



US 20090123324A1

(19) **United States**(12) **Patent Application Publication**
Andersson et al.(10) **Pub. No.: US 2009/0123324 A1**(43) **Pub. Date: May 14, 2009**(54) **IRON-BASE ALLOY CONTAINING
CHROMIUM-TUNGSTEN CARBIDE AND A
METHOD OF PRODUCING IT****Publication Classification**(51) **Int. Cl.****C22C 38/52** (2006.01)**C22C 38/30** (2006.01)**B22D 25/00** (2006.01)**C22C 30/00** (2006.01)(75) Inventors: **Carl-Hakan Andersson**, Goteborg
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164/57.1**

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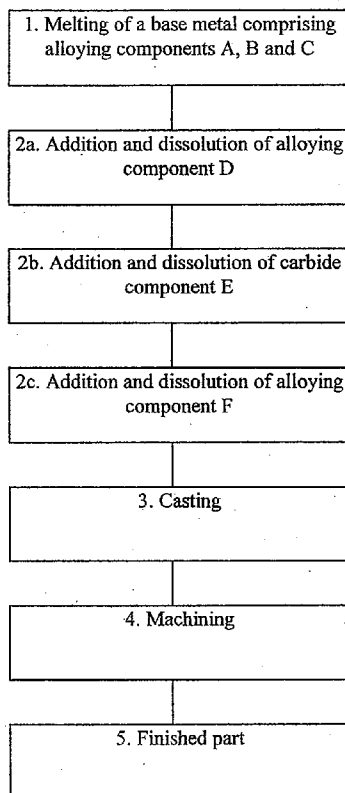
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Jul. 25, 2003, now Pat. No. 7,442,261.(30) **Foreign Application Priority Data**

May 16, 2000 (SE) SE 0001785-5

(57)

ABSTRACT

A method and cast wear resistant component made of an alloy that includes carbon, tungsten, chromium, and cobalt with the balance essentially iron and other alloying components made using waste, surplus or worn-out cemented carbide product, such as cemented carbide cutting tool inserts. In one method, the alloy further includes silicon, manganese, nickel, titanium, and molybdenum. In practicing the method, pieces of waste, surplus or worn-out cemented carbide product having tungsten carbide (WC) are added to a cast iron alloy melt. The melt includes enough chromium to control solubility of the WC. In one method, precipitated carbide structure having chromium and carbon is produced with tungsten in the melt being substitutionally dissolved. In one implementation, tungsten is substitutionally dissolved in a lattice of the precipitated carbide structure. Carbide can be added to the melt via super inoculation. The cast wear resistant component can be a cutting tool.



