

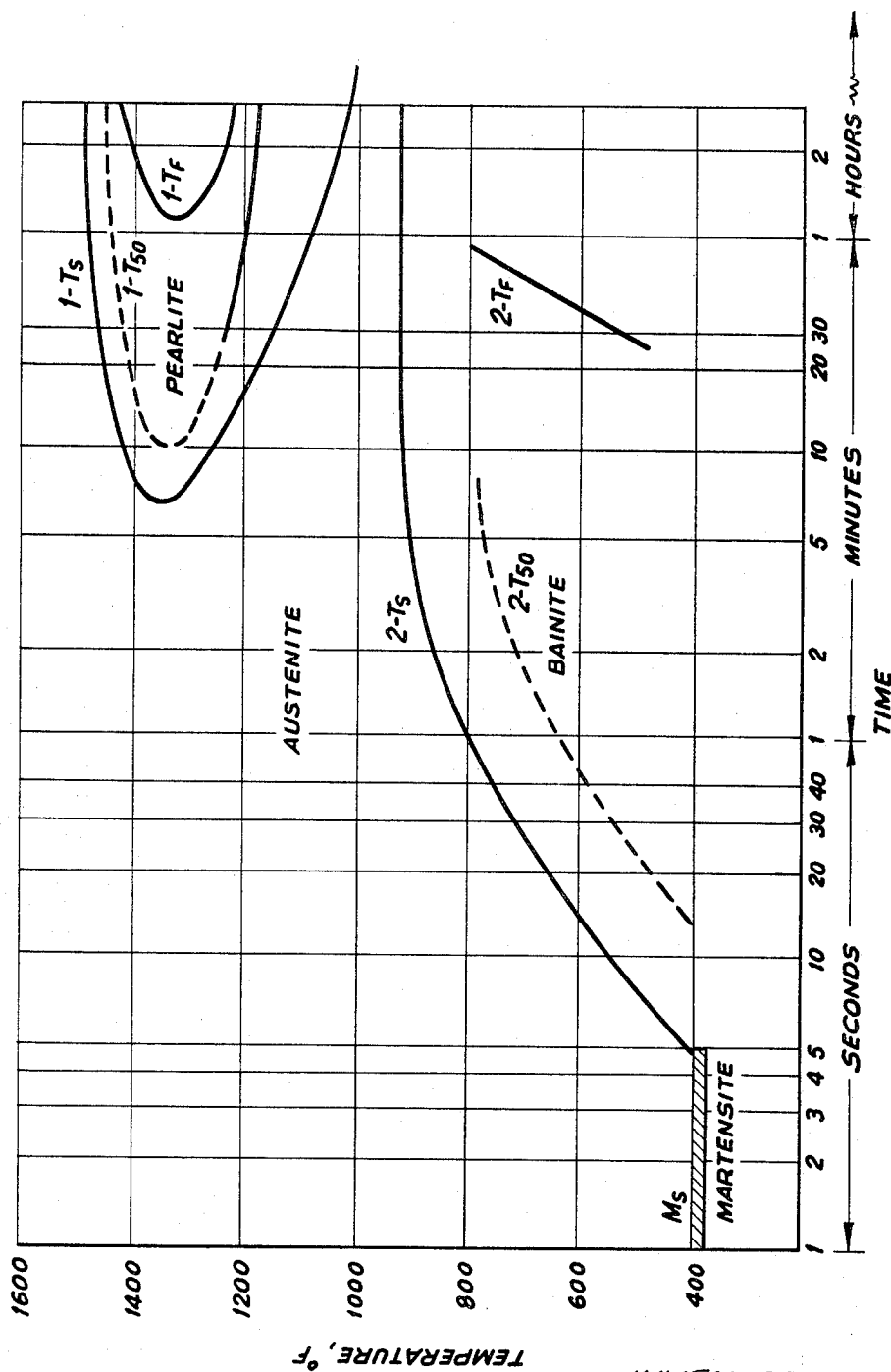
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METHOD FOR HEAT TREATING TITANIUM CARBIDE TOOL STEEL

