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## METHOD FOR PRODUCING TOOL STEELS CONTAINING TITANIUM CARBIDE

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The present invention relates to a titanium-containing tool steel and more particularly to a method for producing said steel containing titanium carbide.

In copending application Serial No. 461,143, filed October 8, 1954, now Patent No. 2,828,202, a titanium tool steel alloy is disclosed comprising by weight about 10% to 70% titanium substantially all combined as a titanium base carbide distributed substantially uniformly as small particles through a ferrous matrix containing iron as a major alloying element, the ferrous matrix comprising carbon steel, medium alloy steel or high alloy steel.

Heretofore, it had not been possible to utilize titanium in large amounts commercially in the production of tool steels in the manner that tungsten and other refractory metals such as molybdenum and vanadium have been used. One important reason is that additions of over 5% titanium to molten carbon-containing, ferrous metal have been known to have embrittling effects on the resulting ferrous alloy as to make the alloy unworkable and unsuitable for commercial production of useful products. This is because titanium, when in excess to the carbon content, precipitates easily as a dendritic carbide upon solidification in the form of an undesirable continuous phase which cannot be broken up into discrete particles by working, and therefore imparts extreme brittleness to the alloy.

In copending application Serial No. 461,143, the aforementioned difficulty is overcome by employing titanium and carbon together in the combined form comprising substantially titanium carbide using a binder of steel which, as a matrix surrounding the carbide particles, cooperates with the titanium carbide in producing the desired results. The steel binder contains iron as the major alloying element which generally comprises at least about 60% by weight of the binder. In effect, the novel alloy product is essentially a high titanium, high carbon ferrous alloy having the heat treatability of commercial high alloy tool steels, such as high speed steels, and at the same time having some of the desirable attributes of cemented carbide, e.g. cemented tungsten carbide. However, the novel tool steel has the advantage over cemented carbides in that its matrix can be softened by heat treatment to form pearlite, spheroidite and martensitic decomposition products or hardened to a structure comprising martensite or bainite. Thus, in the soft condition the tool steel can be cut and shaped easily by conventional means without requiring the special and expensive techniques used in the cemented carbide field.

In the aforementioned copending application, a method is described for producing said novel alloy by interstitially casting molten steel into the interstices of a coherent porous structure made up of titanium carbide grains. This is achieved by coalescing titanium carbide grains into a porous skeleton body by briquetting followed by firing at an elevated temperature, generally from about 1000° C. to 1600° C. for about ¼ hour to 6 hours

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under substantially non-oxidizing conditions, preferably at a vacuum or sub-atmospheric pressure not exceeding about 200 microns of mercury column. The fired porous skeleton is prepared for casting by encasing it in a mold of substantially inert refractory material, for example high purity thoria, with a portion of the skeleton left exposed to receive the steel infiltrant. The mold of refractory material and the porous carbide structure supported therein is then placed into a suitable casting furnace. Sufficient amount of steel to produce the casting is placed at the mold opening and the whole brought to a temperature of generally up to about 100° C. above the melting point of the steel so that the molten steel flows interstitially into the porous body, completely filling it and providing excess feed for shrinkage cavities, pipes, etc. The casting is achieved in vacuum or at a sub-atmospheric pressure generally not exceeding about 200 microns of mercury. After the steel has interstitially filled all of the voids in the porous titanium carbide structure, and then allowed to reach equilibrium with it, the carbide is modified by partial solution in the liquid phase, whereby it is disrupted into discrete and uniformly distributed grains. The interstitially cast ferrous alloy body is cooled in vacuum, is removed from the furnace and is finally separated from the refractory mold. The product is then annealed, e.g. by heating in a furnace at a temperature of at least about 700° C. and up to about 1050° C. for up to about 4 hours under non-oxidizing conditions, for example a reducing atmosphere comprising about 93% nitrogen and about 7% hydrogen, followed by controlled cooling of less than about 15° C. per hour down to a temperature of about 540° C. or lower.

While the foregoing method has enabled the production of an alloy product exhibiting new and improved properties, it was found that the composition of the titanium carbide powder which is used in forming the product had a big effect on the microstructure, particularly with respect to its carbon content. This was especially true in the production of relatively large sections by the infiltration of large porous bodies of titanium carbide. It was believed that the infiltration of the carbide skeleton containing carbon in the form of free carbon resulted in a concentration of excess carbon at the end which infiltrated last whereby this end would be so enriched in dissolved carbon as to form cementite needles on cooling which bridged the matrix areas between the carbide particles resulting in a brittle material having non-uniform microstructure.

