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HARD METAL TOOL ALLOY

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11 Claims. (Cl. 75—136)

This invention refers to a hard metal tool alloy and method of producing the same.

This invention forms a continuation in part of my copending application Ser. #727,781, filed May 26, 1934, and of my copending application Ser. #743,717, filed September 12, 1934, and issued into Patent #2,122,157, which were in turn copending with my application Ser. #656,103, filed February 10, 1933, and issued into Patent #1,959,879, and my application Ser. #625,042, filed July 27, 1932, and issued into Patent No. 2,091,017, which were in turn copending with my application Ser. #452,132, filed May 13, 1930 and I of course do not claim herein anything which is subject matter of the claims in my above mentioned earlier patents.

It is an object of the invention to increase the hardness of such hard metal tool alloys without impairing their toughness.

It is another object of the invention to increase the resistance of such hard metal tool alloys against mechanical wear and chemical effects such as of the oxygen of the surrounding air, or moisture, or a cooling liquid such as water.

It is another object of the invention to adjust the heat conductivity of the hard metal tool alloy without impairing its hardness or resistance against oxidation.

It is still another object of the invention to increase the speed at which hard alloys of this kind can be used for cutting, drilling, milling, and other machining purposes.

This and other objects of the invention will be more clearly understood when the specification proceeds.

Hard metal tool alloys of the type referred to have been made of tungsten carbide and auxiliary metal taken substantially from the iron group, in amounts from about 3 to 20%. The tungsten carbide has been finely powdered and mixed with the auxiliary metal, and the mixture heated to sintering temperature. Such hard metal tool alloys could be utilized for machining cast iron but do not prove efficient in high speed machining steel and other compositions of metal.

In contradistinction hereto the invention proceeds from fundamentally new considerations. It no longer uses one carbide alone, viz. tungsten carbide, and cements it by auxiliary metal in the heat.

The present invention particularly refers to a tool alloy comprising a consolidated product containing the usual cementing auxiliary metal amounting to about 3 to 22% of one or more metals of the group containing nickel, cobalt and iron and two carbides for instance of tungsten, (i. e. an element of the sixth group of the periodical system), boron (i. e. an element of the third group of the periodical system), titanium, (i. e. an element of the fourth group of the periodical system), and vanadium (i. e. an element of the fifth group of the periodical system) which are substantially or entirely compounded by heating to a sufficient extent into crystalline solid solutions or homogeneous carbide crystal structures each of which contains atoms of two different selected elements capable to form such structures besides, of course, atoms of carbon required to form carbide with those selected elements.

Experiments have shown and science has given the rule that the hardness of solid solutions of elements is a function of their proportion, and that this function possesses a maximum. It is particularly advantageous to choose for use in the present invention carbides which form the above defined homogeneous carbide crystal structures, and to choose the range of their composition so that structures exhibiting the maximum hardness will be produced which increase correspondingly the overall or average hardness of the composition containing those structures.

Let me take the rules given by the science based on the investigations of Kurnakow and Zemczuzny in the "Zeitschrift für anorganische Chemie" 1908, volume 60, page 1, and 1910, volume 68, page 123, referred to in the standard book of Reinglass "Chemische Technologie der Legierungen", second edition, pages 52, 53, and in the "Metall- und Legierungskunde" of Dr. M. v. Schwarz, Professor of the College at Munich, second edition (1929), page 49, in which the investigaitons of Kurnakow are referred to and it is verbatim stated: "In an uninterrupted series of solid solutions the curve of hardness increases with the concentration gradually up to a flat maximum, which lies mostly at the simple atomic composition." If Schwarz says "atomic composition," it is to be considered that he mentions metals and not chemical compounds such as carbides. If such compounds are to be taken, then instead of "atoms" which exist only for the pure metals, "molecules" are to be taken which in compounds are equivalent to the atoms of the pure metal.