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METHOD FOR HEAT TREATING TITANIUM CARBIDE TOOL STEEL

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ABSTRACT OF THE DISCLOSURE

A method is provided for inhibiting cracking and/or distortion in the heat treatment of a refractory carbide tool steel comprising 30 to 60% by volume of primary carbide grains based on titanium carbide dispersed through a steel matrix making up the balance, the matrix comprising by weight about 0.3% to 0.8% C, 1% to 6% Cr, 0.3% to 6% Mo, and the remainder substantially iron. The tool steel is heated to an austenitizing temperature exceeding 1600° F. for a time sufficient to insure transformation to austenite throughout, followed by quenching the austenitized refractory carbide tool steel to an austenite bay soaking temperature ranging from about 925° F., to 1050° F. and holding it at the soaking temperature until the tool steel has reached uniform temperature throughout. The soaked steel is then rapidly cooled to room temperature.

This invention relates to a method of fully hardening by heat treatment a titanium carbide based tool steel containing substantial amounts of primary titanium carbide grains distributed through a matrix of chromium-molybdenum steel while inhibiting said tool steel from distorting and/or cracking. By "primary carbide" is meant the carbide which is added in making up the composition and which is substantially unaffected by normal heat treating practices.

In U.S. Patent No. 2,828,202, dated Mar. 25, 1958, and issued to the same assignee, a tool steel of high carbon content based on titanium carbide is disclosed in which the amount of titanium employed is at least 10% substantially all combined in the form of a primary carbide. The titanium carbide is uniformly distributed through a heat treatable ferrous matrix comprising either carbon steel, medium alloy steel or high alloy steel.

As pointed out in the aforementioned patent, the composition is formed by employing titanium and carbon together in a combined form as titanium carbide as an alloying ingredient together with a steel matrix which reacts with the carbide to a certain extent in producing the desired composition. The steel employed in forming the matrix contains at least about 60% iron by weight of the steel matrix composition.

Powder metallurgy is employed as the preferred method of producing the desired composition which comprises broadly mixing powdered titanium carbide with powdered steel-forming ingredients and forming a compact by pressing the mixture in a mold, followed by preferably subjecting the compact to liquid phase sintering under nonoxidizing conditions such as in a vacuum.

In producing a titanium carbide tool steel composition containing, for example, about 33% by weight of TiC (approximately 45 volume percent) and substantially the balance a steel matrix, such as chromium-molybdenum steel composition, about 500 grams of TiC (of about 5

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to 7 microns in size) are mixed with 1000 grams of steel-forming ingredients in a mill half filled with stainless steel balls. To the powder ingredients is added one gram of paraffin wax for each 100 grams of mix. The milling is conducted for about 40 hours using hexane as a vehicle.

After completion of the milling, the mix is removed and dried and compacts of a desired shape pressed at about 15 t.s.i. and the compacts then subjected to liquid phase sintering in vacuum at a temperature of about 2640° F. (1450° C.) for about one-half hour at a vacuum corresponding to 20 microns of mercury or better. After completion of the sintering, the compacts are cooled and then annealed by heating to 900° C. for 2 hours followed by cooling at a rate of about 60° F. (15° C.) per hour to about 212° F. (100° C.) and thereafter furnace cooled to room temperature to produce an annealed microstructure containing spheroidite. The annealed hardness is in the neighborhood of about 45 R_C and the high carbon tool steel is capable of being machined and/or ground into any desired tool shape or machine part prior to hardening.

The hardening treatment heretofore employed comprised heating the machined piece to an austenitizing temperature of about 1750° F. for about one quarter hour followed by quenching in oil or water to produce a hardness in the neighborhood of about 70 R_C.

