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WESLEY P. SYKES, OF CLEVELAND HEIGHTS, OHIO, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK

METAL WORKING ALLOY

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My invention relates to alloys which are suitable for tools and dies and which have the property of retaining their hardness at high temperatures. More particularly, my invention relates to alloys of iron with metals such as tungsten or molybdenum, or both, and probably the more important class of alloys is that in which the iron predominates. Such alloys are called iron base alloys. As will appear from the specification and claims, my invention is applicable also to tungsten or molybdenum base alloys, and also to various other combinations of metals such as iron with a hardening metal such as tungsten or molybdenum. It has been the accepted opinion that in order to obtain hardness in metals of this nature, it is necessary to incorporate carbon even where tungsten and molybdenum are used. I have been able to produce alloys of iron and tungsten or molybdenum having a very high degree of hardness and durability under high temperature conditions where the carbon is practically absent or present in comparatively low percentages.

According to my invention, as applied to iron base alloys, a body of such metals in close association and containing upwards of ten per cent of tungsten, molybdenum or both, is heated up to the temperature at which tungsten and/or molybdenum goes into solid solution in the iron. With the higher percentages of tungsten and molybdenum there will also be present a certain quantity of a compound of tungsten or molybdenum with iron. At this temperature the grains of the metal have what is known as the body centered cubic space lattice structure. The metal is then cooled rapidly as by quenching, and then raised to an intermediate temperature at which there is a precipitation of the iron and tungsten or molybdenum compound which is probably iron tungstide or molybdide, or a mixture. I attribute the hardness to the presence of this compound dispersed through the metal body.

My invention is distinguished from the prior art of hardening steels containing substantial percentages of carbon in which it is the practice to heat the steel above what is known as the "critical" temperature, and then to cool rapidly as by quenching. The critical temperature is the temperature at which the so-called face centered cubic space lattice structure changes to the body centered cubic space lattice structure. The rapid cooling or quenching produces a fine grained structure which has body centered cubic space lattice, the reason for the fine grains being that, on account of the quenching, the grains of body centered lattice formed after the transition from the face centered cubic space lattice structure do not have a chance to grow. My invention, on the other hand, does not involve a change of the crystal structure as the metal is always of the body centered cubic space lattice structure. According to prior methods, the hardness is obtained by quenching. Any further heating and the treatment results in a softening to a certain degree. On the other hand in the case of my invention, the hardness is produced by the aging heat treatment which takes place after the quenching.

The following are specific examples of my invention.

Alloys of iron and tungsten

In these cases the iron may run from ninety per cent to sixty per cent, the tungsten from ten per cent to forty per cent, and the carbon less than one-tenth per cent. For example, an alloy composed of seventy per cent iron, thirty per cent tungsten, and less than two-hundredths per cent carbon was prepared by mixing the tungsten and iron in the form of powders obtained by hydrogen reduction of the respective oxides. The mixed powders were pressed into bars one-half inch by one-half inch by sixteen inches under a pressure of fifteen to eighteen tons per square inch. One of the bars was heated for one hour at approximately 1500° C. in an atmosphere of hydrogen, and then quenched in water. The Brinell hardness of this metal was 196, and the Rockwell hardness was C. 15. When this alloy was heated for ten hours at a temperature of approximately 700° C., the Brinell hardness had increased to 460, and the Rockwell hardness to C. 52.

Alloys of iron and molybdenum

In these cases the iron constituted ninety to seventy per cent, the molybdenum ten to thirty per cent, and the carbon less than one-tenth per cent. An alloy of seventy-eight per cent iron, twenty-two per cent molybdenum, and carbon below two-hundredths per cent was prepared by mixing the iron and molybdenum powder obtained by hydrogen reduction of iron and molybdenum oxides. The mixture was pressed into bars one-half inch by one-half inch by sixteen inches at a pressure of fifteen to eighteen tons per square inch. A bar was heated in a hydrogen atmosphere at approximately 1410° C. for one hour, and then quenched in water. After quenching, the Brinell hardness of the alloy measured 214. This bar was then heated for sixty hours at approximately 600° C. and this caused the Brinell hardness to increase to 531. Dies were made from this alloy and heat treated as above described, and this showed a life many times that of high speed steel dies when used for hot swaging of tungsten metal. A piece of this alloy used as a tool bit for turning chromium bearing steel cut four times as much metal as the regular high speed steel tool before losing its cutting edge.

