

[54] **HIGH SPEED TOOL ALLOYS AND PROCESS**

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**Related U.S. Application Data**

- [63] Continuation-in-part of Ser. No. 518,181, Jan. 3, 1966, abandoned, which is a continuation-in-part of Ser. No. 435,733, Feb. 26, 1965.  
[52] U.S. Cl. .... **75/123 J, 75/123 K, 75/126, 75/170, 75/203, 75/226, 148/11.5 F, 148/126**  
[51] Int. Cl. .... **C22c 39/08, C22c 39/50, C21d 7/14**  
[58] Field of Search ..... **75/0.5 BB, 0.5 BC, 123, 203, 75/226, 170, 126; 148/126, 11.5 F, 11.5 R, 12.1**

[56] **References Cited**

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3,244,506 4/1966 Reen. .... **75/0.5 BC**

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[57] **ABSTRACT**

Compositions suitable for tool use and containing from about 10 to about 40% of a material selected from the group consisting of tungsten and molybdenum and mixtures thereof; from about 0.5 to about 4% carbon; at least one reactive metal selected from the group consisting of chromium, vanadium, niobium, tantalum, silicon and manganese; the balance a mixture of iron and cobalt. The alloy is formed by the hot consolidation of pre-alloyed powders and results in an alloy having a uniformly dispersed carbide phase of a grain size less than 3 microns.

**13 Claims, 5 Drawing Figures**



FIG. 1

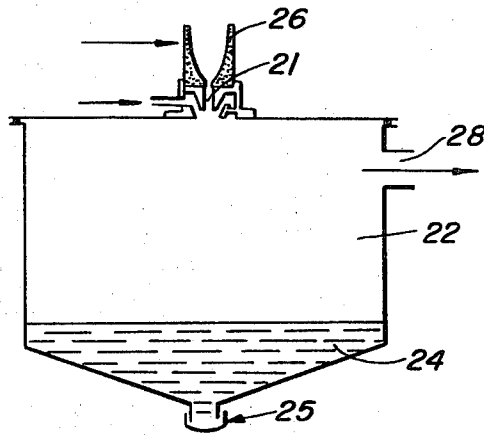
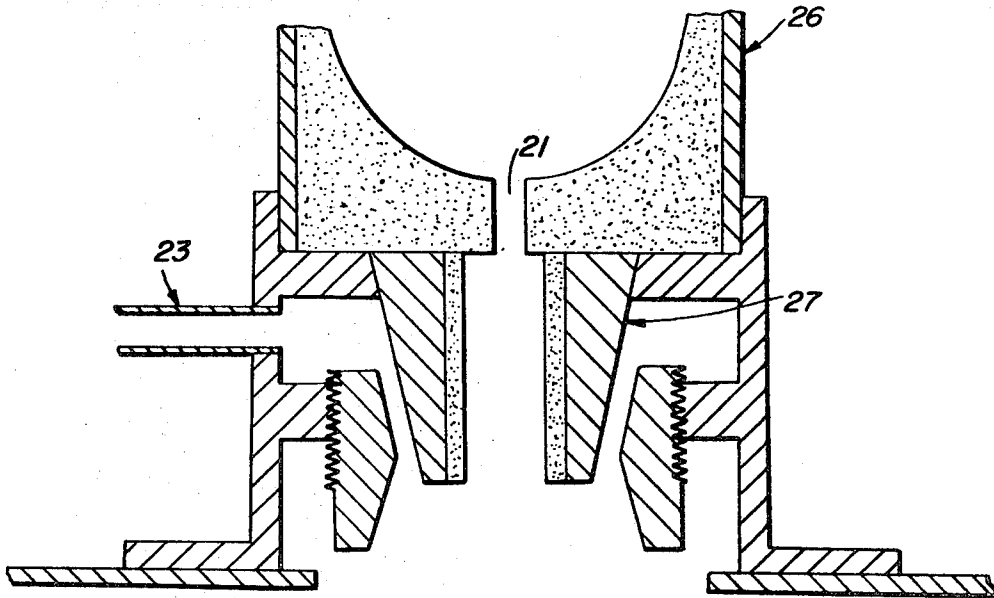


