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ALLOY

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The present invention relates to a new and useful alloy and relates particularly to an alloy containing as essential components boron, tungsten, molybdenum, chromium, iron, carbon, and cobalt.

This application is a continuation in part of my co-pending application Serial No. 211,809, filed June 4, 1938.

The object of the present invention is to provide an alloy having certain inherent physical properties and characteristics which can be developed and controlled by means of thermal treatment, and further to provide an alloy which can be manufactured in finished or semi-finished forms by means of casting, and particularly centrifugal casting.

The alloy of the present invention has a combination of physical properties and characteristics which render it especially valuable for metal cutting tools and many other industrial articles.

I have found through experiment that by alloying or otherwise intimately combining boron, tungsten, molybdenum, chromium, iron, carbon, and cobalt within the range of boron 0.25% to 2.50%, tungsten 5% to 20%, molybdenum 1% to 15%, chromium 1% to 10%, iron 5% to 40%, carbon up to a maximum of approximately 0.75%, and cobalt substantially the balance, I obtain metallic compositions which possess a combination of valuable physical properties and characteristics. An important essential characteristic of the present composition is that it is well adapted for the manufacture of cast forms by means of centrifugal casting. Another advantage is that such cast forms are readily amenable to thermal treatment for the improvement and control of important physical properties, such as hardness and tensile strength.

I have found by means of research that the superior physical properties and characteristics of the present alloy are obtained through the presence of boron, within the range disclosed herein, in combination with the other essential alloy elements.

I have found that the preferred structure of an aggregate of the present composition comprises at least two principal constituents: (*a*) a relatively hard intermetallic compound of boron and carbon with one or more of the other essential components; and (*b*) a solid solution containing boron and two or more of the other essential components, which has a lower degree of hardness and functions as a matrix for the hard intermetallic boron compounds. When the alloy is to be used for metal cutting tools, or various other metal working operations, I have found it to be advantageous to have an appreciable percentage of the intermetallic boron-carbon compound in the form of finely divided particles disseminated through the matrix. The ratio of submicroscopic particles to larger particles, as well as the amount of boron retained in solid solution in the matrix, can be accurately controlled by means of thermal treatment.

The ratio of boron to carbon present is highly important in determining the cutting efficiency of the alloy of the present invention. The boron-carbon ratio also has an important influence upon other physical properties and characteristics of the alloy, and I have found that the optimum range of cutting efficiency is attained only when boron and carbon are present in such relative amounts as to insure all, or substantially all, of the carbon being in the form of a chemical compound with boron and at least one of the other essential components, such, for example, as tungsten boro-carbide, or molybdenum boro-carbide. I have determined that boro-carbides of tungsten or molybdenum possess physical properties markedly superior to those of the heretofore employed straight carbides of tungsten or molybdenum. For example, the boro-carbides are apparently somewhat harder than the carbides of tungsten or molybdenum which are produced by the solidification of molten metals. Even more important is the fact that the boro-carbides are not dissolved in the matrix metal at any temperatures developed in the tips of metal cutting tools. In addition, I have found that the boro-carbides of the present alloy are not decomposed in ordinary atmospheres at temperatures within and somewhat above the red heat range. Consequently, the complex boro-carbides are not dissolved or decomposed during the operation of tools at high speeds or on heavy duty cutting.

I have found that the percentage of boron in the alloy should be somewhat in excess of the percentage of carbon in order to insure substantially all of the carbon being in the form of metal boro-carbides. When it is desired to produce a tool having approximately maximum metal cutting efficiency, it is essential to employ an excess of boron over the amount theoretically required to combine with all of the carbon present. Such excess boron may be present as a boride of one or more of the other essential components, or it may be in solid solution in the matrix metal. The retention of some boron in solid solution in the matrix is apparently an important factor in

the formation of a matrix having markedly superior physical properties to the matrix of a non-boron containing alloy.

I have further found that it is essential to have sufficient boron in the alloy to combine with all, or substantially all, of the tungsten and molybdenum present to form either a complex boro-carbide or a boride. It should be understood that a portion of the tungsten and molybdenum will be present more or less in solid solution in the matrix and that such condition is preferred to one in which all of the tungsten and molybdenum is in the form of hard particles.

Therefore, it will be obvious that in order to produce a composition of the present invention having advantageous and superior physical properties and characteristics, the actual amount of boron employed will be determined largely by two factors: first, the amounts of tungsten and molybdenum present and, second, the amount of carbon present.

The ratio of tungsten and molybdenum is also important. I generally prefer to have the percentage of tungsten materially in excess of the percentage of molybdenum. In order to produce an alloy having a high degree of cutting efficiency, I prefer that the amount of tungsten should constitute a minimum of 55% of the combined weight of tungsten and molybdenum present.