Furthermore, the science says, that the maximum does not always lie at simple atomic proportions. If one element materially exceeds another element in hardness, then the maximum

hardness is "shifted" in favour of the harder element in the solid solution and consequently two (or three) atoms of the harder (or exceedingly harder) element form together with one atom of the softer element the solid solutions of greatest hardness. By analogy, according to the invention the carbides are to be present approximately in a ratio to give the relatively greatest hardness, the higher ratio applying to the relatively harder carbide, if one of the composed carbides is essentially harder than the other. Lastly, if building up a curve of hardness of solid solutions depending on the content of the respective carbides, then the maximum of the curve is flat and does not form a peak so that solid solutions of about the greatest hardness are practically obtained over a range of composition of about 5% to 10%.

Let me take an alloy having 10% auxiliary metal and therefore 90% carbide. Let me further take that tungsten-carbide and titanium-carbide are to be compounded to form the hardest composition. Then we have to divide these 90% in the proportion of 60:196, which means that we have to take about 20% (by weight) titanium-carbide, about 70% tungsten-carbide and about 10% auxiliary metal.

Let me take the carbide of vanadium, of the fifth group of the periodical system, and the carbide of tungsten, of the sixth group of the periodical system. Then the correct molecular proportion will be about 1:2, because tungsten-carbide exceeds in hardness. Consequently the alloy will contain upon heat treatment of the constituents a homogeneous carbide crystal structure composed of about 76% tungsten-carbide and about 14% vanadium-carbide, corresponding to the molecular weight of 196 of tungsten-carbide (WC) and 63 of vanadian carbide (VC), if 10% auxiliary metal is present.

Let me take molybdenum-carbide and titanium-carbide. Titanium-carbide is exceedingly hard, at least considerably harder than molybdenum-carbide, and is furthermore very light. Consequently the optimum of hardness is to be expected at a proportion of about 1:3. At 1:3 we have about 49.5 (that means less than 50%) molybdenum-carbide and 40.5% titanium-carbide, if 10% auxiliary metal is present.

Let me take vanadium-carbide (carbide of the fifth group) and titanium-carbide (carbide of the fourth group). Considering that titanium-carbide exceeds in hardness vanadium-carbide, the molecular proportion is to be chosen at about 1:2 and consequently the hard metal will contain about 60% titanium-carbide and about 30% vanadium-carbide in order to remain within the range of greatest hardness, if 10% auxiliary metal is present.

Let me take, as last example, boron-carbide (of the third group) and titanium-carbide (of the fourth group). Boron-carbide is known as one of the hardest carbides. The boron-carbide is investigated as B_6C with a molecular weight of 78. Taking that the hardness of both carbides is about the same, the homogeneous carbide crystal structure has to be made of about equal proportions of the molecules, which means in the proportion of about 78:60. Consequently such an alloy will contain about 50% boron-carbide and about 40% titanium carbide, if 10% auxiliary metal is present.

Hard metals of the above compositions particularly exhibit high resistance against oxidation at elevated temperatures, great hardness and relatively small specific weight.

In the examples given, 10% auxiliary metal is chosen only for the sake of uniformity. But the amount of auxiliary metal essentially of the iron group may vary between about 3% and 22%. The amount may be smaller if heavy mixtures of carbides are concerned and larger if lighter mixtures of carbides (e. g. with titanium-carbide) are concerned.

As a consequence of the considerations presented, the following compositions exhibit the approximately hardest homogeneous carbide crystal structures or solid solutions: 10 to 20% vanadium-carbide, 85 to 65% tungsten-carbide, 5 to 20% auxiliary metal; 50 to 70% titanium-carbide, 40 to 20% vanadium-carbide, 5 to 20% auxiliary metal; 3 to 50% titanium-carbide, 60 to 40% boron-carbide, 5 to 20% auxiliary metal; 15 to 25% titanium-carbide, 75 to 55% tungsten-carbide, 5 to 20% auxiliary metal.

Such solid solutions are cemented by auxiliary metals such as nickel, cobalt and iron singly or in suitable mixtures. Thereby the fine grain imparted to the powdered carbide is substantially maintained and a desirable toughness of the alloy or tool obtained.