FIG. 2

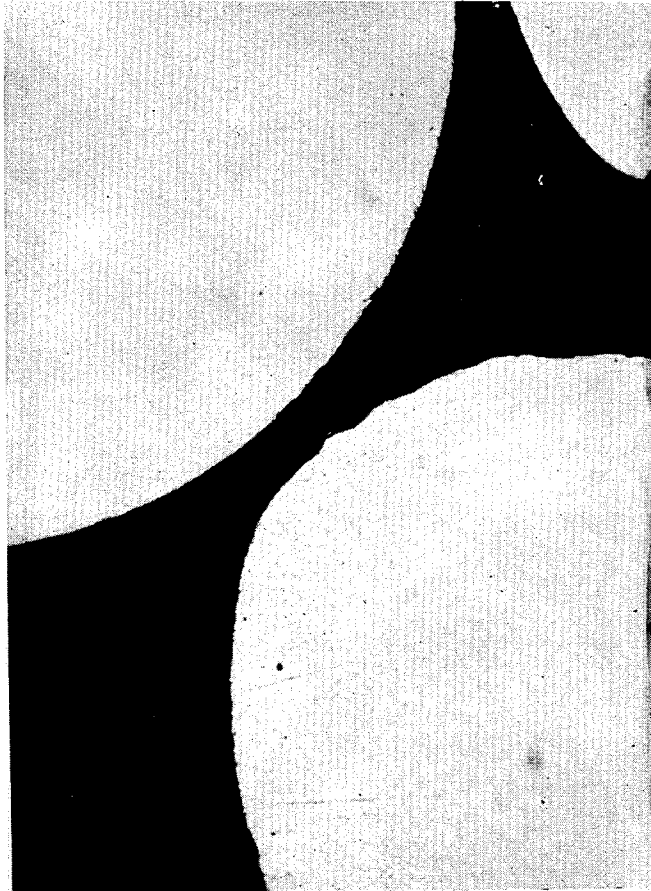


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**FIG. 3**

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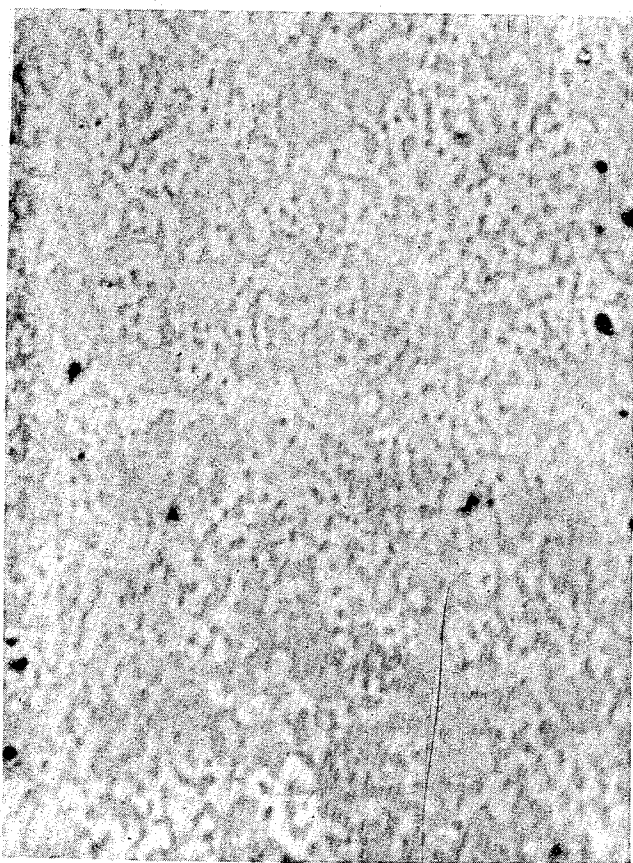
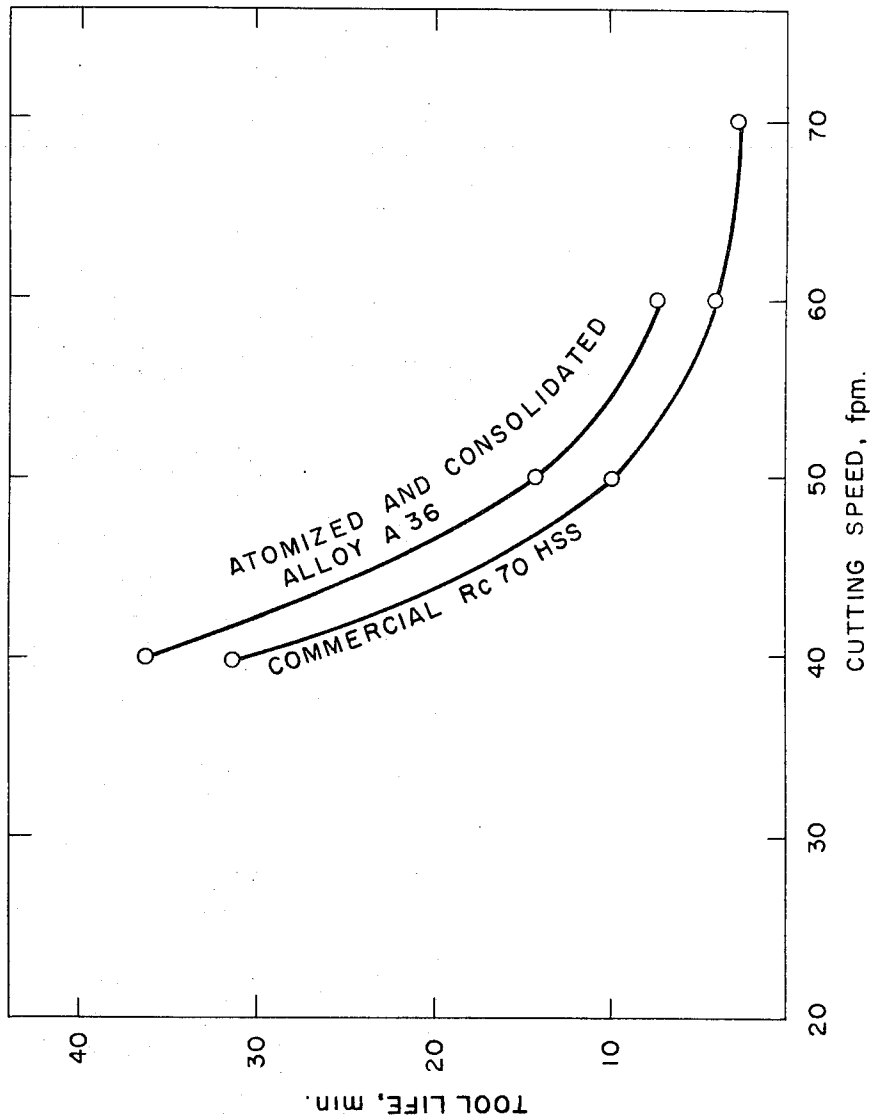