In an endeavor to minimize the foregoing effect, an attempt was made to remove free carbon by reacting it with substantially stoichiometric amounts of iron oxide under conditions conducive to the formation of carbon monoxide at sub-atmospheric pressure, the carbon-containing gas being thereafter removed, the reduced iron remaining being subsequently absorbed by the steel infiltrant. While, to a certain extent, an improvement in microstructure was obtained, the foregoing step did not eliminate the difficulty entirely.

Additional work later indicated that free carbon per se was not the only factor to be considered.

An improved method has now been discovered whereby the foregoing difficulty can be avoided, thereby enabling the production of titanium tool steel of uniform microstructure substantially free from primary cementite.

The method is based on the discovery that carbon in addition to the free carbon must be compensated for in order to obtain the desired results. This additional carbon results from the decomposition of titanium carbide (combined carbon) during processing at an elevated temperature. In other words, as titanium carbide is heated to an elevated temperature, for example above 800° C., it

tends to decompose to a lower and more stable combined carbon content. For the purposes of this invention, it has been found that this value of the combined carbon content is in the neighborhood of about 17% (e.g. 16.5% to about 17%). Thus, for a commercial grade titanium carbide having a total carbon content of about 19.5%, a combined carbon content of about 18%, and a free carbon content of about 1.5% (this being the difference between total and combined carbon), the amount of carbon to be compensated for based on a reference point for combined carbon of about 17% is 2.5%, which is determined as the difference between total carbon and 17%. Putting it another way, it is the summation of the free carbon and the additional carbon resulting from the decomposition of TiC. This carbon, whether determined by either of the foregoing methods, is referred to herein as the "reactable" carbon content, and it is this carbon that must be considered in determining the relative proportions of the ingredients used in carrying out the invention. The reactable carbon content may range from about 0.3% to 5%, generally from about 0.5% to 3.5%.

The method comprises mixing with free carbon-containing titanium carbide powder an amount of iron oxide, such as  $\text{Fe}_3\text{O}_4$ , sufficient to react with and remove as a gaseous product substantially all of the reactable carbon by heat treatment. The mixture is formed into a porous compact of desired porosity, heated at an elevated temperature under subatmospheric pressure under substantially non-oxidizing conditions, the temperature being sufficient (for example at an elevated temperature up to about 1250° C.) to effect reaction between the reactable carbon and the combined oxygen of the iron oxide. As the gaseous products are evolved, they are continuously evacuated until the pressure falls to a low value, for example to less than 300 microns of mercury column. After the reaction has, for all practical purposes, ceased the temperature is raised to strengthen the skeleton (for example above 1250° C.) which is thereafter infiltrated with a steel infiltrant under conditions conducive to forming a substantially pore free product. The microstructure of the steel matrix formed by this method is substantially uniform and is substantially free from primary cementite.

$\text{Fe}_3\text{O}_4$  is preferred as the source of oxygen. The amount of  $\text{Fe}_3\text{O}_4$  employed in removing excess carbon from titanium carbide is proportioned substantially stoichiometrically in accordance with the reactable carbon content, the reaction for calculating the amounts of oxide used being based on one in which the gaseous product formed is substantially carbon monoxide. Thus, for a titanium carbide powder comprising 17.97% total carbon, 0.34% free carbon, and 17.63% combined carbon, the reactable carbon content, based on a combined carbon content reference point of about 17%, would be about 0.97%. Thus, 100 parts of TiC powder containing 0.97 parts of reactable carbon would require stoichiometrically about 4.7%  $\text{Fe}_3\text{O}_4$ .

One of the advantages of using iron oxide, aside from its use as an oxidizer and remover of carbon, is that it prevents abnormal shrinkage of the skeleton during sintering. This is important as it enables the production of skeletons of substantially controlled dimensions and porosity. As illustrative of the method employed in carrying out the invention, the following examples are given:

#### Example I

In producing a titanium tool steel in accordance with the invention, a titanium carbide powder of less than 44 microns with a total carbon content of about 18.8%, a free carbon content of about 2.18%, and a combined carbon content of about 16.62% was employed as the starting material. Since the combined carbon content fell within the reference point range of about 16.5 to 17% the reactable carbon content was the same as the free carbon content of 2.18%.

