method defined in any one of claims 14 to 21 comprises selecting the refractory material to have minimal solid solubility in the liquid host metal.

23. A method of forming a wear resistant hard metal material, the method comprising adding (a) niobium or (b) niobium and titanium to a melt containing a host metal in a form that produces particles of niobium carbide and/or particles of a chemical mixture of niobium carbide and titanium carbide with particle sizes less than 500 microns that are insoluble in the host metal of the melt in a range of 10 to 40 wt% of the total weight of the hard metal material in a microstructure of a solidified metal alloy, and allowing the melt to solidify to form the solid hard metal material.

24. The method as defined in claim 23 comprising adding the niobium and/or the titanium to the melt to produce particles of niobium carbide and/or niobium/titanium carbides in a range of 12 wt% to 33 wt% niobium carbides and niobium/titanium carbides of the total weight of the solidified hard metal material.

25. The method as defined in claim 23 or claim 24 wherein the particles of niobium/titanium carbides have a general formula $(\text{Nb}_x, \text{Ti}_y)\text{C}$.

26. The method as defined in any one of claims 23 to 25 comprising adding niobium and/or titanium to the melt in the form of particles of niobium carbide and/or niobium/titanium carbides.

5 27. The method as defined in claim 26 comprising forming a slurry of particles of niobium carbide and/or niobium/titanium carbides suspended in the melt and allowing the melt to solidify to form the solidified hard metal material.

10 28. A method of casting a hard metal material having a dispersion of a chemical mixture of niobium carbides and titanium carbides with particle sizes less than 500 microns in a host metal which forms a matrix of the hard metal material, with the niobium/titanium particles being insoluble in the host
15 metal, the method comprising selecting the density of the niobium/titanium particles in relation to the density of the host metal and therefore selectively controlling the dispersion of the niobium/titanium particles in the matrix ranging from a uniform dispersion to a non-uniform dispersion.

20 29. A casting of the metal alloy made by the method defined in claim 28.

30. The casting defined in claim 29 comprising a uniform dispersion of niobium/titanium particles in the matrix.

31. The casting defined in claim 29 comprising a
25 non-uniform dispersion of niobium/titanium particles in the matrix.

32. The casting defined in any one of claims 28 to 31 wherein the metal alloy is a ferrous alloy, a stainless steel or an austenitic manganese steel.

33. The casting defined in claim 32, wherein the ferrous
5 alloy is a steel or a cast iron.

34. The casting defined in claim 32, wherein the ferrous alloy is a high chromium white cast iron.

35. The casting defined in claim 32, wherein the austenitic manganese steel is a Hadfield steel.

10 36. A method of forming a hard metal material comprising:

(a) forming a slurry of a hard metal material comprising 5-50 volume % particles of a refractory material with particle sizes less than 500 microns dispersed in a liquid host
15 metal, with the particles being insoluble in the liquid host metal, and

(b) allowing the slurry to solidify to form a solid hard metal material.

37. A method of forming a wear resistant hard metal
20 material, the method comprising adding any one or more of the nine transition metals titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum and tungsten to a melt of a host metal in a form that produces particles of carbides and/or nitrides and/or borides of any one or more of the nine
25 transition metals in a range of 5 to 50 volume % of the total

volume of the hard metal material, and allowing the melt to solidify to form the solid hard metal material.

38. A method of casting a hard metal material having a dispersion of refractory material particles of carbides and/or nitrides and/or borides of any one or more of the nine transition metals titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum and tungsten with particle sizes less than 500 microns in a host metal, with the particles being insoluble in the host metal, and with the host metal forming a matrix of the hard metal material in a solid casting, the method comprising selecting the density of the refractory material particles in relation to the density of the host metal and therefore selectively controlling the dispersion of the refractory material particles in the matrix of a solid casting ranging from a uniform dispersion to a non-uniform dispersion.