Alloys of iron with molybdenum and tungsten

These alloys contained iron seventy-five per cent to seventy per cent, molybdenum five to twenty-five per cent, tungsten twenty per cent to five per cent, and carbon less than one-tenth per cent. An alloy composed of iron seventy-three per cent, tungsten five per cent, molybdenum twenty-two per cent, and carbon below two-hundredths per cent was prepared by mixing the hydrogen reduced metal powders. The mixture was pressed into a bar five-eighths inches square by sixteen inches at a pressure of sixteen tons per square inch. A portion of this pressed bar was heated in a hydrogen atmosphere at about 1410° C. for one hour and quenched in water. The Brinell hardness number of this alloy as quenched was 225, and its Rockwell hardness measured C. 30. After heating at about 650° C. for four hours, the Brinell hardness had increased to 650 and the Rockwell hardness to C. 53.

Microscopic analyses of the important alloys indicate that at 1525° C. about thirty-three per cent of tungsten may be held in solid solution by the iron. The solubility of the tungsten in iron decreases as the temperature falls below 1525° C. until at 600° only about eight per cent will be retained in solid solution in the iron. If the tungsten is above these percentages, the excess is present in patches of what is presumably the compound iron tungstide Fe_3W_2. If the temperature of the solid solution is lowered slowly from 1525° C., the tungsten is precipitated out in the form of crystals or particles of what is presumably iron tungstide. The slower the rate of the cooling, the more complete will be the precipitation, and the larger will be the size of the crystals or particles of precipitated high tungsten compound. If the alloy as quenched from the high temperature, say from 1525° C., is heated again for several hours at some temperature below 1500° C., the precipitation of the tungstide will occur. The size of the particles of the precipitate will increase as the temperature of heating is increased, and also as the time of heating is prolonged. For example, it has been shown by hardness measurements on pieces of alloys containing between ten and forty per cent tungsten, the remainder being iron, that after quenching from 1500° C. and reheating at various temperatures between 600° C. and 1400° C., the maximum increase in Brinell hardness was obtained by heating at approximately 600° C. for as long as 300 hours. The hardening effect seems to be less as the temperature of aging is raised. For example, it is found that upon reheating for one hour at 1200° C. an alloy of twenty-five per cent tungsten and iron after quenching from 1500° C. no measurable hardening had occurred. If the time of heating is unduly prolonged, the alloys will begin to soften again after passing to maximum hardness. It seems from microscopic examination that as the size of precipitated particles increases, the hardness decreases. It is therefore my theory that the hardening action is due to the precipitated material which is scattered through the alloys in the hardest state as in particles of sub-microscopic dimensions throughout the large grains of the solid solution of tungsten in body centered cubic space lattice iron.

Alloys composed of iron and ten to thirty per cent molybdenum are similar in structure to corresponding alloys of iron and tungsten. At approximately 1440° C. about twenty-four per cent molybdenum will be held in solid solution by iron. With slow cooling from the 1440° C., what is presumably the compound iron molybdide Fe_3Mo_2 is precipitated. At 600° C. about seven per cent of molybdenum will exist in solid solution in the iron. When more than four per cent molybdenum is present in the iron, there is no change in crystal structure upon cooling from above 1400° C. to room temperature, the structure being of body centered cubic space lattice. The maximum hardness is developed in iron alloys containing ten to thirty per cent molybdenum after quenching from about 1425° C. by reheating or aging at a temperature between 600° C. and 650° C. for a period of fifteen hours or more. As in the case of the iron tungsten alloys, it is assumed that the hardening is brought about by sub-microscopic particles of the iron mo-

lybdenum compound precipitated at the relatively low aging temperature through the coarse grained matrix of the solid solution of molybdenum in iron, the latter having the body centered cubic space lattice structure.

Instead of agglomerating the metal powders in the preparation of the alloy, the metals may be melted together in a crucible and cast into the shape desired as in the usual practice. The casting may then be heated, quenched and aged as in the case of the agglomerated metal powders.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. The method of producing substantially carbon free hard alloys of iron with metal from a group consisting of tungsten and molybdenum which consists in heating iron and said metal from a group consisting of tungsten and molybdenum in close association to a temperature at which a solid solution of said metal in the iron will take place, rapidly cooling the body thus formed and finally heating said body to and holding it for at least a few hours at an intermediate temperature, below the initial heating temperature, at which there will be a precipitation of a compound containing a relatively high percentage of said metal.