FIG. 4

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FIG. 5



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## HIGH SPEED TOOL ALLOYS AND PROCESS

This patent application is a continuation-in-part of application Ser. No. 518,181 filed Jan. 3, 1966, and now abandoned which application in turn is a continuation-in-part of application Ser. No. 435,733 filed Feb. 26, 1965, both previous applications having the same inventor and being assigned to the assignee of the present invention.

The present invention relates to iron-cobalt base alloys and to the process of their fabrication into cutting tools. More specifically, the present invention is directed to iron-cobalt base alloys formed from pre-alloyed powders which include minor additions of reactive metals, defined hereinafter, which provide improved cutting performance in high speed, steady state cutting operations.

Co-pending application Ser. Nos. 743,921, now abandoned, and 743,922, filed July 11, 1968, and assigned to the assignee of the present invention, disclose alloy tool steels which are free of reactive metals such as chromium, vanadium, niobium, tantalum, silicon, manganese, titanium and aluminum. As discussed in these previous applications, the presence of these reactive metals tends to impair some of the qualities of the disclosed alloys for cutting purposes as they readily react with oxygen in the ambient air to form oxide films on the pre-alloyed powders. The presence of this oxide film may result in impaired fabricability and reduced strength of the alloy when consolidated from a powder for tool use. Consequently, the presence of reactive metals results in higher cost due to special atomizing methods for the powder production or of special oxide reduction treatments of the finished alloy.

It has subsequently been learned that, while the so-called oxide free or reactive metal free tool steel alloys exhibit very good tool life properties when tools formed therefrom are utilized in discontinuous, e.g., milling, cutting operations or low speed operations such as must be employed in the cutting or boring of difficult to machine alloys, tools formed from oxide free alloys exhibit less satisfactory tool life when employed in high speed, continuous cutting of relatively soft steels, e.g., lathe turning or boring. It is believed that the lesser tool life that has been found to occur when tools formed from oxide free alloys are used in continuous cutting of soft steel is caused in part by a welding of the workpiece to the cutting point of the tool which causes tearing away of the tool material. The net result is a tool life not much better than conventional tool steels when employed in the continuous cutting of relatively soft steel. It is believed that the tendency of the workpiece material and the tip of the oxide free tool to weld together is primarily due to the inability to apply lubricants in sufficient quantities at the tip of the tool in high speed continuous cutting operations because of the speed of the operation and the inaccessibility of the tool tip. The present invention avoids this shortcoming of the oxide free alloys by the inclusion of small amounts of reactive metals to provide a lubricating factor to the alloys of the present invention.

It is an object of the present invention to provide an alloy suitable for fabrication into a tool having increased life in high speed steady state cutting of metals.

It is a further object of the present invention to provide an alloy suitable for fabrication into a tool having increased life in high speed steady state cutting of metals and characterized by the carbide phase of the alloy being substantially uniformly dispersed in a fine grained major phase with substantially all of the carbide phase having a grain size below 3 microns.