39. A hard metal material in the form of a casting including a host metal and a dispersion of 5-50 volume % of particles of a refractory material selected from (a) niobium carbide containing refractory particles with particle sizes less than 500 microns that are insoluble in the host metal at the casting temperature and (b) particles of a chemical mixture of niobium carbide and titanium carbide with particle sizes less than 500 microns that are insoluble in the host metal at the casting temperature, and the host metal is selected from a group comprising a ferrous alloy, a stainless steel, an austenitic-manganese steel, and an iron-based or a nickel-based or a cobalt-based superalloy.

40. A pump impeller in the form of a casting of hard metal material defined in claim 39.

41. A pump throatbush in the form of a casting of hard metal material defined in claim 39.

5 42. A liner of a primary rock crusher in the form of a casting of hard metal material defined in claim 39.

43. A liner as defined in claim 42, wherein the primary rock crusher is a jaw crusher or a gyratory crusher.

44. A method of casting a wear resistant hard metal
10 material, the method comprising adding (a) niobium or (b) niobium and titanium to a melt containing a host metal in a form that produces particles of niobium carbide and/or particles of a chemical mixture of niobium carbide and titanium carbide with particle sizes less than 500 microns in a range of
15 10 to 40 wt% of the total weight of the hard metal material in a solidified casting, with the particles being insoluble in the host metal at the casting temperature, forming a casting of the melt, and allowing the casting to solidify to form a solid hard metal material casting, with the host metal being selected from
20 a group comprising a ferrous alloy, a stainless steel an austenitic-manganese steel, and an iron-based or a nickel-based or a cobalt-based superalloy.

45. A method defined in claim 44, wherein the ferrous alloy is a steel of a cast iron.

25 46. A method defined in claim 44, wherein the ferrous alloy is a high chromium white iron.

