ALLOY SYSTEMS AND PROCESS FOR THE MANUFACTURE THEREOF

Frederick C. Holtz, Jr., Evanston, Ill., assignor to IIT Research Institute, Chicago, Ill., a not-for-profit corporation of Illinois


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ABSTRACT OF THE DISCLOSURE

Compositionally and structurally novel composite alloys consisting of a continuous matrix of a relatively tough and relatively ductile, metal, tool alloy or structural alloy, and a principal dispersed discontinuous constituent consisting of a high carbide volume material, are produced by blending from about 10 to 40 volume percent of the powder continuous matrix constituent from about 60 to 90 volume percent of the atomized, pre-alloyed powder which forms the principal high carbide dispersed, discontinuous constituent, and subjecting the blended powders to the step of hot consolidation to produce a fully dense composite alloy system.

This patent application is a continuation-in-part of application Ser. No. 435,733 filed Feb. 26, 1965 by the same inventor.

The present invention relates to a new group of complex alloy systems and to a process of the manufacture thereof and more especially relates to compositionally and structurally novel composite alloys which illustrate properly and processing advantages over known alloy systems.

The present materials may be characterized by what is termed “duplex” features and preferably consist of a continuous matrix of, for example, a tough tool or structural alloy and a principal dispersed, discontinuous constituent which preferably consists of a high or very high volume of tool material. By combining these two general types of materials, I have been readily able to fabricate alloy systems of desirable hardness and a toughness combinations which, for example, have excellent utility as tool materials, although certainly they can be used for other purposes and I am quite certain that the invention in this art will quickly appreciate their utility. It will subsequently be shown that by the practice taught herein, the incorporation of the tough continuous matrix renders the composite material to be more readily fabricated than the harder principal discontinuous constituent, while virtually no loss of hardness occurs and an increase in strength is obtained, compared to the hardness and strength of the principal constituent (as fabricated without the addition of the tough continuous matrix).

Accordingly, a primary object of my invention is to provide a novel duplex alloy system consisting essentially of a continuous matrix of a tough metallic constituent and a relatively harder dispersed, discontinuous constituent and wherein preferably there is a relatively greater volume of dispersed constituent than continuous matrix.

Another object of my invention is to provide a novel method of making and fabricating such alloys systems which involves in the preferred embodiment the steps of atomizing melts of said alloying constituents to form powders, especially atomizing the principal constituent, and subsequently blending and consolidating such powders.

These and other objects, features and advantages of my invention will become apparent to those skilled in this particular art from the following detailed disclosure.

thereof and the accompanying photomicrograph which discloses the microstructure of one of the present alloy systems, said photomicrograph being at a magnification of 500 x.

The dispersed phase of the present alloy system should be a relatively hard material, i.e., harder than the continuous phase which in the final product surrounds this hard phase particles and in the absolute terms relatively hard. I have achieved good results with dispersed phase materials which consist of ferrous base alloys preferably enriched with large carbide volumes and wherein the carbide phase thereof is of a very fine size (predominantly less than 3 microns) and substantially uniformly distributed throughout the ferrous matrix. It should of course be understood that the dispersed particles are not limited to ferrous base materials and the hardening thereof may be provided by means other than carbide formation and/or large carbide volume. The dispersed particles can consist of non-ferrous components and the hardening thereof may be by either carbide volume or by other mechanisms and compositions. Generally speaking, the dispersed particles are characterized by being essentially hard, brittle types of alloys of various base materials selected from the group iron, cobalt, nickel, and cobalt-tungsten carbide composite, tungsten, chromium, aluminum, copper and other alloy systems characterized as aforesaid.

In the preferred embodiment thereof the dispersed particles are produced by a molten metal atomization technique and especially for the iron, cobalt, nickel and cobalt-tungsten carbide systems, hardening thereof primarily is a result of the high volume, fine size, uniformly distributed carbide phase present therein.


The continuous matrix phase of the present alloy systems is preferably selected from the same major metal base as the dispersed particles but such phase is characterized by a lower hardness and higher toughness, strength and a ductility than the dispersed phase. After consolidation, such dispersed phase exists substantially continuously around the dispersed phase particles, does not interact with the particles to form undesirable, for example, embrittlement compounds and furthermore the dispersed particles and the continuous phase must be fabricable at such temperature and for such times whereby any diffusion between the two is not excessive. However, a small degree of diffusion may be desirable to promote the bonding between dispersed and continuous phase for such minimal diffusion produces a gradual gradation of hard phase content across the interface between the two phases.

The present materials are made by blending followed by hot consolidation of powders of the two constituents. I have used inert-gas atomization of 5-pound melts to produce powders of the hard, wear-resistant principal
3 dispersed, discontinuous constituent. This technique has been described in my co-pending applications, the serial numbers of which will be identified subsequently.

Powders produced by this method are characterized by high carbide volumes which, upon subsequent hot working, exist as a fine, uniform dispersion, usually 3 microns or less in size. While atomization has been used to produce powders of the principal constituent, other powder producing techniques which will yield a similar product—i.e., a hard, wear resistant material characterized by a large volume of fine, uniformly dispersed hard phase—may also be used. As an example, cemented carbides such as powders made by the TIC—CO 4—related liquid-phase sintered tool alloy systems, may be crushed by mechanical means to powder form to fulfill the requirements of the principal, dispersed constituent.

To the powders of the principal dispersed constituent are added powders of the continuous matrix constituent. I have found that about 25 volume percent of the continuous matrix constituent imparts good fabricability, strength, and toughness to the composite product, but obviously if greater toughness is desired the volume percent of the matrix should be increased, and if greater wear resistance is required, the volume percent of the matrix should be decreased. Thus, depending upon the particular application, the matrix constituent could vary from 10 to 40 volume percent while maintaining the desirable features of my invention.