In accordance with the invention, 10 parts by weight of  $\text{Fe}_3\text{O}_4$  was proportioned to 90 parts by weight of the titanium carbide in substantially stoichiometric relation to the reactable carbon content (in this case free carbon).

In preparing a charge, 1350 grams of the TiC powder was mixed and blended with 150 grams of  $\text{Fe}_3\text{O}_4$  by hand for about 15 minutes and the total mixture of 1500 grams then placed in a one gallon stainless steel mill containing 165 steel balls ranging in size from about 0.5 to 1 inch in diameter, the mixture being milled for about 16 hours at 65 revolutions per minute. Upon completion of the milling, the mixture was passed through a 140 mesh screen (U.S. Standard) in preparation for pressing.

About 180 grams of the mixed powder was then cold pressed in a die to a porous body 5 inches long by 1.45 inches wide by one-half inch high at a pressure of about 0.5 ton per square inch.

The cold pressed body was then placed in a vacuum induction furnace and heat treated for about 2½ hours. The body was first brought up to a degassing temperature of about 770° C. under a sub-atmospheric pressure of about 550 microns and then raised to 1065 at the same pressure and held there until degassing diminishes. The temperature was then raised to 1200° C., during which additional degassing occurred as was evidenced by the rise in pressure to 700 microns. Upon substantial completion of degassing, the porous body was raised to a sintering temperature of about 1300° C. and held there for about 40 minutes during which the vacuum improved from 125 microns down to 11 microns. The porous body was then cooled to room temperature and its density found to be about 70.3% by volume.

The sintered porous body of titanium carbide was then prepared for infiltration by packing it in thoria powder, leaving one end of the body exposed to receive an infiltrant comprising SAE 1095 steel, the amount of steel being proportioned 70% in excess of the volume required to fill up the pores. The steel was placed on top of the packed body, the assembly placed in a vacuum induction furnace and brought up to about 1490° C. and held there for about one hour until infiltration was completed, the vacuum ranging from about 30 down to 12 microns. The total time of the run was one hour and 57 minutes.

The resulting body was substantially pore free, had a uniform microstructure and was substantially free from primary cementite.

#### Example II

A test similar to Example I was conducted in which titanium carbide was treated with varying amounts of  $\text{Fe}_3\text{O}_4$  ranging from substantially below the stoichiometric requirements to slightly above that theoretically required. The titanium carbide powder employed as the starting material had a particle size of about minus 5 microns and contained about 19.52% total carbon, about 1.17% free carbon and about 18.35% combined carbon, giving a reactable carbon content of about 2.52% based on a reference point of about 17% carbon (i.e. 19.52% minus 17%). A series of 100 parts of the titanium carbide powder was reacted with 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14 parts, respectively, of  $\text{Fe}_3\text{O}_4$ . Each charge was mixed mechanically by hand and passed three times through an 80 mesh screen. A given weight of such mixture about 15 grams, was then cold pressed into a porous body in a die having a cavity about 0.94 inch in diameter at one ton per square inch to a height of about fifteen-thirty secondths of an inch. Each porous body was then reacted and degassed in a vacuum induction furnace by heating to a degassing temperature followed by heating to a sintering temperature. In the case of the mixture comprising 100 parts titanium carbide and 13 parts  $\text{Fe}_3\text{O}_4$ , the degassing was effective at 1090° C. at 30 micron vacuum followed by sintering for 30 minutes at 1360° C., the vacuum at the sintering temperature ranging from 24 down to 9 microns of mercury column,

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the total time of the run amounting to about 1 hour and 24 minutes. The sintered density was about 72.2% by volume.

The infiltration of each test body was conducted in a vacuum induction furnace, using thoria powder as an investment pack, a portion of the body being left exposed to receive infiltrant metal. In infiltrating the skeleton produced from 100 parts TiC and 13 parts of  $\text{Fe}_3\text{O}_4$ , the infiltrant comprised SAE 1095 steel, an excess of 20% of volume required to fill up the pores being used. The total time of run was 2 hours and 38 minutes, the infiltration being conducted at  $1500^\circ\text{C}$ . for one hour. The vacuum during infiltration was maintained from 16 down to 12 microns of mercury column. The microstructure was uniform and showed hardly a trace of primary cementite.