These and other objects and advantages of the present invention will become apparent in connection with the following detailed description together with the accompanying drawings in which:

FIG. 1 schematically illustrates an atomizing chamber for use in the manufacture of the alloys of the present invention;

FIG. 2 is an enlarged view which schematically illustrates atomizing apparatus of FIG. 1;

FIG. 3 is a photomicrograph at a magnification of 2,000 of atomized particles of one embodiment of the invention;

FIG. 4 is a photomicrograph at 2,000 magnification showing a consolidated and annealed alloy of the present invention; and

FIG. 5 is a graph comparing the cutting test data of one embodiment of the invention with a commercially available high speed cutting steel.

Briefly, the present invention relates to iron-cobalt alloys containing tungsten and/or molybdenum, carbon and a reactive metal. As indicated the disclosed alloys are particularly suited for fabrication into tools for use in high speed cutting operations on relatively soft materials, particularly high speed continuous cutting, for example lathe turning and boring, in which the cutting edge of the tool is continually in contact with the workpiece. Continuous cutting operations require less maximum strength of the tool alloy than milling operations due to a lack of impact loading on the tool.

Alloys suitable for the aforementioned use, as described in detail hereinafter, have a composition, by weight, of from about 10 to about 40% of a material selected from the group consisting of tungsten, molybdenum and mixtures thereof, from about 0.5 to about 4% carbon, a minor addition of one or more reactive metals selected from the group consisting of chromium, vanadium, niobium, tantalum, silicon, manganese and mixtures thereof and the balance a mixture of iron and cobalt wherein cobalt constitutes from about 25 to about 50% and iron constitutes from about 20 to about 48% of the total composition. The amount of each of these reactive metal additions which can be added to the alloy composition while retaining a suitable tool material varies with the specific reactive metal employed.

The preferred ranges of reactive metal additions for the present invention are as follows, each range being given in percent by weight of the total composition: chromium from 0 to about 25%; vanadium from 0 to about 10%; niobium from 0 to about 5%; tantalum from 0 to about 10%; silicon from 0 to about 5%; and manganese from 0 to about 5%. It has been found that when these ranges are exceeded by any substantial amount excess oxide is formed and maintaining suitable strength for tool steel is not feasible.

The ranges specified above are for additions of a single reactive metal to the basic composition. It is also contemplated that mixtures of reactive metals be employed in the same composition.

When more than one reactive metal is employed the specified ranges are no longer valid. An addition of a second reactive metal results in a lowering of the limits for both reactive metals employed. In the case of mixing niobium with silicon or manganese, each of which has an upper limit of about 5%, the substitution would be linear. That is, any mixture would be suitable so long as the total reactive metals constitute no more than 5% of the total composition. The same linear relationship holds for the mixing of vanadium and tantalum, each of which has an upper limit of about 10% of the total composition. However, when mixing reactive metals having different upper limits the relationship changes. Rather than a linear decrease of the metal having the higher limit, the limit is reduced by a percentage equal to the percentage of the limit employed for the lower limit metal. For example, when mixing chromium with vanadium which have respective limits of 25% and 10% when employed alone, a 2% addition of vanadium (constituting 20% of the 10% limit) reduces the allowable limit for chromium to about 20% (a decrease of 20% of the original limit for chromium). Correspondingly, a 4% addition of vanadium (40% of the limit) reduces the allowable limit for chromium to about 15% (a 40% decrease in the chromium limit). Expressed in different terms, if the limit for each reactive metal when used alone is regarded as 100% for that metal, the total of the two or more metals mixed should not exceed 100% treating the portion of each metal as a percentage of its own 100% limit.

The alloys of the present invention are characterized by a carbide phase substantially uniformly dispersed in a fine grained major phase with substantially all of the carbide phase

having a grain size below 3 microns. This structure is achieved by the hot consolidation of pre-alloyed powders by the method described hereinafter. It is this structure which results in the required hardness and strength properties for use of the alloys of the present invention for tool steel purposes.

Referring again to the drawings, FIGS. 1 and 2 schematically illustrate one apparatus suitable for the atomizing of powders. An appropriate alloy charge of the desired composition is first weighed and melted in a suitable crucible. Then the molten alloy is poured through an orifice 21 at the top of an atomizing chamber 22. In such a chamber the molten stream is first broken up into fine droplets and then quickly quenched by a high pressure stream of gas or liquid entering the chamber 22 through a gas inlet port 23 and a manifold 29 which surrounds the orifice 21. At the lower end of the orifice 21 a refractory lined cone 27 is provided extending into the manifold for the atomizing medium. As the molten material exits the lower end of the cone 27 the atomizing medium strikes the molten metal stream to break the stream into fine particles. In addition, this impact quenches the molten particles so that they are solidified even before final cooling in the water reservoir 24 described below.

A water reservoir 24 is positioned at the bottom of the atomizing chamber 22, and the chamber walls and bottom are fabricated of a steel shell which is water cooled. In the illustrated embodiment the chamber is approximately 3 feet in diameter and approximately 4 feet in height; however, other dimensions and geometries may be employed without departing from the scope of the invention. The bottom wall of the chamber is slightly conical and tapers downward to the center at which a capped opening 25 is provided for removal of the quenched metal powder and water.