The thermal treatment used for the development of hardness and other physical properties in the present alloy is substantially the same as the method which is standard for various types of high speed steels. When a body of this alloy is heated to a temperature of approximately 2100 degrees F. or higher, a substantial proportion of the complex constituents containing boron, tungsten, molybdenum, etc., are dissolved in the cobalt-iron rich matrix. When the body is quenched in oil or other suitable medium from the hardening temperature, some of the tungsten and molybdenum will be precipitated in the form of tungsten boro-carbide and molybdenum boro-carbide of varying particle sizes. When the body is subsequently heated to 900 degrees F. or higher for tempering, a further proportion of the tungsten, molybdenum and boron, which was retained in solid solution during the quench, will be precipitated mainly in the form of sub-microscopic particles. It will be understood that the proportion of such sub-microscopic particles, so precipitated, will depend largely upon the temperature at which the operation is conducted, and upon the length of time at which the body is maintained at such temperature. It should be understood that the precipitation of boro-carbides or borides from solid solution will not only result in an increase in the degree of hardness, but will also result in an appreciable increase in the tensile strength. Furthermore, I have discovered that the precipitation of such sub-microscopic, boron containing compounds imparts to the matrix an unusually high degree of resistance to abrasive wear both at normal temperatures and at those generated in cutting tool tips.

I have found that the alloy disclosed herein cannot be economically forged or rolled as it is particularly resistant to deformation at both normal and elevated temperatures. This applies especially to ingots or other forms cast by ordinary methods. I have also found that it is virtually impossible to produce commercially satisfactory shapes or forms of the alloy by means of gravity casting. Such castings do not have the proper density, and I have found that this boron containing composition has an appreciable ratio of shrinkage upon solidification, with the result that a central cavity or pipe invariably occurs in the casting. I have also found that, in general, the physical structure of castings produced by gravity methods is such as to render the alloys more or less unsuitable for use as metal cutting tools, as well as many other industrial applications.

I have discovered that by applying suitable pressure to the molten alloy while it is in the mold that I can produce cast forms having a relatively high density and the requisite physical structure. I have found that while various methods may be used for developing the necessary degree of pressure, that centrifugal casting offers an entirely satisfactory and economical means of manufacturing cast forms of the present composition. I have found that by means of centrifugal casting I can increase the density of cast forms of this alloy from 10% to 20% over the density of forms cast by gravity methods. Another important advantage is that the centrifugally cast forms have, in general, an unusually uniform physical structure and are quite free from massive segregates of hard and brittle constituents, and are readily responsive to thermal treatment.

Cast bodies of the alloy produced by centrifugal casting may be utilized in the as-cast condition. However, I usually prefer to subject the castings to a suitable thermal treatment before using them for metal cutting tools and many other articles.

A distinctive characteristic of a body of the alloy which has been subjected to suitable thermal treatment is the combination of relatively high hardness, e. g., 63 to 72 Rockwell C, and high resistance to impact. Another important property is that virtually all of the hardness developed by thermal treatment is retained when the alloy is subjected to temperatures up to approximately 600 degrees C.

Specific examples of the compositions within the scope of the present invention which I have found to be suitable and valuable for various industrial purposes are the following: tungsten 10%, molybdenum 6%, boron 0.70%, chromium 5%, iron 12%, carbon 0.50%, cobalt substantially the balance; tungsten 14%, molybdenum 5%, boron 0.68%, chromium 4.60%, iron 19%, carbon 0.64%, cobalt substantially the balance; tungsten 8%, molybdenum 5.50%, boron 0.62%, chromium 4.30%, iron 37%, carbon 0.56%, cobalt substantially the balance; tungsten 18%, molybdenum 2%, boron 0.80%, chromium 7%, iron 32%, carbon 0.54%, cobalt substantially the balance.

I have found that materials used in producing this alloy usually contain other elements, more or less in the nature of impurities, such, for example, as manganese, silicon and aluminum. Also in producing the alloys, I usually prefer to employ small amounts of one or more of such elements for deoxidation or other purposes. Consequently, the alloys of my invention usually contain insignificant amounts of elements, other than those specified as essential components, in the nature of incidental impurities. In all cases, the amounts of such impurities should be restricted to percentages which will not adversely affect the properties of the alloy.

It will be evident therefore that the composition of the present invention comprises the

following essential components: boron 0.25% to 2.50%, tungsten 5% to 20%, molybdenum 1% to 15%, chromium 1% to 10%, iron 5% to 40%, carbon up to a maximum of 0.75%, the balance substantially cobalt.

I claim:

1. A cast alloy comprising as essential elements: boron 0.25% to 2.50%, tungsten 5% to 20%, molybdenum 1% to 15%, chromium 1% to 10%, iron 5% to 40%, carbon up to a maximum of 0.75%, the balance cobalt, except for minor amounts of incidental impurities; said cast forms being characterized by being responsive to thermal treatment for the regulation of hardness.

2. A cast alloy comprising as essential elements: boron 0.25% to 2.50%, tungsten 5% to 20%, molybdenum 1% to 15%, chromium 1% to 10%, iron 5% to 40%, carbon up to a maximum of 0.75%, the balance cobalt, except for minor amounts of incidental impurities; in which the percentage of tungsten constitutes at least 55% of the combined weight of tungsten and molybdenum present; said cast forms being characterized by being responsive to thermal treatment for the regulation of hardness.

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