The samples which were prepared with lower amounts of  $\text{Fe}_3\text{O}_4$  were not adequate. Thus, at 5 parts  $\text{Fe}_3\text{O}_4$  large amounts of primary cementite were obtained bridging the steel matrix between grains of titanium carbide. The same was also true of samples treated with 6 parts  $\text{Fe}_3\text{O}_4$  which amount was previously thought sufficient to take care of the 1.17% free carbon, assuming no decomposition of TiC to occur. Primary cementite was also obtained at 7, 8, 9 and 10 parts of  $\text{Fe}_3\text{O}_4$ . At 11 parts of  $\text{Fe}_3\text{O}_4$ , the microstructure resulting after infiltration was much improved, although some primary cementite was still evident. The microstructure obtained after treatment with 12 parts of  $\text{Fe}_3\text{O}_4$  was substantially good, best results being obtained at 13 and 14 parts  $\text{Fe}_3\text{O}_4$ .

In other words, when  $\text{Fe}_3\text{O}_4$  was proportioned substantially stoichiometrically to the reactable carbon content (the free carbon plus carbon releasable by decomposition of TiC), the difficulties with regard to microstructure were greatly diminished.

The expression "substantially stoichiometrically," or similar expression, is meant to include small variations from the theoretical stoichiometric amounts. For example, for the foregoing TiC powder having a reactable carbon content of about 2.52%, 100 parts of the powder required a stoichiometric amount of about 12.2 parts of  $\text{Fe}_3\text{O}_4$ . Actually, from about 12 to 14 parts  $\text{Fe}_3\text{O}_4$  could be employed to obtain substantially the desired results.

In order to produce a product having a low titanium carbide concentration for superior machining properties, iron powder can be used together with iron oxide. The iron powder acts as a spacer for TiC particles and enables the production of an article in which the titanium carbide is widely separated by the steel matrix. The iron powder is preferably blended in amounts ranging up to about 60%, preferably 1% to 30%, to the TiC and iron oxide (e.g.  $\text{Fe}_3\text{O}_4$ ) mixture prior to pressing. Best results are obtained if relatively coarse TiC powder is used, e.g. particle sizes ranging from about 5 to 44 microns. The iron oxide used is first adjusted to the titanium carbide powder as described hereinbefore and the desired amount of iron powder thereafter blended in.

As illustrative of the foregoing, the following example is given:

#### Example III

A titanium carbide powder made up of 10% minus 8 microns size and 90% of 8 to 40 microns size and having a total carbon content of 20.43%, a free carbon content of 2.29%, and 18.14% combined carbon was employed as the starting material. To 100 parts of the powder, about 17 parts of  $\text{Fe}_3\text{O}_4$  was added in substantially stoichiometrical relation to the reactable carbon content of 3.43% (20.43% minus 17%). To the mixture was added sufficient carbonyl iron powder to produce a final mixture containing 20% by weight of carbonyl iron. After mixing and blending the whole by hand for fifteen minutes and further mixing in the same

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stainless ball mill of Example I for 30 minutes, the mixture was then passed through a 45 mesh screen.

A weight of powder, about 780 grams, was then cold pressed in a die to produce a porous body 7.5 inches long by 1.36 inches wide and 1.4 inches high at two tons per square inch. The porous body was then subjected to heating as in Example I, degassing being carried out at  $770^\circ\text{C}$ . at 80 microns pressure and then at  $1200^\circ\text{C}$ . at 60 microns pressure. The temperature was then raised to  $1320^\circ\text{C}$ . and the body sintered for one hour at temperature from 75 to 20 microns of pressure, the total time of the sintering run being 7 hours and 35 minutes. After cooling, the sintered density was found to be about 52.5% by volume.

The sintered porous body was similarly infiltrated with SAE 1095 steel (plus 35% excess of the volume required to fill up the pores), the infiltration being conducted at  $1530^\circ\text{C}$ . for 1 1/4 hours, the pressure being maintained at about 75 to 70 microns of mercury column. The total time of run was 6 hours and 40 minutes.