For special purposes, e. g. for finest cuts or polishing mixtures of titanium-carbide and molybdenum-carbide in about equal proportions forming substantially homogeneous carbide crystal structures or solid solutions and nickel up to 9% and 15% and chromium up to 1 and 2% as auxiliary metals has been proved advantageous.

But I have established good results also by forming substantially solid solutions of about 30 to 15% molybdenum-carbide (Mo_2C), of the sixth group, and about 65 to 70% titanium-carbide (TiC) of the fourth group, adding hereto as auxiliary metals 8 to 15% nickel and 0 to 2% chromium. Within this range the optimum e. g. for high speed work appeared to be at about 8 to 10% nickel and up to 1 to 2% chromium.

Generally, according to this part of my invention compositions are usable which comprise substantial amounts of solid solutions or homogeneous carbide crystal structures formed by heat treatment to sufficient extent of one hard and refractory carbide of one element of the sixth group of the periodical system, and one hard and refractory carbide of one element of the fourth group of the periodical system, cemented by one or more auxiliary metals essentially, i. e. completely or almost completely of the iron group.

Any suitable known method may be used for the production of the solid solutions. The carbides can be suitably comminuted, mixed and heated up to about 1600° to 2000° C. for about 1 to 2 hours until homogeneous carbide crystal structures or solid solutions are formed in substantial amount. Then the selected auxiliary metal or metals are to be added in the desired quantity, the whole is to be intimately mixed and then to be sintered at a temperature of about 1400° to 1600° C. If the carbide crystals are too coarse, then they are suitably pulverized and mixed with the auxiliary metal and then sintered. Before or while sintering, the molding of the powder so obtained takes place, preferably under pressure of several atmospheres per square centimeter, up to e. g. 50 and 75 atmospheres and higher. It is also possible to mix oxides of the selected elements, in finely divided form with additions of suitably pulverized carbon and to heat the mixture to a sufficient extent in an electric furnace,

whereby solid solutions of the carbides concerned in substantial amounts are obtained.

But my invention is not limited to any special process of producing carbides, compounding them substantially or entirely into homogeneous carbide crystal structures or solid solutions and furthermore not to any method of consolidating such mixture to or in any shape adapted for the use intended, say as a tool element.

In particular the tool or hard metal composition according to my invention may be produced by mixing the carbides and auxiliary metal which are to be contained in the tool alloy, in as finely divided a form as possible, shaping and pressing the mixture, if desired, and thereupon sintering it until at least substantial amounts of homogeneous carbide crystal structures are obtained each of which contains atoms of two different selected elements capable of forming such structures in addition to atoms of carbon required to form carbide with those elements. Moreover, the elements or even their oxides, selected to form the desired carbide compounds may be admixed, on one hand, with carbon in sufficient amount so as to carbidize the elements or oxides, and, on the other hand, with the selected auxiliary metal, and the mixture preferably powdered as finely as possible, heated to sintering temperature for a sufficient period of time so that a tough and hard composition results containing the desired compounds, including at least substantial amounts of solid solutions or homogeneous carbide crystal structures as defined above, cemented by the auxiliary metal. Sintering may be performed e. g. by electrical induction heating, if desired, in vacuo.

An electric furnace can be employed for effecting the heating and sintering; the sintering may also be carried out by means of high frequency currents. In some cases particularly good results are obtained by carrying out the heating or sintering in a vacuum.

Electrical heating current may also be led through the body itself or around the body through the mould.

The temperature of the body is to be elevated to about 1400 to 1600° C. and this heat-treatment to be continued for about one or several hours, or a major part of one hour, till the desired structure of the body is obtained.

In case, however, difficult shapes of the body are to be produced not obtainable by usual moulds, or in case sharp edges are desired, or angles difficult to manufacture in such a way, so that the mechanical working or finishing of the hard metal body is needed after sintering, then the following ways are preferable.