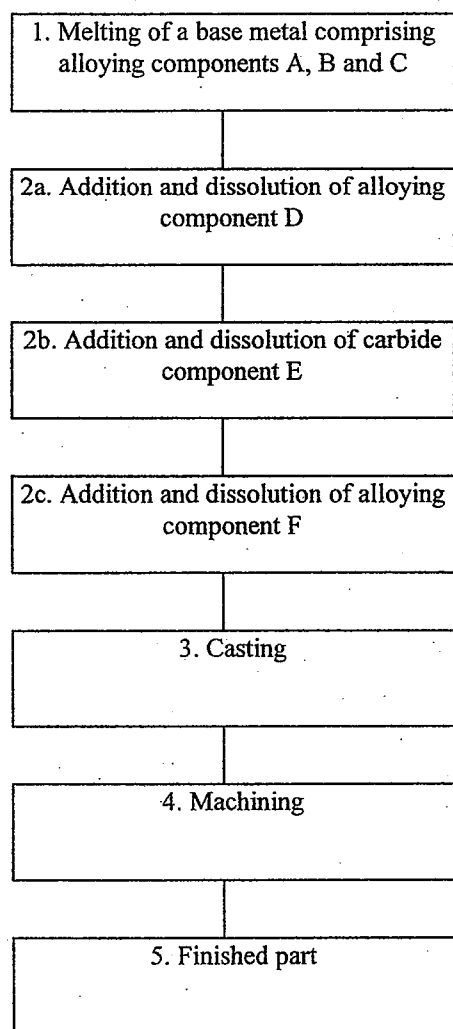


Fig. 1

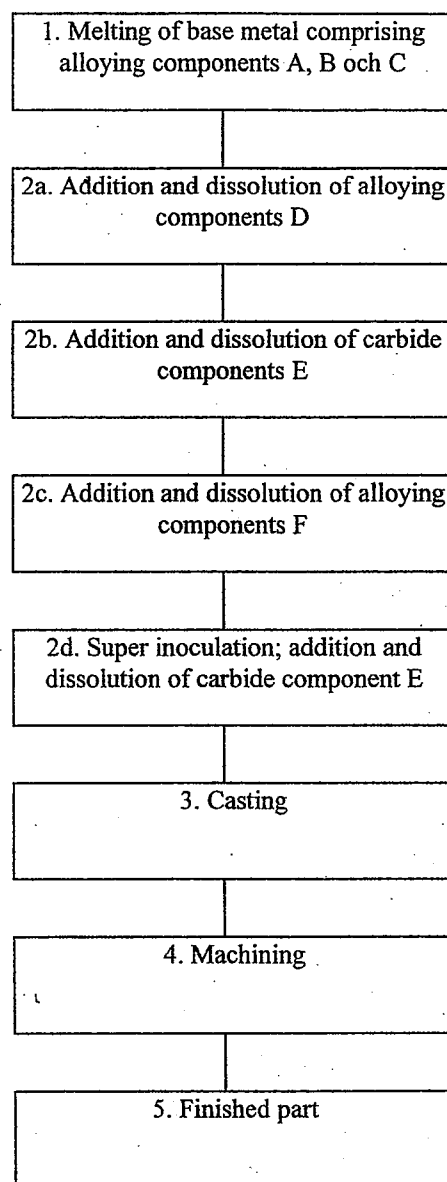


Fig. 2

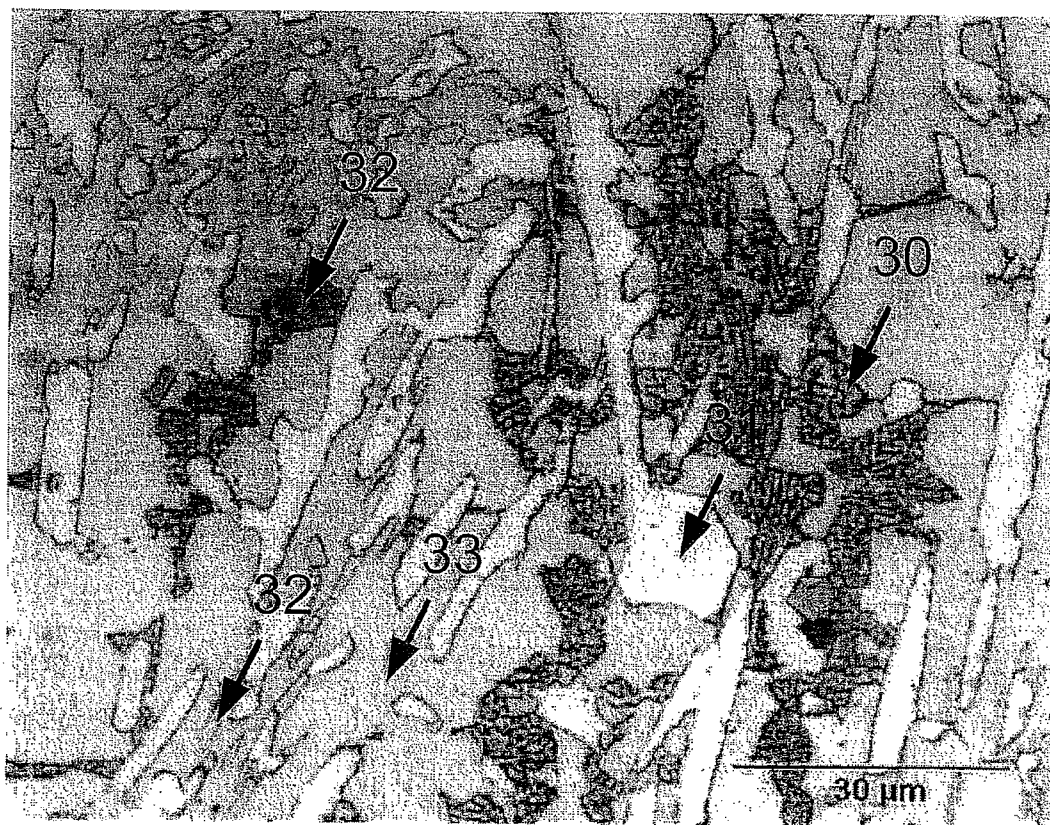


Fig. 3

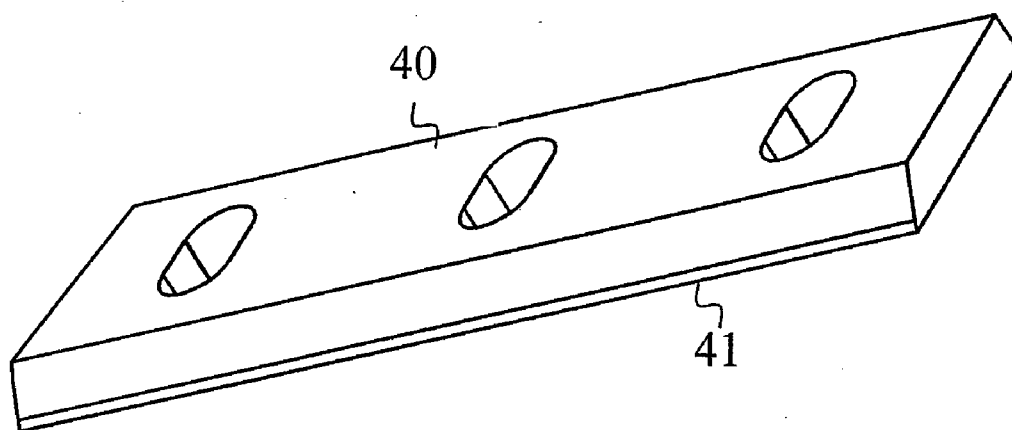


Fig. 4

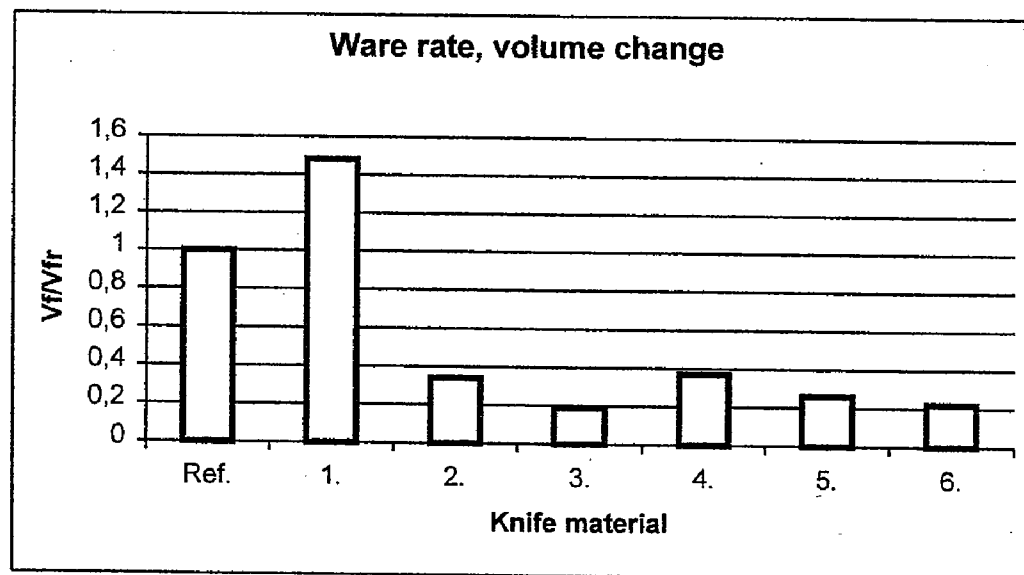


Fig. 5

IRON-BASE ALLOY CONTAINING CHROMIUM-TUNGSTEN CARBIDE AND A METHOD OF PRODUCING IT

FIELD OF THE INVENTION

[0001] The present invention relates to a wear resistant metal material and a method for producing such a material, in particular a material suitable for use in products such as tools, machine elements or similar equipment, devised to be exposed to abrasive wear or chemical exposure.

BACKGROUND

[0002] Tools and machine elements of various kinds are used in a wide range of industries such as manufacturing, pulp, forest and steel industries as well as in different vehicle and defense applications.

[0003] Tool materials are usually divided into two groups depending on field of use; material for cutting and material for plastic and punching machining. Of the two fields of use, cutting tools are faced with the highest demands, such as e.g. cutting edge materials. This field of use demands a material with high wear resistance in combination with high toughness at elevated temperatures to obtain as high abrasion resistance as possible for a tool, i.e. high resistance towards abrasive wear.

[0004] Known tool materials are inter alia tool-steel, high-speed-steel and various cemented carbides. Tool-steel is used for simple hand held tools where only a good edge sharpness is required since the tool-steel requires low temperatures and reasonable forces during use.

[0005] High-speed-steel is alloyed steel with fairly high contents of carbon, chromium and tungsten, molybdenum and vanadium and in some cases even cobalt. High-speed-steel has high wear resistance while maintaining high hardness up to approximately 500° C., depending on the amounts of vanadium and tungsten.

[0006] Cemented carbides are the most common tool material because of the low production costs and are primarily made of tungsten carbide bonded together by cobalt. By varying the proportions of the constituents cemented carbides with material properties suitable for different areas of application can be obtained. By coating the cemented carbide with e.g. titanium carbide the wear resistance and therefore the tool life can be increased. Attempts to coat cemented carbides with a thin layer of synthetic diamond have also been made. To increase the properties of cemented carbides a material called cermets has been developed, a material with nickel instead of cobalt and titanium carbide or titanium-carbon-nitride instead of tungsten carbide. Cutting tools used for metal cutting have an optimal life span of 12-13 minutes, after which the wear mechanisms affect the cutting process negatively and the tool cannot live up to set requirements on surface smoothness and tolerances. The cemented carbide product can thereby be considered to have served its time. Wear mechanisms that affect the life span of a cutting edge are e.g. flank wear and chipping or nicking. Flank wear is a continuous loss of tool material through abrasive and adhesive wear. Chipping or nicking is a crack formation with subsequent fracture of the cutting edge.