2. The method of producing a substantially carbon free hard alloy containing from about 10% to about 40% of metal from a group consisting of tungsten and molybdenum the remainder of said alloy consisting substantially of iron which consists in heating said iron and said metal in close association to a temperature at which a solid solution of said metal in the iron will take place, quenching the body thus formed and thereafter raising said body to an intermediate temperature below the initial heating temperature and holding it at said intermediate temperature for at least a few hours to thereby produce a precipitation of a compound containing a relatively high percentage of said metal.

3. The method of producing substantially carbon free alloys containing from about 10% to about 40% of metal from a group consisting of tungsten and molybdenum, the remainder of said alloy consisting substantially of iron which consists in heating a body consisting of said iron and said metal to a temperature necessary to produce a solid solution of said metal in the iron, then rapidly cooling as by quenching and afterwards heating said body to an intermediate temperature below the initial heating temperature and holding it at said temperature for at least a few hours to thereby produce a precipitation of a compound consisting of submicroscopic particles containing a relatively high percentage of the metal of said group consisting of tungsten and molybdenum.

4. The method of producing a substantially carbon free hard alloy containing from about 10% to about 40% of metal from a group consisting of tungsten and molybdenum the remainder of said alloy consisting substantially of iron which consists in heating a body consisting of said iron and said metal to a temperature above 1400° C. but below the melting point of said alloy, then rapidly cooling as by quenching and afterwards heating said body to an intermediate temperature below the initial heating temperature and ageing it at said temperature to thereby produce a precipitation of a compound containing a relatively high percentage of the said metal from the group consisting of tungsten and molybdenum.

5. The method of producing a substantially carbon free hard alloy containing from about 10% to about 40% of metal from a group consisting of tungsten and molybdenum the remainder of said alloy consisting substantially of iron which consists in heating a body consisting of said iron and said metal to a temperature necessary to produce a solid solution of the said metal from said group in the iron, then rapidly cooling as by quenching and afterwards heating said metal body to a temperature above 600° C. but below 1200° C. and holding it at said temperature for at least a few hours.

6. The method of producing a substantially carbon free alloy containing from about 10% to about 40% of metal from a group consisting of tungsten and molybdenum the remainder of said alloy consisting substantially of iron which consists in heating a body consisting of said iron and said metal to a temperature above 1400° C. but below the melting point of said alloy, then rapidly cooling as by quenching and afterwards heating said body to a temperature above 600° C. and holding it at said temperature for at least a few hours to thereby produce a precipitation of a compound containing a relatively high percentage of said metal.

7. A hard alloy consisting substantially of iron and metal from a group consisting of tungsten and molybdenum, said alloy containing not more than one-tenth per cent of carbon, said alloy comprising a structure in which sub-microscopic particles of a compound consisting of iron and tungsten and/or molybdenum are distributed throughout said alloy, said alloy having the property of retaining hardness when used for metal cutting or drawing above normal temperatures.

8. A substantially carbon free alloy consisting substantially of iron and tungsten or molybdenum said alloy comprising sub-microscopic particles of iron tungsten or iron molybdenum compound precipitated through a coarser grained matrix of the solid solution of the tungsten or molybdenum in the iron.

9. A substantially carbon free alloy containing at least 60% iron, the remainder of

the alloy consisting substantially of tungsten or molybdenum said alloy comprising submicroscopic particles of iron tungsten or iron molybdenum compound precipitated through a coarser grained matrix of the solid solution of the tungsten or molybdenum in the iron.

10. A substantially carbon free alloy consisting of at least 60% iron the remainder of the alloy consisting substantially of tungsten or molybdenum said alloy comprising submicroscopic particles of iron tungsten or iron molybdenum compound precipitated through a coarser grained matrix of the solid solution of the tungsten or molybdenum in the iron.

11. A hard alloy containing at least 60% iron and less than .1% carbon, the remainder of said alloy consisting substantially of metal from a group consisting of tungsten and molybdenum, said alloy comprising submicroscopic particles of iron tungsten and/or molybdenum compound precipitated through a coarser grained matrix of the solid solution of the tungsten and/or molybdenum in the iron.

12. An alloy substantially carbon free and containing from 60 to 90% iron, the remainder of said alloy consisting substantially of metal of the group containing tungsten and molybdenum, said alloy having a Brinell hardness of about 460 or more and having sub-microscopic particles of iron tungsten and/or molybdenum compound precipitated through a coarser grained matrix of the solid solution of the tungsten and/or molybdenum in the iron.

13. The method of producing a substantially carbon free hard alloy consisting substantially of about 60% to about 90% iron and about 10% to about 40% of metal of the group containing tungsten and molybdenum which consists in heating said metal and iron in close association for an appreciable period of time at a temperature of about 1500° C. to thereby form an alloy, quenching said alloy and reheating the alloy to a temperature of about 600° C. or higher but less than 1200° C. for a few hours.