The powders of the continuous matrix constituent have been made by the aforementioned metal atomization process and also by the reduction of iron oxide by hydrogen, and by the mixture of iron powder with finely divided carbides, as will be shown in the list of materials which I have prepared. While these methods yielded the desirable types of continuous matrix alloy powders, other known powder producing methods may also be employed to yield powders which fulfill the requirements of the continuous matrix phase—i.e., relatively low carbide volume and hardness, but relatively high strength and toughness. Examples of such other powder producing methods include reduction of single or mixed oxides, carbonyl powders, or powders prepared by comminution of metal or alloy stock.

Having added the appropriate volume of powders which will form the continuous matrix constituent to the powders which will form the principal dispersed, discontinuous constituent, the powders are then blended by tumbling, ball milling, jar-blending, or other suitable mixing method which will insure that the constituent powders are thoroughly mixed and homogeneous. The powders I have used were predominantly minus 80 mesh in particle size, but coarser powders (up to at least 1/8 inch diameter) can readily be substituted. The mixed powders are then consolidated into substantially fully dense stock by hot working. I have produced such stock by sealing the powder mixture into Inconel cans, then forging and hot rolling the cans until subsequently all porosity is eliminated. Alternative powder working methods such as hot-pressing or powder extrusion may also be used to accomplish the same results without departing from the scope of my invention.

During consolidation, the powders of the softer matrix constituent are readily plastically deformed at the hot working temperatures which typically are those used for forging or rolling. In my said method, the range of 1850° to 2200° F. If the matrix constituent is a mild steel, a die steel, a high-speed steel, or a nickel or cobalt-base "superalloy," for example. The particles of the principal dispersed, discontinuous constituent may also exhibit a degree of plastic deformation during hot working of the composite body, depending upon the temperature used. FIG. 1 illustrates Alloy No. A18, which contains 30 wt. percent hydrogen reduced iron powder and 70 wt. percent of the composition Fe—18W—4Cr—6V—1.8C (the latter constituent prepared by atomization and identi-
alloy A60 which contained an M2 high-speed steel matrix in combination with a highly alloyed cobalt-base tool material as the principal dispersed phase.

Some examples of the improvements obtained by the practices taught herein are set forth below:

Alloy 36 to be identified (Fe-27Co-20Cr-9W-6Mo-3C), when consolidated without the addition of a tough matrix had a transverse-rupture strength of 213,000 p.s.i. When the same alloy 36 contained 35 wt. percent of a matrix of H13 die steel (identified as Alloy No. 57 in Table I), the strength increased to 297,000 p.s.i., with virtually no change in hardness. The “duplex” material was also more readily fabricable.

Such Alloy 36, when used as a cutting tool for the lathe-turning of AISI 4340 bar stock, Rc 40 hardness, had a tool life of 9 min. at a cutting speed of 90 f.p.m. When this Alloy 36 contained the H13 die steel matrix, made according to the practice taught herein and identified as Alloy A57 in Table I, the tool life when cutting a similar workpiece material at 93 f.p.m. was approximately 10 min. But even more importantly, the tool wear was more uniform due to the absence of chipping as was observed when the relatively more brittle Alloy 36 was tested.

A further advantage of the alloys which are the subject of my invention is that they can be hot worked at temperatures somewhat lower than those which would be required to consolidate only the alloy which makes up the principal constituent. This reduction in hot working temperature is made possible because the continuous matrix constituent, by virtue of its reduced hard-phase—i.e. carbide—content is more readily plastically deformed.

A further advantage of the present composite alloys is that the thermal and electrical conductivities thereof, may be controlled and varied by the selection of the appropriate matrix material. Since the matrix is continuous, as compared with the isolated, dispersed constituent, the former governs to a large extent such conductivity properties of the composite. Accordingly, for example, a copper matrix in combination with a hard, wear resistant, dispersed constituent can offer excellent potential as an electrical contact material. Similarly, aluminum can be so used.

While the matrix and principal dispersed constituents listed in Table I are based on tool, die, or structural alloys of iron, nickel, and/or cobalt, it is obvious to those skilled in the art of powder metallurgy that other alloy systems such as aluminum, copper, tungsten, chromium, etc., may be employed advantageously as matrix-dispersed constituent combinations.

It will be understood that various modifications and variations may be effected without departing from the spirit or scope of the novel concepts of my invention.

I claim as my invention:

1. A composite alloy consisting essentially of: a continuous matrix constituent selected from the group consisting of iron-base, cobalt-base and nickel-base alloys and a dispersed, discontinuous constituent selected from the same group; said continuous matrix constituent being present in amounts ranging from 10 to 40 volume percent; said continuous matrix constituent being characterized by relatively greater toughness and ductility than said dispersed, discontinuous constituent; said dispersed, discontinuous constituent being characterized by relatively greater hardness and wear resistance than said continuous matrix constituent and being further characterized by containing a relatively larger volume of a fine, substantially uniformly dispersed, hard phase; both said constituents being so selected as to not form undesirable compounds upon hot consolidation thereof.

2. The alloy as defined in claim 1 wherein the fine, substantially uniformly dispersed hard phase in said discontinuous constituent is a carbide phase predominantly less than 3 microns.

3. The alloy as defined in claim 1 wherein the continuous matrix constituent has a carbon content ranging from 0 to 3% and the dispersed, discontinuous constituent has a carbon content ranging from 0.6% to 4%.

4. The process of making a composite, substantially fully dense, alloy as defined in claim 1 comprising the steps of blending powders of the named constituents and hot consolidating said powders.

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L. DEWAYNE RUTLEDGE, Primary Examiner
W. W. STALLARD, Assistant Examiner

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