[0007] Various ceramic materials exist which have good wear resistance and strength at elevated temperatures but have the drawback that they are brittle.

[0008] Material wise it has been impossible to manufacture materials with both high wear resistance and combinations of hardness and toughness, hence, compromises have been made. In simple applications the geometrical shape of the tool may for instance be designed in such a way that the tool exhibits acceptable wear resistance and strength.

[0009] Previous attempts have been made to design wear resistant material, like the one suggested by the present invention, in which tungsten and carbon have been added to a white iron alloy. These attempts have however failed on account of the fact that the right proportions between tungsten and carbon, which decides the final properties of the material, are very difficult to obtain. Tungsten as a raw material is also quite expensive, a fact that has limited the development.

[0010] A traditional approach for manufacturing tools or other equipment includes the following steps:

Alloy⇒Casting⇒Plastic machining⇒Cutting⇒Hardening+annealing⇒Grinding⇒Finished part

[0011] The Japanese patent JP 2301539 discloses a method for manufacturing a

[0012] Ni—Cr white iron comprising TiC and TiCN at which a material with high hardness and wear resistance is obtained.

[0013] In the European patent application EP 0 380 715 a composite material with high resistance to abrasive wear is disclosed. The composite material contains particles of cemented carbide, of which at least 70% have a grain size in the range of 2-15 mm, as well as white iron. The white iron alloy contains a complex carbide component to which an alloying element is added. Furthermore, the white iron alloy comprises 2.5 to 4.0% carbon and exhibits a Cr to C relation (Cr %/C %) in the range of 1-12. Furthermore, a way to produce the above mentioned composite is disclosed in the document, comprising the step of casting molten white iron around the cemented carbide particles.

[0014] In the US patent U.S. Pat. No. 4,365,997 a compound material and a way to produce such a material is disclosed. The compound material contains a metal matrix, which includes cemented carbide grains with a size of between 0.1 mm and 5 mm. The metal matrix includes carbon, silicon, manganese, vanadium, chromium, tungsten, aluminum and iron. The cemented carbide comprises WC, W₂C, TiC, TaC or a mixture of these materials. The method for producing the above mentioned compound material is to add grains of cemented carbide to the molten metal matrix. The grains are encapsulated in a polymer-based matrix, which evaporates when the grains are added to the molten metal matrix, and subsequently the molten material solidifies.

[0015] Patent application WO 94/11541 announces a method for the manufacture of engineering ferrous metals such as cast iron and steel, which method includes adding to a molten engineering ferrous metal modified carbide particles, in solid state, and thereafter allowing the ferrous metal to solidify. The carbide particles are modified in the sense that they are covered with e.g. iron or a ferrous alloy so that the modified carbide particles receive a density equal to or close to the density of the ferrous metal. This density matching results in a uniform distribution of the carbide particles in the ferrous metal melt.