47. A method defined in claim 44, wherein the stainless steel is duplex, ferritic, austenitic or martensitic.

48. A method defined in claim 44, wherein the austenitic-manganese steel is a Hadfield steel.

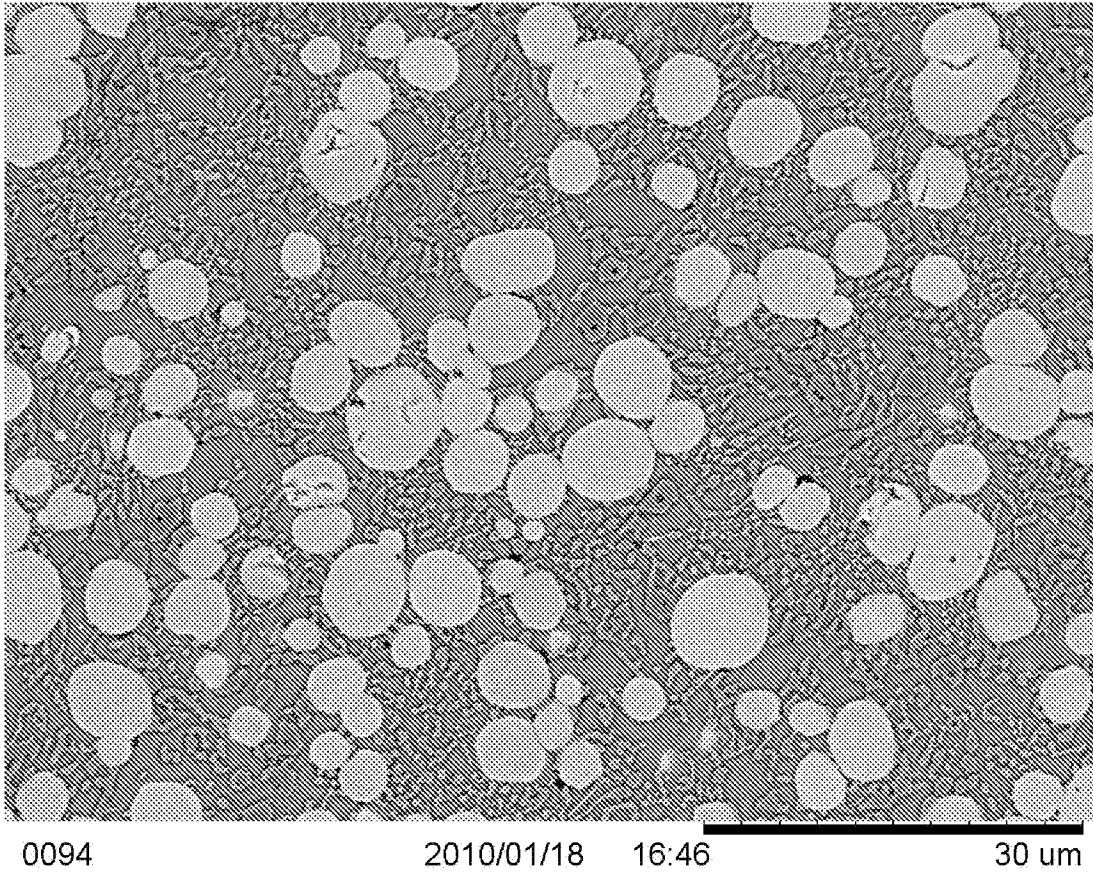
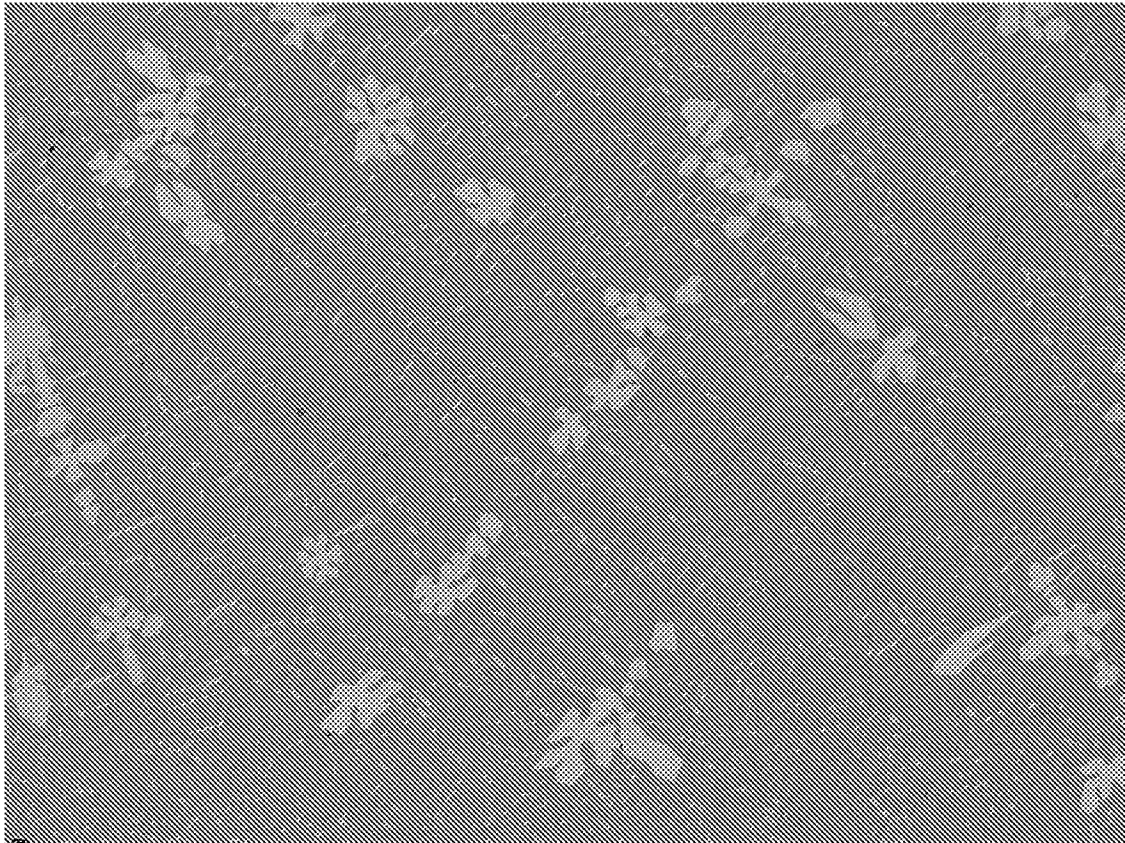