An inert gas such as argon is supplied through the inlet port 23 at reasonably high pressure, for example, 350 psi. A tundish 26 is also provided above the orifice 21 to hold the molten metal charge before it flows into the atomizing chamber 22. The argon is permitted to exit from the atomizing chamber at an exhaust port 28 provided in the side wall. Atomization in the described apparatus results in powders approximately 75-85% of which are finer than 80 mesh and from 15-30% finer than 325 mesh.

Consolidation of the alloyed powders into fully dense solid stock can be accomplished by a number of different methods. One of these methods involves the canning of the powders in Inconel cylinders lined with molybdenum foil to permit easy stripping of the canning material from the hot worked ingot. Consolidation of the powders is accomplished by hammer forging and hot rolling at temperatures of the order of 2,150° F. An optional step in the process involves the evacuation of the Inconel can prior to sealing it in order to prevent additional oxidation of the powder particles. For the particular compositions disclosed and claimed herein, however, the evacuation of the can does not produce significant improvements in the consolidated product. Additional details of the consolidation process applied to powders generally are set forth in co-pending application Ser. No. 435,733, filed Feb. 26, 1965. After consolidation the alloys are heat treated by standard procedures set forth in more detail hereinafter.

TABLE I

Alloy No.:	Composition percent by weight						Solution-izing temperature, ° F.	Maximum hardness Rockwell C
	Fe	Co	W	Cr	Other	C		
A 36.....	35	27	9	20	6 Mo..	3	1,650-2,100	71
A 148.....	38.7	40	10	10	-----	1.3	1,600-1,800	67.9
A 149.....	38.7	40	-----	10	10 Mo.	1.3	1,550-1,750	66
A 166.....	38.2	40	10	10	-----	1.8	1,650-1,800	71
A 178.....	39.2	40	17	2.5	-----	1.3	2,050	70.2
A 180.....	38.7	40	18	-----	2 V	1.3	2,200	70.7
A 181.....	39.7	40	14	-----	5 V	1.3	2,200	69.0
A 184.....	38.95	40	17.5	1.25	I V	1.3	2,200	70.8

Table I indicates the composition and hardness of several alloys formed in accordance with the present invention and con-

solidated for tool purposes. It should be noted from Table I that the additions of reactive materials are quite small in most cases with the exception of chromium which has been added in amounts up to 20% by weight of the finished product. It has been discovered that small additions of a reactive metal greatly improved the high speed cutting properties of the finished tool alloy over those of an oxide free or reactive metal free alloy. In addition, the disclosed alloys have been compared with available commercial steels for high speed cutting. The results of such tests are set forth in Table II and in FIG. 5, and show that the alloys tested were equal or superior to the commercial steels in all tests.

TABLE II.—CUTTING TESTS

Alloy No.	Workpiece AISI #	Workpiece hardness	Cutting speed, s.f.p.m.	Tool life, min.
A36.....	4340	Rc 42.....	60	28
A36.....	4340	Rc 42.....	80	12
A36.....	4340	Rc 42.....	110	15
A36.....	4340	Rc 50.....	60	8
M43, Rc 68 <sup>1</sup> .....	4340	Rc 50.....	60	4
A36.....	4340	Rc 50.....	50	14
M43, Rc68.....	4340	Rc 50.....	50	10
A36.....	4340	Rc 50.....	40	37
M43, Rc68.....	4340	Rc 50.....	40	31
A166.....	4150	Rc 32.....	80	24
M43, Rc68.....	4150	Rc 32.....	80	5
A180.....	1045	Brinell 185.....	140	55
A181.....	1045	do.....	140	95
M43, Rc68.....	1045	do.....	140	55

<sup>1</sup> Commercial premium grade high speed steel.

Compositions within the scope of the present invention which exhibited particularly good cutting properties on AISI 4340 steel involved the addition of relatively high amounts of chromium, from 15 to 25%, to a basic alloy comprising from about 25 to about 30% cobalt, from about 7 to about 12% tungsten, from about 4 to about 8% molybdenum, from about 2 to about 4% carbon, balance iron with incidental impurities. Of these compositions alloy A 36 consisting of 20% chromium, 27% cobalt, 9% tungsten, 6% molybdenum, 3% carbon and 35% iron with incidental impurities exhibited a tool life twice that of commercial high speed steel in machining AISI 4340 of Rc 50 at a speed of 60 surface feet per minute.