[0016] The Japanese patent JP 59104262 discloses a composite material with an inner steel layer and an outer layer comprising cast iron in which tungsten carbide particles or similar hard carbide particles have been evenly distributed. Furthermore, a method for producing such a material is dis-

closed. The method includes adding pre-heated carbide particles to molten cast iron and then casting the molten material around a pre-heated steel tube.

[0017] SE 185 935 relates to methods for alloying metal melts, predominantly including cast iron. In the document, an alloy, which can contain both chromium and tungsten, is mentioned, but nothing about any carbide structure.

[0018] EP 571 210 concerns the manufacture of a corrosion resistant alloy based on vanadium carbide. The material is created by e.g. the melting of a powder material.

[0019] SE 399 911 concerns the casting in of cemented carbide particles in iron based cast iron alloys. The suggested solutions is not intended to create melting and alloying, even though it is mentioned that alloys between the cast metal and the cemented carbide can occur and that these, generally speaking, are non advantageous. The patent does not describe the substitutional solution of tungsten in a chromium carbide structure.

[0020] DE 649 622 describes an alloy, which can contain both tungsten and chromium, but nothing of the interactions between the two during the formation of carbides.

[0021] GB 348 641 describes an alloy, which can contain both tungsten and chromium, but nothing of the interactions between the two during the formation of carbides.

OBJECT OF THE INVENTION

[0022] An object of the present invention is to provide a material for use in products or applications subjected to abrasive wear, and in particular a material more resistant to wear than previously known material in an unhardened state, as well as a method for producing such a material.

[0023] Another object of the invention is to provide a material in which the number of processing steps to finished product can be reduced. Since the number of processing steps to finished part is directly linked to the final cost of the product, the invention presents a cost efficient method to produce a wear resistant and high strength material.

[0024] Yet another object of the present invention is to provide a method for reusing worn-out cemented carbide.

SUMMARY OF THE INVENTION

[0025] According to the present invention the above mentioned objects are fulfilled by a method for manufacturing a metal material with high wear resistance, characterized by the steps of melting a base metal comprising iron and carbon; adding particles comprising a carbide component to the molten base metal, whereby said particles are dissolved in the base metal melt by way of diffusion; and casting the melt. Preferably the method includes the step of adding a solution limiting alloying component to the melt, which alloying component controls the solubility of the carbide component in the melt. The alloying component is carbide forming, whereby the properties in solid state for carbides based on said alloying component are improved by substitutional solution of said carbide component in the crystal formation for said carbides based on said alloying component (D). The carbide based alloying component (D) is however not soluble in the carbide component (E).

[0026] In one embodiment of the invention said particles are waste or surplus products originating from the production of cemented carbide products, which waste or surplus products comprise said carbide component. In a preferred embodiment said particles are added from a piece of worn-out

cemented carbide product, comprising said carbide component, e.g. a worn-out cemented carbide cutting tool or a cemented carbide roller. The possibility to use worn-out cemented carbide products follows from the fact that the particles are dissolved by diffusion in the melt, whereby no machining of the particles which are to be added is required, in order to obtain a particular size or surface finish. Consequently, whole cemented carbide tools in size up to 40 mm and above can be added directly into the melt. This is economically advantageous, on the one hand because cemented carbide tools are worn-out quickly and are thus available in abundance, and on the other hand because this requires a minimum of processing steps. Another advantage with the use of waste or worn-out cemented carbide pieces is that the desired cemented carbide, e.g. WC, comprising tungsten and carbon, already is available in a balanced proportion, since they form molecular pairs in the carbide component.

[0027] In the added particles said carbide component is usually included with a grain size $\leq 10 \mu\text{m}$, preferably 1-5 μm . If complete dissolution by diffusion of grains of said carbide component has not occurred, grains with a size of $\leq 10 \mu\text{m}$ may exist in the final material.

[0028] Before the dissolution of the particle in the melt said carbide component is preferably bonded in said particle, or piece, by a metal material which gives melting at a lower melting point than the base metal. This material is preferably cobalt, but can also include nickel. The added solution limiting alloying component preferably includes chromium but can also include vanadium or molybdenum, and gives the final alloy an increased corrosion resistance as well as lowering the melting point of the melt in its molten state and lowering its surface tension. The base metal preferably includes stabilizing and supplementing alloying components like Si and Mn and constitutes in one embodiment white cast iron.

[0029] In a preferred embodiment of the invention said carbide component consists of tungsten carbide but can also include titanium carbide or niobium carbide. In one embodiment said carbide component is added to the melt in a melting furnace, in an amount of >5 weight-% of the final material, and is dissolved therein. In another embodiment said carbide component is added to the molten alloy, so that it comprises <15 weight-% of the final material, immediately prior to casting by an inoculation process, so-called super inoculation. This procedure differs from ordinary inoculation, where a material, arranged not to affect the constitution of the final material, is added in a very small dose. An inoculation substance can, for example, according to well-known technology, be added to a cast iron melt to act as nucleation points in order to achieve a finer grain microstructure. According to the super inoculation procedure of the invention a material, which is an essential part of the final alloy is added, and in an amount, which is of considerable importance for the final composition of the alloy. Said carbide component is included in the final material with between 5-40 weight-%, preferably 10-20 weight-%.

[0030] In one embodiment of the invention an additional alloying component is added to the melt, which additional alloying component facilitates the dissolution of said carbide component in the melt and decreases the carbon affinity. The additional alloying component is easily dissolvable in the molten alloy and does not affect the application properties of the final material. Furthermore, said additional alloying component contributes to an increased ability to anneal the final

material by meta-stable states after casting. Preferably said additional alloy includes cobalt or nickel.