The resulting infiltrated body had a uniform structure, was substantially free from primary cementite and the carbide grains isolated to a larger degree from each other.

Summarizing the invention, in utilizing titanium carbide containing combined carbon in excess of about 17%, the carbide is mixed with iron oxide, preferably  $\text{Fe}_3\text{O}_4$ , the amount of oxide being substantially stoichiometrically proportioned to the reactable carbon content. The mixture is subjected to heating at an elevated temperature at a sub-atmospheric pressure, preferably not exceeding about 300 microns of mercury column pressure, the reaction for calculating the amount of iron oxide being based on the formation of carbon monoxide. After substantially all of the reactable carbon has been removed as carbon monoxide, the carbide may be cooled to room temperature, or, if previously compacted to a porous skeleton, further heated at a higher temperature at sub-atmospheric pressure preferably not exceeding 150 microns of mercury column, in order to strengthen the skeleton for handling in subsequent infiltration steps.

The temperature of the degassing step is generally up to about  $1250^\circ\text{C}$ ., the sintering step for forming a strong skeleton being carried out at temperatures above  $1250^\circ\text{C}$ .

Tests have indicated that for consistent results, a double degassing step is preferred. The first degassing step is preferably carried out at about  $650^\circ\text{C}$ . to  $850^\circ\text{C}$ . and the second from about  $1050^\circ\text{C}$ . to  $1250^\circ\text{C}$ . The sintering step in forming the skeleton preferably ranges from about  $1250^\circ\text{C}$ . to  $1450^\circ\text{C}$ . The infiltration step is carried out above the melting point of the infiltrant and generally up to  $100^\circ\text{C}$ . above the melting point.

While the production of titanium tool steel has been described with respect to the use of iron oxide per se as the carbon-reacting agent, it will be appreciated that where the steel infiltrant contains other alloying ingredients, such as nickel and/or cobalt, the iron oxide may have mixed with it oxides of such alloying elements in amounts proportioned to the steel composition without substantially affecting the original steel analysis. As has been stated hereinbefore, the method of the invention is applicable to the production of titanium steels containing about 10% to 70% titanium, preferably about 20% to 58%. The ferrous alloy product produced by the invention containing the aforementioned amounts of titanium over the broad range of 10% to 70% by weight corresponds to titanium carbide of about 20% to 90% by volume, with the balance substantially steel in amounts ranging from about 80% to 10% by volume. The preferred range of 20% to 58% by weight of titanium corresponds to about 40% to 80% by volume of titanium carbide, with the balance substantially about 60% to 20% by volume of the steel. By employing titanium carbide as the alloying ingredient in place of metallic

titanium, massive carbide dendrites and continuous segregates are avoided and a useful product is obtained.

Examples of steels which may be employed in combination with titanium carbide in producing the ferrous alloy of the invention include low, medium and high carbon steels. Such steels include SAE 1010 steel, SAE 1020 steel, SAE 1030 steel, SAE 1040 steel, preferably SAE 1080 or 1095 steel, etc. Low, medium and high alloy steels may also be employed.

The titanium carbide employed in the alloy may contain limited amounts of other carbides, preferably in solid solution therewith, without departing from the scope of the invention. Thus, the titanium carbide may be replaced in part by up to about 35% of tungsten carbide, up to about 35% vanadium carbide, up to about 25% zirconium carbide, up to about 10% columbium carbide, up to about 10% tantalum carbide, etc., the total amount of these carbides not exceeding about 50% by weight of the total carbides present. In other words, the carbide employed in the ferrous alloy may comprise titanium-base carbides which include titanium carbide per se.

As has been stated hereinbefore, the ferrous alloy of the invention is amenable to heat treatment. Thus, to soften the alloy, it is cooled slowly through the  $A_1$  temperature so as to produce a microstructure in the ferrous matrix consisting of pearlite. By  $A_1$  temperature is meant that temperature at which all the austenite is transformed to ferrite. In hardening, the alloy is heated to an austenitization temperature sufficient to convert substantially the matrix to austenite and for a time sufficient to effect a uniform structure and then subsequently quenched by cooling in air, oil or water, depending upon the hardenability characteristics of the ferrous alloy, thus transforming austenite to martensite. The austenite may also be transformed into bainite by isothermally quenching the alloy in accordance with the TTT characteristics of the steel matrix.