It was noted with regard to certain titanium carbide tool steel compositions produced by the foregoing method and heat treatment that, depending upon the size and configuration of a particular article, it was not always possible to achieve full hardness throughout the cross section of certain shapes and also achieve the desired dimensional tolerance. For example, where a particular composition was known to give a relatively high hardness recovery and good dimensional tolerance after heat treatment for a particular size or shape, different results would be obtained for other sizes and shapes. It was also noted that because of the presence of substantial amounts of hard primary titanium carbide grain dispersed through the matrix of the tool steel (for example 50% by volume of TiC), the product tended to be sensitive to cracking so that it would not always be sure that certain articles of complicated shape would be free from cracking and/or distortion.

It was additionally noted that as to some sizes the martensite at the surface of a particular element tended to be tempered or that greater amounts of austenite were retained, whereby the desired hardness was not always realized.

It has now been found that the foregoing problems can be obviated by using a novel heat treatment that not only assures obtaining full and optimum hardness, but which also inhibits substantially the tendency towards cracking and distortion.

It is thus the object of this invention to provide a method of fully hardening a sintered titanium carbide tool steel product comprising primary titanium carbide grains dispersed through a chromium-molybdenum steel matrix.

Another object is to provide a method of inhibiting cracking and/or distortion in a titanium carbide tool steel composition.

These and other objects will more clearly appear when taken in conjunction with the following disclosure and the appended drawing which is an isothermal transformation diagram of a sintered titanium carbide tool steel

composition comprising primary titanium carbide grains dispersed through a chromium-molybdenum steel matrix.

It has been discovered in working with a titanium carbide tool steel product containing about 33% by weight of TiC and substantially the balance about 67% by weight of a steel matrix and wherein the final steel matrix contains approximately 3% Cr, about 3% Mo, about 0.5% C, some dissolved titanium (for example up to 4% dissolved titanium by weight), and the balance substantially iron, that in oil quenching such a tool steel product from an austenitizing temperature above 1600° F. (870° C.), for example, about 1750° F. (955° C.), a change in thermal conductivity occurs at the surface of the product as martensite forms which affects the rate at which heat is conducted from the interior of the product to the bath. It is noted, for example, that the foregoing composition in the annealed condition has a thermal conductivity of about 0.083 calories/cm.²/cm./°C./sec. as compared to about 0.062 when the titanium carbide tool steel is transformed to martensite, a decrease of about 25%. Similarly, there is a difference in thermal conductivity between martensite and austenite. Thus, as an element of the foregoing composition is quenched from 1750° F. (955° C.) in oil as heretofore practiced, an outer skin of martensite immediately forms which affects the rate at which heat is extracted from the interior of the element to pass through the martensite boundary and thence to the oil bath. Because heat is retained longer in the piece being quenched, particularly in larger sizes, the martensite which has formed initially may then be tempered by the flow of heat through it from the interior. In large pieces, the amount of tempering and the consequent decrease in hardness are usually undesirable. In addition, because heat is retained longer within the piece, full hardness is similarly not achieved in the interior of the piece, as other transformation products of austenite will form, such as bainite or perhaps pearlite.

Where the shape has thin portions and/or is complicated, cracking and/or distortion are apt to occur. However, this and the foregoing problem can be obviated by subjecting the titanium carbide tool steel of the aforementioned type to a controlled heat treatment in accordance with the invention, wherein the tool steel is heated to an austenitizing temperature above about 1600° F. (870° C.), for example about 1750° F. (955° C.), held there, for example, for about one hour per inch of cross section followed by quenching in a salt bath to about 950° F. (510° C.) and held there for example, for about one hour per inch of cross section, after which the tool steel is quenched in warm oil. It is possible by this thermal homogenization treatment to obtain a uniform temperature of 950° F. throughout any diameter section while still retaining the matrix in the fully austenitic state (a condition necessary for subsequent full hardening). Where large and complicated sections are involved, they can be held at 950° F. (510° C.) after quenching from 1750° F. (955° C.) for a prolonged period of time of upwards of 16 hours to insure dissipation of the bulk of the heat.