Also the importance of having sufficient carbon is illustrated by comparing alloys A 148 and A 166 which contain 1.3% and 1.8% carbon respectively and are otherwise similar. The result of the added carbon in A 166 is an increase in hardness from 67.9 to 71.0 Rockwell C. This increase was achieved by forming added carbides without sacrificing the fine grained structure. Cutting data for A 166 shows a tool life approximately five times that of M 43 commercial steel when cutting AISI 4150 steel of Rc 32 hardness.

It is also interesting to note in referring to the cutting data and the compositions of alloys A 180 and A 181 that while A 181 is of a lower hardness and in all probability possesses a lower transverse rupture strength than the alloy of A 180 due to an additional 3% of vanadium, the lubricating effect is quite pronounced and the tool life of the higher vanadium content alloy A 181 is almost double that of alloy A 180 which was roughly comparable to the commercially available alloy for

cutting at the speed indicated and on the material indicated. All cutting tests in Table II were conducted on a 40 Hor-

sepower engine lathe with universally adjustable speed. Each tool was ground to standard positive rake with a feed of 0.010 inches per revolution a depth of cut of 0.0625 inches. The tool life was based on a flank wearland of 0.060 inches measured optically, the only exception being the tests conducted on AISI 1045 in which the cutting was based on a flank wearland of 0.040 inches due to the long tool life and a shortage of stock material.

The selection of the particular group of metals termed herein reactive metals is based on what is commonly termed the negative free energy of formation of the particular metals involved. The negative free energy of formation is a commonly used measure of the ease with which metal oxides are formed and the degree of difficulty in reducing the oxide, once formed, to the free metal form. The metals listed have been selected from common alloying elements based on a negative free energy of formation having values ranging from  $-58$  to  $-72$  K cal/gm - atom at  $1,500^\circ$  K. It has been found that the amount of each metal which can be employed varies from one metal to another. The variation is believed to be at least in part related to the negative free energy of formation and the atomic weight of the particular metal. It has also been found that chromium can be employed in amounts up to about 25% while retaining tool properties. The reason for this higher limit for chromium is not known.

Other common alloying agents such as Ti, Al, Zr and Mg having negative free energies of formation ranging from  $-91$  to  $-101$  K cal/gm - atom at  $1,500^\circ$  K are not suitable additions because they tend to form a much greater proportion of oxide even for small additions than do the reactive metals in the preferred range of negative free energy of formation. Additionally, the oxides of Ti, Al, Zr and Mg once formed are proportionately more difficult to reduce than the preferred metals. Thus additions of these metals even in small amounts weaken the alloy sufficiently that tool use is not practical.

The addition of the preferred reactive metals also results in a somewhat reduced transverse rupture strength over that exhibited by the same composition without the addition of the reactive metal. However, for the high speed, steady state, cutting of steels, having a Rockwell C value up to about 50, the addition of small amounts of the reactive metals results in a greatly improved tool life over that exhibited by the oxide free alloys. As mentioned earlier, it is believed that the improved tool life is at least partially the result of a lubricating factor caused by the addition of one or more of the reactive metals. This lubricating property is particularly important in the high speed cutting operations described earlier in which the relative speed between the tool and the workpiece might be as high as 140 surface feet per minute. At such speeds it is very difficult to reach the cutting surface of the tool with conventional liquid lubricants. The additions of reactive metals to tools to be utilized in the high speed, steady state cutting environment has resulted in an elimination of the welding phenomenon of the workpiece to the tool tip exhibited by the oxide free alloys.

While the addition of these materials to the alloy produces an unexpected increase in tool life for a particular type of cutting operation, a consideration of the metallurgy involved indicates that the amount of reactive metal addition must be kept relatively a small part of the total alloy. As stated earlier, each of these reactive metals tends to form an oxide on the metal powder, which oxide is relatively difficult to reduce to the pure metal state after the alloy powder has been formed. During the atomizing process a thin film of oxide forms on each alloy droplet. This oxide is a mixture of the oxides of all of the metallic alloy constituents including the easily reduced oxides of iron, cobalt, tungsten and molybdenum as well as of the reactive metal additions. This does not mean, however, that all of the reactive metal additive forms an oxide. Some of the reactive metal additive partitions, one portion uniting with carbon to form the carbide phase such as vanadium carbide, and the other portion remaining in solution in the alloy matrix.

When the powders are jacketed in the Inconel can and

heated to  $2,000^\circ$  to  $2,100^\circ$  F. for approximately 45 minutes prior to consolidation, the oxides on the surface of the powder react with the carbon in the alloy and much of the oxide is reduced during the consolidation. It has been found that for very small additions such as 2.5% chromium there are no deleterious oxides remaining in the alloy after consolidation. For higher percentages of chromium, in excess of 10%, removal of all oxides formed by the chromium is impractical since the ingot would require soaking for several hours within the specified temperature range or for a shorter time at a much higher temperature range. Thus, for chromium contents in excess of 10% by weight and for additives of the other specified reactive metals even in much smaller amounts, some oxide will remain in the finished alloy after consolidation. During the heating and hot working of the ingot the oxides which are on the outside of the individual powder particles and are not reduced by the carbon in the alloy are dispersed into fine particles of oxide due to the mechanical working of the alloy. In this form the oxide, which would substantially reduce the strength of the alloy if left as a continuous film on the powder particles, results in only a moderate reduction of strength. However, the reduction of strength is not sufficient to impair the steady state metal cutting performance of the alloy at high speeds.