[0031] The final material is usable for the manufacture of compound materials by die casting or on casting on a core material. During on casting a protective gas or active gas is preferably provided in order to obtain a solution hardening effect. According to the invention, one way to achieve on casting is the use of induction heating of the core material prior to casting, and to carry out the on casting in a shell mould.

[0032] A product manufactured by the final material is, according to the present invention, usable in a recycling cycle, in which the product or a part of the product is added and dissolved in a melt of a base metal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] Preferred embodiments of the present invention are described in detail below with reference to the accompanying drawings, in which:

[0034] FIG. 1 shows a flow chart of a first method according to the invention.

[0035] FIG. 2 shows a flow chart of a second method according to the invention, comprising a super inoculation process.

[0036] FIG. 3 shows the microstructure for one embodiment of the material according to the present invention.

[0037] FIG. 4 shows a cutting element, which may advantageously be manufactured in the material according to the present invention.

[0038] FIG. 5 shows a diagram showing the wear resistance for different embodiments of the present invention, as well as for some known materials.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0039] The method according to the invention for producing a wear resistant and durable material, so-called carbide steel, can be described in the following steps (FIGS. 1 and 2):

1. Alloying

[0040] a. production of a base alloy; including

[0041] a base metal containing

[0042] an alloying component A, such as iron;

[0043] an alloying component B comprising stabilizing and supplementing alloying components, such as silicon and manganese;

[0044] an alloying component C, such as carbon;

[0045] an alloying component D comprising a solution limiting alloying component, such as chromium, vanadium or molybdenum; and

[0046] b. melting and adding of a carbide component E, such as tungsten carbide, titanium carbide or niobium carbide, and possibly adding of an other alloying component F, such as cobalt or nickel;

3. Casting; and

4. Machining.

1. Alloying

[0047] The base material in the method according to the invention is a base metal including iron A, stabilizing and supplementing alloying component B, e.g. silicon and manganese and an alloying component C, e.g. carbon. A base

alloy is obtained by complementing the base metal with a solution limiting alloying component D, preferably chromium, but vanadium or molybdenum can be used.

The alloying component D should fulfill the following functions:

[0048] in molten state, to lower the melting point and lower the surface tension of the base alloy and limit the solubility of other materials in the base alloy; and

[0049] in solid state, to be a property enhancing component of the final alloy, the so-called carbide steel, by the formation of carbides so that carbides with desired properties are formed, having an electrochemical potential contributing to corrosion limiting properties.

[0050] During the alloying stage alloying component D is devised to limit the solubility and the speed of dissolution of carbide component E in the molten base alloy. The carbide component E is preferably added as tungsten carbide, but also e.g. titanium carbide or niobium carbide can be added. The carbide component E is pre-heated to minimize under-cooling of the base alloy before more than 5-% by weight of the carbide component E is added to the molten base alloy. Because of alloying component D the added carbide component E is only dissolved to such an extent permitted by alloying component D. This way the manufacturer can control the solubility of the carbide component E and a desired part of carbide component E can therefore constitute un-dissolved particles in the final alloy. With regard to desired properties of the finished carbide steel more than one carbide component can be added.

[0051] Carbide component E is soluble in alloying component D, but the reverse relation does not apply, i.e. single sided solubility exists. This is especially advantageous since the carbide steel then exhibits a large eutectic interval, i.e. an interval within which the carbide steel exhibits a lower melting point than the pure metals each do. The size of the interval depends on chosen carbide component and base alloy. As the molten alloy solidifies two or more solid phases simultaneously precipitate which gives an alloy with very good material properties and castability. Thus, the single sided solubility enhances the castability within a large interval of composition.

[0052] An additional alloying component F can be added to the molten alloy to further ease the dissolution of the added carbide component E in the molten alloy. Components that decrease the carbon affinity can for example be preferred. Preferably cobalt is used, but also nickel or aluminum can be suitable. The alloying component F should only be added to a limited extent and be easily dissolvable in the molten alloy in order not to affect the unique properties of the final alloy too much. The alloying component F further adds to an increased hardenability by meta-stable conditions after casting.

[0053] Under controlled conditions there are no obstacles against integrating steps 1a and 1b above for the manufacturing of the carbide steel according to the invention. Some weight-%, less than 15 weight-%, of carbide component E, e.g. tungsten carbide, is advantageously added to the molten alloy immediately prior to casting. This inoculation process, so-called super inoculation, then takes place to such an extent that notable changes in composition as well as extra grain formation points are obtained, for the purpose of giving a finer microstructure as well as improving the material properties by an increased amount of carbides.

[0054] An example of a suitable base alloy for step 1a above is a white cast iron alloy type SS0466. A typical white cast

iron alloy can in its original composition consist of at least 2.9 weight-% carbon, 0.7 weight-% silicon, 0.4 weight-% manganese, 18 weight-% chromium, 1.0 weight-% nickel, 0.3 weight-% titanium and the remaining part iron.

[0055] White cast iron can then be alloyed with a worn-out cemented carbide component which has served its time (step 1b above), in which the carbon balance for the modified white iron alloy is not changed compared with its original composition, since the method according to the invention allows a release of the carbon content for the alloying components bonded to re-created carbides during the solidification of the molten alloy.

[0056] In one embodiment of the final material, i.e. the alloy according to the invention, the alloy comprises, in weight-%, 1-5% carbon, 10-40% chromium, 2-40% tungsten and the balance iron and other alloying components. Preferably said other alloying components comprise, in weight-%, 0.5-2% silicon, 0.3-10% manganese, 0-7% nickel, 0-2.5% titanium, 0-5% molybdenum and 0.1-15% cobalt.