14. An alloy substantially carbon free and containing about 60 to 90% iron, the remainder of the alloy consisting of metal from a group consisting of tungsten and molybdenum, said alloy having been heated for an appreciable time at a temperature of about 1500° C. quenched and thereafter aged at a temperature of about 600° C. or higher but less than 1200° C., said alloy being characterized by a structure in which particles of an iron tungsten or iron molybdenum compound are distributed through said alloy.

15. An alloy substantially carbon free and containing about 60 to about 90% iron, the remainder of the alloy consisting of a metal from a group consisting of tungsten and molybdenum, said alloy having been heated at a temperature above 1000° C. but lower than the melting point of said alloy, quenched and thereafter aged at a temperature of about 600° C. or higher but less than said first mentioned temperature to thereby cause precipitation of an iron molybdenum or iron tungsten compound through said allow.

16. The method of producing a hard, substantially carbon free alloy consisting substantially of metal of the iron group and metal from a group consisting of tungsten and molybdenum which comprises heating said metals in close association to a temperature above 1000° C. but lower than the melting point of the alloy, quenching the body thus formed and thereafter heating said body at an intermediate temperature below the initial temperature to thereby cause precipitation of a compound of said metals throughout said body, said precipitated compound being in particles of submicroscopic dimensions.

17. The method of producing a substantially carbon free alloy consisting substantially of metal from a group consisting of tungsten and molybdenum and metal of the iron group said metal of the iron group comprising the main constituent of said alloy, said metal from the group consisting of tungsten and molybdenum comprising from about 10% to about 40% of said alloy, which comprises heating said metals in close association to a temperature at which a solid solution of said metal from the group consisting of tungsten and molybdenum in said metal of the iron group will take place, rapidly cooling the body thus formed and finally raising it to an intermediate temperature below the initial heating temperature and holding it at said intermediate temperature to thereby precipitate a compound consisting of submicroscopic particles containing a relatively high percentage of tungsten and/or molybdenum.

18. The method of producing a hard, substantially carbon free alloy consisting substantially of metal of the iron group and metal from a group consisting of tungsten and molybdenum, said metal of the iron group forming the main constituent of said alloy and said metal of the group consisting of tungsten and molybdenum comprising from about 10 to about 40% of said alloy, which comprises forming said metals into a coherent mass, heating said mass to a temperature between about 1400° and about 1500° C., quenching the mass and reheating it at an intermediate temperature, below the initial heating temperature, at which there will be a precipitation of a compound containing a relatively high percentage of said metal from a group consisting of tungsten and molybdenum.

19. The method of producing a hard, substantially carbon free alloy consisting of about 10 to 40% of metal from a group con-

sisting of tungsten and molybdenum, the remainder of said alloy consisting substantially of metal of the iron group which comprises forming said metals into a coherent mass, heating said mass to a temperature between about 1400° and 1500° C., quenching the mass, reheating it to an intermediate temperature below the initial heating temperature and holding it at said intermediate temperature to thereby produce a precipitation of a compound consisting of sub-microscopic particles containing a relatively high percentage of said metal from a group consisting of tungsten and molybdenum.

20. A hard, substantially carbon free alloy consisting mainly of iron but containing at least 10% of metal from a group consisting of tungsten and molybdenum, said alloy comprising a structure in which sub-microscopic particles of a compound consisting of iron and tungsten and/or molybdenum are distributed throughout said alloy, said alloy having the property of retaining hardness when used for metal cutting or drawing above normal temperatures.

21. A hard, substantially carbon free metal body containing about 10% to about 40% of metal from a group consisting of tungsten and molybdenum, the remainder of said metal body consisting substantially of metal from the iron group, said metal body comprising sub-microscopic particles of a compound of said metal of the iron group and said metal from the group consisting of tungsten and molybdenum precipitated throughout said metal body.

22. A substantially carbon free alloy containing about 10% to about 40% of metal from a group consisting of tungsten and molybdenum the remainder of said alloy consisting substantially of metal of the iron group, said alloy having been heated at a temperature at which solid solution of the tungsten and/or molybdenum in the metal of the iron group will take place, quenched and thereafter aged at an intermediate temperature below the initial heating temperature to thereby cause precipitation of a compound of said metal of the iron group and said metal of the group containing tungsten and molybdenum throughout said alloy.

In witness whereof, I have hereunto set my hand this 18th day of October, 1926.

WESLEY P. SYKES.