The pressed and preformed body is to be submitted to sintering temperatures as mentioned before, but such sintering has to be done only in a short period of time, say 1 to 5 to 10 minutes so that the particles are sufficiently fritted together to withstand mechanical treatment without presenting, however, the hardness of a fully sintered body. Such a body is then subjected to finishing in any way and then the sintering at the same temperature is continued until the fully sintered body is achieved.

Another way consists in having admixed to the powders ready for preforming, glycerin, glycol or other alcohols, shaped this mixture and, if desired, pressed and treated at elevated temperature of about 100 to 200° C. but preferably below 180° C., then worked and finished this body of sufficient cohesion whereupon the sintering is possible without any further interruption.

Generally, the body according to my invention is consolidated by using auxiliary metals of the kind and in the amount as mentioned before and treating it at elevated temperature, e. g. in the range up to about 1400 to 1600° C. until the body of desired structure and quality is obtained.

When I refer in the appended claims to carbide of elements selected from the third, fourth, fifth and sixth group of the periodical system, I mean carbides adapted for use in hard tool elements, having a suitable hardness and not being dissolved by water or other liquid employed for cooling or similar purposes at operation temperatures. Such carbides are boron-carbide (belonging to the third group), titanium-carbide, (belonging to the fourth group), vanadium-carbide, columbium-cabide, tantalum-carbide (belonging to the fifth group), and tungsten-carbide, molybdenum-carbide (belonging to the sixth group).

When I refer in the appended claims to formation of solid solutions or homogeneous carbide crystal structures, as defined hereinbefore, in a substantial amount of heat treatment, I mean a minimum amount of about 10% as disclosed in my co-pending application No. 743,717, filed September 12, 1934, and issued into Patent 2,122,157.

It is quite difficult to mention any minimum amounts of carbide to be present. Nevertheless, the minimum amount of carbide to be present and forming part of a solid solution or homogeneous carbide crystal structure, as defined hereinbefore, according to the invention, has to be substantial, and as a minimum about 1% by weight of the alloy.

Tool alloys prepared according to the invention are, as a rule, not used for the production of the entire tool, but merely for the part of the tool which in practice is used directly for cutting, drilling, etc. and which is subject to wear.

From the above description it appears that the carbides to be cemented by auxiliary metal may either be compounded into solid solutions or homogeneous carbide crystal structures, as defined hereinbefore, entirely or in substantial amount before a substantial amount of auxiliary metal is added, or the preferably extremely finely powdered carbides may be first mixed with the auxiliary metal and sintered in such manner that the homogeneous carbide crystal structures are formed at least in substantial amount, in the presence of auxiliary metal during sufficiently extended sintering. It has been found that solid solutions or homogeneous carbide crystal structures, as defined hereinbefore, resist recrystallization to a large extent. Thereby finest grain of carbides present in the alloy including homogeneous carbide crystal structures or solid solutions are retained, and a tough and very efficient, clean cutting material is obtained.

What I claim is:

1. A tough cemented hard metal sintered by heat treatment and consisting substantially of auxiliary metal selected essentially from the iron group in amounts from about 3% to 22% and two carbides of elements selected from the third, fourth, fifth and sixth group of the periodical system, said carbides containing together substantially more than 2.6% carbon and being present in finely divided state, said carbides heat treated to form solid solutions in substantial amount.

2. A cemented hard metal composition sintered by heat treatment into a hard and tough body for tool elements and other working appliances, consisting substantially of auxiliary

metal selected essentially from the iron group in amounts from about 3% to 22% and two carbides of elements selected from boron, titanium, vanadium, columbium, tantalum, tungsten, said carbides containing together substantially more than 2.6% carbon and being present in finely divided state, said carbides heat treated to form solid solutions in substantial amount.

3. A tough cemented hard metal composition sintered by heat treatment, for tool elements and other working appliances, consisting substantially of auxiliary metal essentially of the iron group, in amounts of about 3% to 22% and finely divided hard carbide crystal structures formed by heat treatment from carbon and two different elements other than carbon belonging to different groups of the periodical system and selected from the third to sixth group thereof, substantial amounts of said structures homogeneously containing atoms of said two selected elements in addition to carbon atoms.