[0057] In one embodiment of the alloy according to the present invention the alloy includes, in weight-%, 2-3.5% carbon, 20-30% chromium, 5-20% tungsten and the balance iron and other alloying components. The mentioned other alloying components are preferably, in weight-%, 0.8-1.2% silicon, 0.4-2% manganese, 0.8-2% nickel, 0.2-0.5% titanium, 0-1% molybdenum and 0.5-5% cobalt.

[0058] In one embodiment of the alloy according to the invention, said other alloying components amount to, in weight-%, 0-5%. The final material predominantly comprises a structure of chromium carbide, which has been formed during the solidification of the melt by the strongly carbide-forming chromium atoms, which have bonded carbon atoms in a lattice structure. Since these chromium carbides dissolves tungsten carbide, a material according to the invention is obtained in which tungsten is substitutionally dissolved in the lattice crystal of the chromium carbide structure, wherein complex carbides based on chromium and tungsten are obtained.

[0059] In table 1 below the chemical composition, the bulk analysis, of one embodiment of the carbide steel according to the present invention, comprising 15 weight-% cemented carbide (WC—Co), is shown. The presented level reflects the chemical composition of the particular sample exhibited at the analysis.

TABLE 1

Chemical composition in weight-%, the bulk analysis, of one embodiment KS15(3) of the material according to the present invention.												
Fe	Cr	W*	C	Si	Mn	Ni	Ti	Mo	Co	Al	P	S
62.0	23.97	9.30	2.70	1.76	0.255	0.341	0.115	0.085	0.760	0.010	0.044	0.048

* Analyzed with XRF

[0060] However, during casting, iron scrap comprising more or less of certain alloys, is advantageously used, wherein the above mentioned material can be considered a sample of an embodiment with 15 weight-% WC—Co, characterized by the range of composition, in weight-%, 2.5-3.5% carbon, 8-12% tungsten, 20-28% chromium, 1.6-2.0% silicon, 0.2-0.4% manganese, 0.3-0.5% nickel, 0.1-0.2% titanium, 0-0.7% molybdenum and 0.5-1.0% cobalt.

[0061] In FIG. 3 the microstructure and the structural components of an alloy according to the present invention, in an

embodiment comprising 15 weight-% cemented carbide (WC—Co), is shown. The arrows in the figure indicate: **30**—eutecticum, **31**—chromium carbide, **32**—complex carbide with tungsten dissolved in the chromium carbide and titanium carbide, and **33**—matrix. From the figure it is evident that the WC particles or pieces added to the melt cannot be localized in the microstructure of the material according to the present embodiment, because of the dissolution obtained of said particles or pieces in the melt, e.g. in an induction melting furnace.

[0062] In FIG. 4 an application of the material according to the present invention is shown, in a product shaped as a granulator knife **40**, devised with a cutting edge **41**. Industrial trials with granulator knives cast in an alloy according to the present invention, in an embodiment comprising 5 weight-% and 15 weight-% cemented carbide (WC—Co), have shown large differences in wear resistance, compared to a standard tool material SS2310 (SS indicates Swedish Standard). Also the weight-% WC has been shown to affect the wear resistance. FIG. 5 illustrates a diagram showing the results from granulation of PVC during one month of production conditions. In the diagram the wear resistance is shown as the change in volume of the cutting edge of the knife compared with reference SS2310, a common tool material. On the horizontal axis different knife materials are indicated, where Ref is the standard tool-steel SS2310. Furthermore, **1** is a white iron alloy SS0466, a well known material. Knife material **2** indicates an alloy according to the present invention, called carbide steel KS5(**1**), with 5 weight-% cemented carbide (WC—Co). Knife material **3** is another alloy according to the invention, called carbide steel KS15(**1**), manufactured with 15 weight-% cemented carbide (WC—Co). Both material **3** and **4** are based on said white iron alloy SS0466. The differences between the materials according to the invention, in the embodiments 2 and 3, and the known-materials Ref. and **1**, are striking.

[0063] Furthermore, in FIG. 5 the result of a more advanced white iron **4**, SS0466BTI, containing a certain amount of titanium, is shown. This material is considerably more wear resistant than the reference. Despite this, an alloy according to the invention based on this titanium containing white iron alloy SS0466BTI will have an even more increased wear resistance. Knife material **5** indicates an alloy according to the invention called carbide steel KS(BTI)5(**1**), manufactured

with 5 weight-% cemented carbide (WC—Co), and knife material **6** indicates an alloy carbide steel KS(BTI)15(**1**) with 15 weight-% cemented carbide (WC—Co). The later alloy in particular has a wear resistance, which is 5-6 times better than the reference, and SS0466BTI.

[0064] The alloying levels can under certain conditions be adjusted so that a toughness adjustment can be carried out by the precipitation of secondary complex carbides by means of annealing. Trials have also shown that it is possible to carry

out a localized heat treatment based on induction technology. A toughness optimization of e.g. the edge or other areas of the tool or product can therefore be carried out. For known heat conduction properties and known transformation conditions localized heat treatment can be realized by controlling the cooling gradient by control of boundary conditions. For more complicated devices a technology based on finite element analysis (FEA) can provide an important tool for this type of heat treatment.

[0065] Studies carried out unambiguously show that as-cast products of the final alloy, the carbide steel, according to the invention, can be machined with modern and advanced cutting tool material at most competitive prices in comparison with martensitic materials, on condition that optimal cutting data combination are chosen. Already at rough machining a unique surface finish has been obtained.

[0066] The method according to the invention makes it possible to reuse a worn-out product, made of the alloy according to the invention. This recycling system can on the one hand be based on a direct re-melting and recasting of the product for use in new products, and on the other hand as a base alloy, in which further amounts of the alloying components can be added for the manufacture of a new melt according to the invention. Furthermore, a return system can be based on worn-out tool material, preferably cemented carbide, included in a recycling cycle for the manufacture of an alloy according to the invention. This recycling procedure is possible because the molten alloy, completely or partly is saturated with carbides or carbide forming alloying elements D and E.