Figure 1



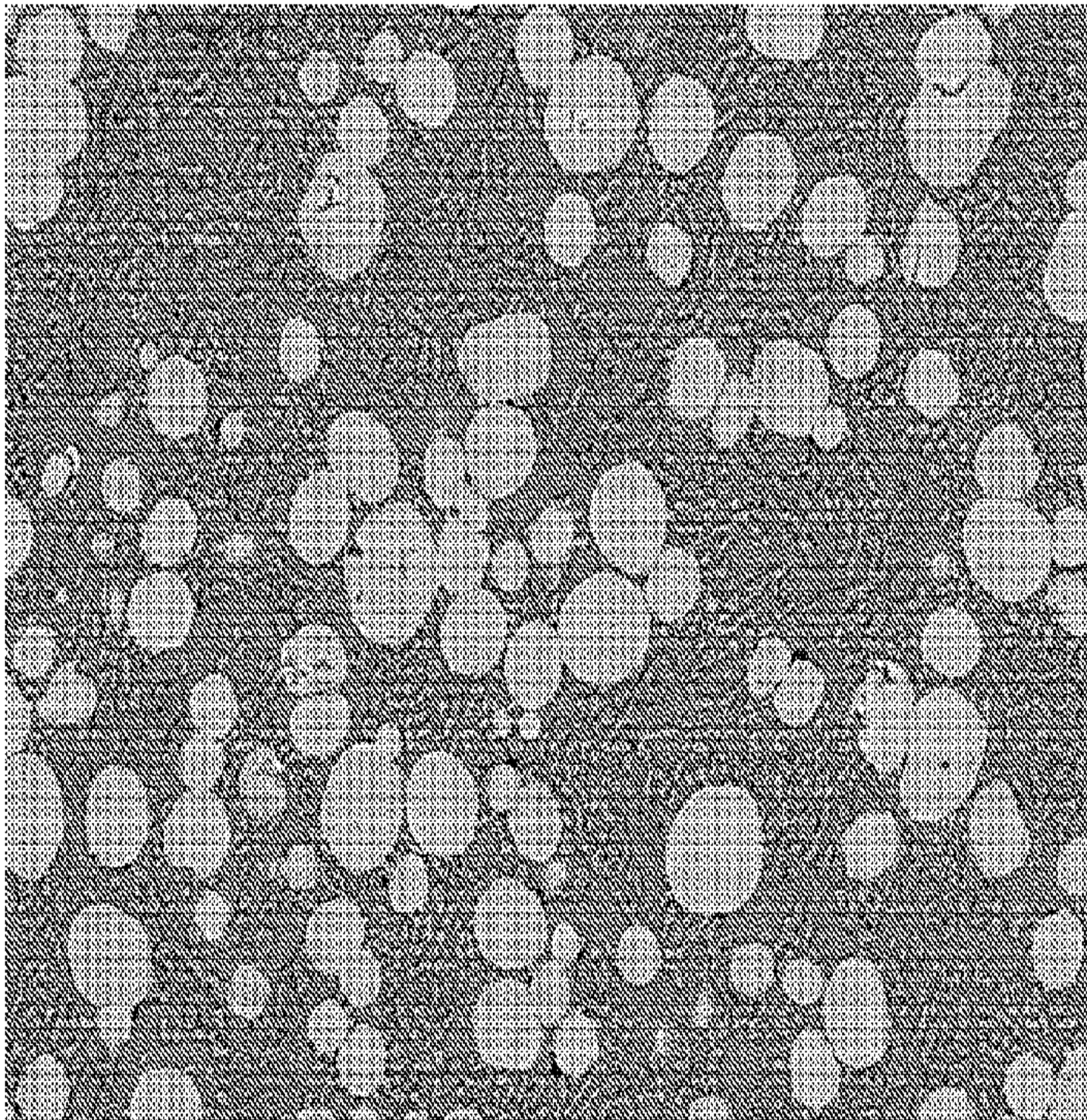
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