The feasibility of this treatment is related to the isothermal transformation characteristics of the titanium carbide tool steel matrix as will be apparent from the isothermal transformation diagram attached which expresses the extent of austenite transformation as a function of temperature and time. Referring to the figure, it will be noted that a large bay of austenite stability extends to the right of the diagram and converges below about 1200° F. (about 650° C.) to a temperature range of about 925° F. (500° C.) to about 1050° F. (565° C.). In the upper right hand corner of the graph, a pearlite transformation loop is shown starting with solid line 1— T_S (the start of pearlite transformation) and ending with solid line 1— T_F (the end of pearlite transformation). It will be noted that solid line 1— T_S moves downwardly to the right and approaches somewhat asymptotically

the temperature of about 1000° F. (538° C.). Thus, for austenite soaking times exceeding about 2 hours, it is desirable that the temperature of soaking not exceed 975° F. (522° C.), to insure that no transformation to pearlite occurs.

In the lower portion of the graph, a martensite and bainite transformation area is shown, the latter starting with solid line 2— T_S (the start of transformation) and ending with solid line 2— T_F (the end of transformation). It will be noted that line 2— T_S rises upwardly with time and approaches somewhat asymptotically the temperature of about 925° F. (500° C.). Thus, for austenite soaking times exceeding about 2 hours, the soaking temperature should not fall below about 925° F. (500° C.).

Generally speaking, the austenite bay soaking or "aus-quenching" temperature below 1200° F. may range from about 925° F. to 1050° F., and more advantageously range from about 925° F. to 975° F. It has been found that a temperature of 950° F. $\pm$ 25° F. is commercially effective in carrying out the aims and objectives of the invention. By austenite bay soaking or "aus-quenching" temperature is meant that temperature at which austenite still exists.

The sintered titanium carbide tool steel composition to which the invention is applicable may comprise about 30 to 60% by volume of a primary carbide based on titanium carbide and substantially the balance a steel matrix comprising a chromium-molybdenum steel composition, said matrix containing by weight about 0.3% to 0.8% C, about 1% to 6% Cr, about 0.3% to 6% Mo, some dissolved titanium, and the balance substantially iron. More advantageously the matrix may comprise about 0.3% to 0.8% C, about 2% to 5% Cr, about 1% to 5% Mo and the balance substantially iron.

It will be appreciated that the titanium carbide may have included with it limited amounts of other carbides, such as up to about 50% tungsten carbide, up to about 50% molybdenum carbide, up to about 10% chromium carbide, up to about 25% zirconium carbide, up to about 25% titanium carbide and the like. The total amounts of other carbides will generally range up to 50% by weight of the primary carbides present. The term "a carbide based on titanium carbide" employed herein and in the claims is meant to include the presence of said other carbides in the amounts stated hereinabove as well as to cover titanium carbide per se.

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.

What is claimed is:

1. A method of producing a refractory carbide tool steel part comprising 30 to 60% by volume of primary carbide grains based on titanium carbide dispersed through a steel matrix making up the balance, said matrix comprising by weight about 0.3% to 0.8% C, 2% to 5% Cr, 1% to 5% Mo and the remainder substantially iron, which comprises producing a powder metallurgically sintered part of said composition, annealing said part, machining said part to a desired dimension, heating said part to an austenitizing temperature exceeding 1600° F. for a time sufficient to insure transformation to austenite throughout, quenching said austenitized part to an austenite bay soaking temperature ranging from about 925° F. to 1050° F., and holding said part at said soaking temperature until the part has reached uniform temperature throughout, and then rapidly cooling said part to room temperature.

2. The method of claim 1 wherein the austenite bay soaking temperature ranges from about 925° F. to 975° F.

3. The method of claim 1 wherein said matrix com-

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prises by weight about 0.5% C, about 3% Cr, about 3% Mo, and the remainder substantially iron.
4. The method of claim 3 wherein the soaking temperature ranges from about 925° F. to 975° F.

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