[0067] For example, a white iron alloy modified according to the invention, can obtain a hardness of 660 hardness Brinell (HB) at an addition of 15 weight-% carbide component E and 650 HB at an addition of 5 weight-% carbide component E. These hardness values should be compared with the maximum hardness of 550 HB, which a white iron alloy can obtain in its as-cast state.

[0068] According to the present invention an extremely wear resistant material, so-called carbide steel, can be obtained from a white iron alloy according to the above with a suitable portion of carbide component E. The carbide steel has for its field of use a favorable ratio between hardness and toughness, and wear resistance, without the need of subsequent heat treatment. The favorable properties of the carbide steel are received after controlled solidification and cooling. In the applications for which the carbide steel according to the invention is adapted, no annealing is necessary. If the carbide steel is annealed a tougher material is obtained.

[0069] By the term high alloy white iron is here meant a castable iron alloy including more than 3 weight-% of other alloying components than those that made part of the base metal. Such high alloy white irons are well suited for use in applications exposed to abrasive wear. The reason for this is that a large portion of the carbon is bonded as carbides, giving the alloy a high hardness and good chances to withstand degradation concerning both geometry and structure. The carbides are imbedded in a matrix with a structure which, depending on the composition, can be adjusted to achieve optimum relation between wear resistance and toughness. High alloy white iron contains high levels of chromium, which stabilises the carbides in the microstructure of the matrix and prevents graphite from being precipitated during solidification. White cast iron is characterised by a chemical compound of iron carbide, such as cementite, Fe_3C , in a base

material of, depending on the amount of chromium, ferrite, pearlite, austenite and/or martensite. High levels of chromium in high alloyed white iron means complete or partly pearlitic matrix, where the amount of complex carbides controls the wear resistance of the alloy. The micro hardness for the chromium carbide is between 840 and 1400 hardness Vickers (HV) (HV50), depending on the chromium to carbon relation in the composition of the alloy. Present chromium carbides in white iron alloys having a high amount of chromium may include M_3C 840-1100 HV (HV50), M_7C_3 1200 to 1800 HV (HV50) and/or Mo_2C 1500 HV (HV50). Low ratios between chromium and carbon result in a matrix of austenite that can be transformed into pearlite during cooling. The wear resistance can be further increased by heat treatment of several white iron alloys so that the matrix is transformed into martensite.

2. Casting

[0070] When carbide steel is manufactured according to the method according to the invention the material is cast in order to obtain a final product with desired shape. By controlling the cooling of the molten alloy the hardness of the carbide steel can be controlled, i.e. rapid cooling results in lower hardness whereas a lower cooling speed gives a carbide steel with higher hardness. This property is unique for the carbide steel according to the invention with the consequence that the carbide steel exhibits unique heat-treating properties, i.e. an adjustment of hardness and toughness can be done depending on application. The carbide steel according to the invention exhibits a case depth, which is essentially identical through a section of a cast product. Normally a thick cast white iron alloy would exhibit a lower hardness at the center of the material, as this solidifies last, compared with the hardness of the surface because of different cooling speeds. This may mean that a desired microstructure (with accompanying mechanical properties and hardness) is not achieved throughout the entire cast product.

3. Machining

[0071] A finishing cut of the final product is carried out by machining of the surfaces of the final product in order for it to fulfill the tolerances that the application demands.

[0072] The carbide steel manufactured according to the invention has, when used in tools, exhibited a life expectancy range of up to five times the life expectancy range of comparable materials.

Further Developments

[0073] A further development of the method according to the present invention applies to the use of the carbide steel during the manufacture of so-called compound materials. The carbide steel is then cast in or on together with a light alloy or a steel alloy in which the carbide steel basically maintains its mechanical properties in contrast to martensitic steel. This means that the carbide steel can be used in hot applications or methods of production up to 900° C. without any mentionable change in the microstructure due to the stable microstructure of the carbide steel. In casting in a light metal can be carried out for example by die-casting, whereas on casting with steel with higher toughness can be carried, inter alia, out by casting with shell moulds. On casting can be carried out by pre-heating of e.g. steel plates in a cast mould by induction heating followed by the filling of the mould by the carbide steel.

This casting can be carried out with various types of surrounding protective atmospheres, e.g. protective gas or active gas, which can give a solution hardening effect and thereby creating a more even transition between a tough and hard material.

[0074] The proposed technology for the manufacture of so-called compound steel components is of great interest within different fields of applications where a combination of toughness and hardness, alternatively toughness and high wear resistance is desired. Such a compound material solution can be of interest also with respect to following machining. For example, the wheel center of a pump wheel can be manufactured by tool steel with good machinability while the rest of the pump wheel is manufactured from carbide steel according to the invention. In the same fashion can e.g. the "core material" in a stirrer (pump wheel/impeller) be manufactured by choosing a tougher steel, while the parts exposed to abrasive wear are made of carbide steel according to the present invention.

[0075] By in casting of carbide steel reinforcements can be received in a light metal alloy. Parts of the reinforcements can extend to the edge of the light metal component whereby a high wear resistance or load-bearing ability is obtained. This design is not possible in a martensitic steel alloy because of the annealing effects, which arise during casting.

[0076] In FIG. 1 the process steps according to the invention are illustrated by in flow chart. In step 1 a melt of a base metal is provided, which base metal includes iron A, stabilizing component B, e.g. silicon and/or manganese, and carbon C.

[0077] In what is described as step 2 more additives are added. In step 2a a solubility limiting alloying component D, e.g. chromium, is added. The melt of the base metal and alloying component D is referred to as the base alloy, and in the case that an already existing material has the desired composition of components A-D according to the base alloy, step 2a can be excluded.