It is not clear whether the beneficial lubricating properties of the reactive metals are achieved only from the metal which has been reduced to the free state or which has formed carbides or whether the oxide form also contributes to the lubricating feature. It is known, however, that as the oxide content increases due to presence of the reactive metals beyond the ranges specified herein, the strength of the alloy rapidly becomes lower and the achievement of the required hardness for tool use also becomes increasingly difficult. The balance in each alloy is between adding sufficient reactive metal to lubricate without weakening the structure too much for tool use.

There are, of course, other advantages due to the addition of the reactive metals to the alloys, some of which are already known. Chromium, for example, is known to impart hardenability and oxidation resistance to the finished alloy, that is, oxidation resistance of the tool point due to contact with the workpiece during cutting. This property is to be distinguished from the tendency to form oxides on the powder during atomizing as set forth herein. Vanadium is added to some of the tool steels of the present invention to form very hard carbides for wear resistance. One particular advantage of the small additions of the reactive metals in the preatomized and consolidated type of alloy is the ability in many of the compositions to adequately harden the material for tool use by employing a solutionizing temperature of the order of  $1,700^\circ$  F. In standard commercial high speed steels temperatures considerably above  $2,000^\circ$  F. are required to obtain hardness values approaching the Rockwell C 70.  $1,700^\circ$  F. is sufficiently low to permit brazing of tool alloys to low cost steels and solutionizing without melting the brazing metal. The ability to utilize the lower hardening temperature also results in less scaling of the tool material and in much finer structure in the finished alloy, both in terms of the ultrafine carbide dispersion and the crystal growth within the alloy matrix itself. In this connection it should be noted that the solutionizing temperature of  $2,200^\circ$  F. employed for some of the alloys in Table I was not necessary to achieve desired properties.

Conventionally processed tool steels and other ferrous alloys are melted and then poured into ingot molds which are of such a size, shape and are characterized by such a thermal conductivity that the metal requires at least several minutes before solidification is complete. During this time interval the carbide phase nucleates and grows to appreciable size. Subsequent hot working of the ingots causes some break-up of the carbides but they remain relatively coarse and tend to be aligned in the direction of hot working. On the other hand the alloys which are made as taught in the present invention are cooled from the molten state in the form of fine spherical



droplets (mostly less than 0.007 inches in diameter) which solidify into particles in a fraction of a second. These particles have a finely dispersed high volume of carbides (FIG. 3) of a diameter predominantly less than 3 microns. The extremely short time interval for solidification does not permit the carbide phase to grow appreciably. The atomized powders are then heated for consolidation and for subsequent heat treatment. It should be noted that this heating is done at a temperature (about 2,150° F.) below that at which there is an undue coarsening or agglomeration of the carbide phase. As can be seen by comparing FIGS. 3 and 4 there is only a slight growth in the size of the carbides during consolidation. Because of the extra fineness of the hard carbide particles, the atomized and consolidated alloys of the present invention may be hot worked at temperatures similar to, or even lower than, those used for conventionally produced tool steels and the alloys do not contain large carbide particles which would act as sites for crack initiation and propagation. Thus, another advantage of the present alloys and the herein described method of making them is that greater carbide volumes may be had without impairing alloy workability. It should be appreciated also that consolidation of the powders into wrought stock was accomplished in the present case without resorting to conventional sintering techniques and without adding carbon in any manner to the powders. The amount of carbon desired in the particular alloy is selected prior to atomization and substantially this exact amount will be uniformly distributed in the final wrought stock. This amount is important to the formation of the carbide phase and to the hardness achieved as can be seen from alloys A 148 and A 166 in Table I. The carbon content if too low will prevent the alloy from reaching required tool hardness.

As briefly mentioned above, the atomized and consolidated alloys of the present invention may be heat treated by methods commonly employed for conventional tool and die steels. After hot working the consolidated alloys may be rendered more readily machinable by heating to temperatures of 1,500° or 1600° F. followed by slow cooling such as furnace cooling. After the appropriate finished shape has been fabricated from the stock, it may then be hardened by standard commercial practices.