4. A tough cemented hard metal composition sintered by heat treatment, for tool elements and other working appliances, consisting substantially of auxiliary metal essentially of the iron group in amounts of about 3% to 22% and finely divided hard carbide crystal structures formed by heat treatment from carbon and two elements selected from the group consisting of boron, titanium, vanadium, columbium, tantalum, tungsten, substantial amounts of said structures homogeneously containing atoms of said two selected elements in addition to carbon atoms so as to increase the average hardness of the composition.

5. A cemented hard metal composition sintered by heat treatment into a hard and tough body for tool elements and other working appliances, consisting substantially of two hard carbides of elements of the fifth group of the periodical system, these carbides being selected and admixed in proportions adapted to yield and heat treated to form approximately hardest solid solutions in substantial amounts, and auxiliary metal taken essentially from the iron group in amounts from about 3% to 22%.

6. A cemented hard metal composition sintered by heat treatment into a hard and tough body for tool elements and other working appliances, consisting substantially of a hard carbide of an element of the third group and of a hard carbide of an element of the sixth group of the periodical system, these carbides being present in substantial amounts in proportions adapted to form approximately hardest homogeneous carbide crystal structures containing atoms of said two elements in addition to carbon atoms and auxiliary metal essentially of the iron group in amounts from about 3% to 22%, said carbide crystal structures formed by heat treatment in substantial amount.

7. A tough cemented hard metal composition sintered by heat treatment, for tool elements and other working appliances, consisting substantially of two hard carbides of different elements belonging to different groups of the periodical system and selected from the third, fourth, fifth, and sixth group thereof, and auxiliary metal essentially of the iron group in amounts of about 3% to 22%, the minimum amount of a selected carbide to be 1%, said carbides being present in finely divided state and heat treated to form in substantial amount homogeneous carbide crystal structures containing atoms of said selected two elements in addition to carbon atoms.

8. A tough cemented hard metal composition sintered by heat treatment, for tool elements and other working appliances, consisting substantially of auxiliary metal essentially of the iron group in amounts from about 3% to about 22%, and two hard carbides of elements selected from the group consisting of titanium, tantalum, columbium, and tungsten, the minimum amount of a selected carbide to be 1%, said carbides present in finely divided state and heat treated to form in substantial amount homogeneous carbide crystal structures containing atoms of said selected two elements in addition to carbon atoms.

9. A tough cemented hard metal composition sintered by heat treatment, for tool elements and other working appliances, consisting substantially of auxiliary metal essentially of the iron group in amounts of about 3% to 22% and finely divided hard carbide crystal structures formed by heat treatment from carbon, titanium and tungsten, substantial amounts of said structures homogeneously containing atoms of titanium and tungsten in addition to carbon atoms.

10. A tough cemented hard metal composition sintered by heat treatment, for tool elements and other working appliances, consisting substantially of two hard carbides of different elements belonging to different groups of the periodical system and selected from the third, fourth, fifth and sixth group thereof, and auxiliary metal essentially of the iron group in amounts of about 3% to 22%, the minimum amount of a selected carbide to be 1%, said carbides being present in finely divided state and heat treated to form in substantial amount homogeneous carbide crystal structures containing atoms of said selected two elements in addition to carbon atoms and to increase the average hardness of the composition.

11. A tough cemented hard metal composition sintered by heat treatment, for tool elements and other working appliances, consisting substantially of two hard carbides of different elements belonging to different groups of the periodical system and selected from the third, fourth, fifth and sixth group thereof, and auxiliary metal essentially of the iron group in amounts of about 3% to 22%, the minimum amount of a selected carbide to be 1%, said carbides being present in as finely divided a state as possible and heat treated to form in substantial amount homogeneous carbide crystal structures containing atoms of said selected two elements in addition to carbon atoms and to increase the average hardness of the composition.

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