[0078] Component D is arranged to limit the solubility of carbide component E, which is added to the melt in step 2b. The carbide component E is e.g. tungsten carbide bonded by cobalt, and can be added as powder or as pieces of used or worn-out cemented carbide products.

[0079] In step 2c an additional alloying component F, e.g. cobalt or nickel with advantageous properties according to the above, can be added if so desired. It is obvious that the order of steps 2a-2c is not critical and they can be carried out simultaneously since the added components are to be dissolved in the melt.

[0080] According to the embodiment described in FIG. 1, the final material, also called the final alloy, is then cast in step 3. After cooling, the material is ready to be machined, in step 4, into a final part, step 5.

[0081] Another embodiment of the invention, illustrated in FIG. 2, includes the steps described in FIG. 1 and with step 2d added. In this step the new super inoculation step is carried out during which a to the composition significant component, carbide component E, is added in an amount of considerable importance to the composition of the final material, immediately prior to casting. This amount can correspond to a part of the final alloy of up to 15 weight-%, but preferably <5 weight-%.

[0082] The present invention has been described by means of preferred embodiments, and it is evident for a person

skilled in the art that modifications thereof can be carried out without leaving the scope of the attached claims.

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35. A cast wear resistant component comprised of an alloy made with waste, surplus or worn out cemented carbide product and having an as-cast composition consisting essentially of 2-3.5% weight percent carbon, 5-20% weight percent tungsten, 20-30% weight percent chromium, and 0.5-5% weight percent cobalt, with the balance essentially iron and other alloying components.

36. The cast wear resistant component of claim 35 wherein the component is machinable.

37. The cast wear resistant component of claim 36 wherein the component is heat treatable.

38. The cast wear resistant component of claim 35 wherein the component comprises a tool.

39. The cast wear resistant component of claim 38 wherein the component comprises a cutting tool.

40. The cast wear resistant component of claim 35 wherein the component has an as-cast composition consisting essentially of 2-3.5% weight percent carbon, 5-20% weight percent tungsten, 20-30% weight percent chromium, 0.8-1.2% weight percent silicon, 0.4-2% weight percent manganese, 0.8-2% weight percent nickel, 0.2-0.5% weight percent titanium, 0-1% weight percent molybdenum.

41. The cast wear resistant component of claim 35 wherein the component is comprised of chromium carbide arranged in a lattice structure having tungsten substitutionally dissolved therein.

42. A method for making a wear resistant component comprising the steps of:

(a) melting a quantity of metal comprised of cast iron alloy;
(b) adding to the melt, pieces of waste, surplus or worn-out cemented carbide product comprised of tungsten carbide wherein there is chromium in the melt in an amount sufficient to control the solubility of tungsten carbide; and

(c) casting a wear resistant component consisting essentially of 2-3.5% by weight carbon, 5-20% by weight tungsten, 20-30% by weight chromium, and 0.5-5% by weight cobalt, with the balance essentially iron.

43. The method of claim **42** wherein the pieces of waste, surplus or worn-out cemented carbide product added to the melt during step (b) comprises cemented carbide cutting tool inserts.

44. The method of claim **42** wherein the pieces of waste, surplus or worn-out cemented carbide product added to the melt during step (b) comprise tungsten carbide.

45. The method of claim **42** wherein the wear resistant component cast during step (c) comprises a cutting tool.

46. The method of claim **42** wherein the wear resistant component formed during step (c) is comprised essentially of 2-3.5% carbon, 5-20% tungsten, 20-30% chromium, 0.8-1.2% silicon, 0.4-2% manganese, 0.8-2% nickel, 0.2-0.5% titanium, 0-1% molybdenum, 0.5-5% cobalt, and the balance essentially iron.

47. The method of claim **42** wherein chromium is added in a further step.

48. The method of claim **42** wherein the cast iron alloy comprises white cast iron.

49. The method of claim **42** comprising a precipitated carbide structure comprised of chromium and carbon and wherein tungsten in the melt substitutionally dissolves in a lattice of the precipitated carbide structure.

50. The method of claim **42** wherein before step (c) adding carbide to the melt via super inoculation.

51. The method of claim **50** wherein the carbide added to the melt via super inoculation comprises tungsten carbide.

52. A method for making a wear resistant component comprising the steps of:

(a) melting a quantity of metal comprised of cast iron alloy;
(b) adding to the melt pieces of waste, surplus or worn-out cemented carbide product comprised of tungsten carbide wherein chromium is provided in the melt in an amount sufficient to control the solubility of tungsten carbide; and

(c) forming a wear resistant component consisting essentially of 2-3.5% carbon, 5-20% tungsten, 20-30% chromium, 0.8-1.2% silicon, 0.4-2% manganese, 0.8-2% nickel, 0.2-0.5% titanium, 0-1% molybdenum, 0.5-5% cobalt, and the balance essentially iron with incidental impurities.

53. The method of claim **52** wherein the pieces of waste, surplus or worn-out cemented carbide product added to the melt during step (b) comprises cemented carbide cutting tool inserts.

54. The method of claim **52** wherein the pieces of waste, surplus or worn-out cemented carbide product added to the melt during step (b) comprise tungsten carbide.

55. The method of claim **52** wherein the wear resistant component cast during step (c) comprises a cutting tool.

56. The method of claim **52** wherein chromium is added in a further step before step (c).

57. The method of claim **52** wherein the cast iron alloy comprises white cast iron.

58. The method of claim **52** comprising a precipitated carbide structure comprised of chromium and carbon and wherein tungsten in the melt substitutionally dissolves in a lattice of the precipitated carbide structure.

59. The method of claim **52** wherein before step (c) adding carbide to the melt via super inoculation.

60. The method of claim **59** wherein the carbide added to the melt via super inoculation comprises tungsten carbide.

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