The hardening or austenitizing is most readily accomplished by first heating the alloy to a temperature of approximately 1,700° to 2,200° F. depending on the particular composition involved, holding at this temperature for a sufficient length of time to permit adequate solution of carbides into the matrix, then cooling by immersion in oil or by air cooling. Following this quenching the alloys are then tempered by reheating to a temperature near 1,000° F. for several hours. This tempering treatment may be performed two or three times cooling to room temperatures between each heating cycle to impart additional toughness to the alloy.

It should be noted that the heat treatments employed during annealing, austenitizing and tempering are conducted at temperatures which do not permit excessive growth or agglomeration of the carbide phase during the heating periods used for such atomized and consolidated alloys.

While the present invention has been described with respect to particular compositions within the specified range, it will be understood that various modifications and variations may be effected without departing from the spirit or scope of the invention as set forth in the following claims.

We claim:

1. An alloy formed by the consolidation of pre-alloyed powders to a fully dense condition and adapted for high speed cutting operations, said pre-alloyed powder having a composition by weight consisting essentially of from about 10 to about 40% of a material selected from the group consisting of tungsten and molybdenum and mixtures thereof; from about 0.5 to about 4% carbon; at least one reactive metal selected from the

group consisting of from 0 to about 25% chromium, from 0 to about 10% vanadium, from 0 to about 5% niobium, from 0 to about 10% tantalum, from 0 to about 5% silicon and from 0 to about 5% manganese; the balance of the alloy being a mixture of iron and cobalt wherein cobalt constitutes from about 25 to about 50% and iron constitutes about 20 to about 48% of the total composition, said alloy being characterized by a substantially uniformly dispersed carbide phase in a fine-grained major phase matrix, and by substantially all of said carbide phase having a grain size less than 3 microns, said alloy further being characterized by a hardness in excess of 60 Rockwell C.

2. A composition as set forth in claim 1 wherein said reactive metal consists of from about 1 to about 25% chromium.

3. A composition as set forth in claim 1 wherein said reactive metal consists of from about 1 to about 10% vanadium.

4. A composition as set forth in claim 1 wherein said reactive metal consists of from about 1 to about 5% niobium.

5. A composition as set forth in claim 1 wherein said reactive metal consists of from about 1 to about 10% tantalum.

6. A composition as set forth in claim 1 wherein said reactive metal consists of from about 1 to about 5% silicon.

7. A composition as set forth in claim 1 wherein said reactive metal consists of from about 1 to about 5% manganese.

8. An alloy composition as set forth in claim 1 wherein the composition by weight consists essentially of from about 15 to about 25% chromium; from about 7 to about 12% tungsten; from about 4 to about 8% molybdenum; from about 2 to about 4% carbon; the balance being a mixture of cobalt and iron wherein cobalt constitutes from about 25 to about 30% of the total composition.

9. An alloy as set forth in claim 1 wherein the composition consists essentially of about 20% chromium, about 9% tungsten, about 3% carbon, about 6% molybdenum, about 27% cobalt and about 35% iron with incidental impurities.

10. An alloy as set forth in claim 1 wherein the composition consists essentially of about 10% tungsten, about 10% chromium, about 1.8% carbon, about 40% cobalt, balance iron.

11. An alloy as set forth in claim 1 wherein the composition consists essentially of about 14% tungsten, about 5% vanadium, about 1.3% carbon, about 40% cobalt, balance iron.

12. The method of making a solid alloy composition characterized by a substantially uniformly dispersed carbide phase in the major phase matrix, said carbide phase having a grain size predominantly of less than 3 microns which comprises the steps of: atomizing an alloy charge comprising from 25 to 30% cobalt, from 15 to 25% chromium, from 7 to 12% tungsten, from 4 to 8% molybdenum, from 2 to 4% carbon, balance iron with incidental impurities, rapidly quenching said atomized material and consolidating said material into solid metal stock without the formation of deleterious oxides.

13. The method of making a fully dense alloy composition suitable for tool use and having a Rockwell C hardness of at least 60 and a substantially uniformly dispersed carbide phase in the major phase matrix, said carbide phase having a grain size predominantly of less than 3 microns which comprises the steps of atomizing an alloy charge comprising from about 10 to about 40% of a material selected from the group consisting of tungsten and molybdenum and mixtures thereof; from about 0.5 to about 4% carbon; a reactive metal selected from the group consisting of chromium, vanadium, niobium, tantalum, silicon and manganese, said reactive metals being in amounts as follows, chromium from 0 to about 25%, vanadium from 0 to about 10%, niobium from 0 to about 5%, tantalum from 0 to about 10%, silicon from 0 to about 5% and manganese from 0 to about 5%; the balance of the alloy being a mixture of iron and cobalt wherein cobalt constitutes from about 25 to about 50% and iron constitutes about 20 to about 48% of the total composition, rapidly quenching said atomized material to form a pre-alloyed powder, and hot consolidating said pre-alloyed powder into fully dense stock suitable for tool use.

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