The invention enables the production of high titanium, high carbon ferrous alloy which in the form of bar stock, rounds, squares, blocks, ingots and other shapes can be utilized in the fabrication of cutting tools, blanking dies, forming dies, drawing dies, rolls, hot extrusion dies, forging dies, upsetting dies, broaching tools, and in general all types of wear resisting elements, tools or machine parts.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended claims.

I claim:

1. A method for producing by infiltration a heat treatable titanium tool steel of substantially uniform composition from titanium carbide powder having a reactable carbon content determined as the sum of the free carbon contained in said titanium carbide and the carbon resulting from the decomposition of said titanium carbide during subsequent heating which comprises, mixing with said titanium carbide powder an amount of iron oxide powder substantially stoichiometrically proportioned to the said reactable carbon content, the stoichiometric reaction being based on the formation of carbon monoxide, forming a porous compact of said powder mixture, subjecting said porous compact to heating at an elevated temperature up to about 1250° C. at sub-atmospheric pressure to effect reaction between the said reactable carbon and the iron oxide, maintaining said porous compact under said sub-atmospheric pressure until substantially all the gaseous products have been removed, raising the temperature to above 1250° C. to strengthen

the skeleton and then subjecting said treated skeleton to infiltration with a steel infiltrant at sub-atmospheric pressure, whereby a titanium tool steel is obtained characterized by a microstructure of titanium carbide grains distributed through a heat treatable steel matrix, said matrix being substantially free from primary cementite.

2. A method for producing by infiltration a heat treatable titanium tool steel of substantially uniform composition from titanium carbide powder having a reactable carbon content of about 0.3% to 5%, determined as the sum of the free carbon contained in said titanium carbide and the carbon resulting from the decomposition of said titanium carbide during subsequent heating which comprises, mixing with said titanium carbide powder an amount of  $Fe_3O_4$  powder substantially stoichiometrically proportioned to the reactable carbon content, the stoichiometric reaction being based on the formation of carbon monoxide, forming a porous compact of said mixture, subjecting said porous compact to heating at an elevated temperature of up to about 1250° C. at sub-atmospheric pressure to effect reaction between the said reactable carbon and  $Fe_3O_4$ , maintaining said porous compact under said sub-atmospheric pressure until substantially all the gaseous products have been removed, raising the temperature to above 1250° C. to strengthen the skeleton and then subjecting said treated skeleton to infiltration with a steel infiltrant at sub-atmospheric pressure, whereby a titanium tool steel is obtained characterized by a microstructure of titanium carbide grains distributed through a heat treatable steel matrix, said matrix being substantially free from primary cementite.

3. A method for producing by infiltration a heat treatable titanium tool steel of substantially uniform composition from titanium carbide powder having a reactable carbon content of about 0.3% to 5% determined as the sum of the free carbon contained in said titanium carbide and the carbon resulting from the decomposition of said titanium carbide during subsequent heating which comprises, mixing with said titanium carbide an amount of iron oxide powder substantially stoichiometrically proportioned to the reactable carbon content, the stoichiometric reaction being based on the formation of carbon monoxide, forming a porous compact of said mixture, subjecting said porous compact to a first heating at about 650° C. to 850° C. at sub-atmospheric pressure until degassing has diminished, then subjecting said compact to further heating from about 1050° C. to 1250° C. and maintaining said porous compact under sub-atmospheric pressure until substantially all the gaseous products have been removed, raising the temperature to about 1250° C. to 1450° C. to strengthen the skeleton, and then subjecting said treated skeleton to infiltration with a steel infiltrant at sub-atmospheric pressure, whereby a titanium tool steel is obtained characterized by a microstructure of titanium carbide grains distributed through a heat treatable steel matrix, said matrix being substantially free from primary cementite.

4. The method of claim 3, wherein the iron oxide employed is  $Fe_3O_4$ .

5. The method of claim 1 wherein to the combined amounts of iron oxide and titanium carbide powders is added up to about 60% by weight of iron powder.

6. The method of claim 5, wherein the amount of iron powder ranges from about 1% to 30%.

7. The method of claim 6, wherein the iron powder added is carbonyl iron.

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