

UNITED STATES PATENT OFFICE.

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ALLOY AND METHOD OF MAKING THE SAME

No Drawing.

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This invention relates to alloys, more particularly those designed for use in the production of high speed cutting tools.

This application is a continuation in part of my applications Serial Nos. 463,033, filed April 20, 1921; 493,108, filed August 17, 1921, and 626,801, filed March 22, 1923.

It is necessary that alloys for such purposes have the property of "red hardness" so that a tool made therefrom may maintain its cutting edge after the same has become red hot.

In addition to heat resistance the alloy must also possess abrasive hardness and, for this purpose, should contain embedded in the metallic matrix, hard crystals, usually metallic carbides.

The principal object of this invention is to improve the matrix of carbide containing alloys of this character to increase their strength and heat resistance and also reduce their liability to flake, crack or splinter during use.

Other and further important objects of the invention will hereinafter appear.

I have found that an alloy formed of hard carbides and a matrix composed of both cobalt and nickel as its basal components gives a much superior cutting tool to one made with either cobalt or nickel alone.

The metals of the chromium group form hard carbides which are suitable for the present purpose although metals of other groups may also be used if desired.

The metals of the chromium group comprise chromium, tungsten, molybdenum and uranium. While these metals show many resemblances to each other, both chemical and physical, they are far from being identical in properties. The same is true of the somewhat closely allied metals nickel and cobalt. To obtain the best results the individual characteristics of these metals should be blended, although the invention is not restricted to the use of a plurality of metals of the chromium or other group. Thus chromium gives strength rather than hardness as compared with tungsten. Then again, molybdenum will give a similar hardening effect to tungsten. Further, alloys

with nickel alone have a tendency to be "hot-short" while the cobalt alloys are "cold-short". Moreover, unless the quantity of nickel is properly limited the product will not be satisfactory especially as regards its heat resisting qualities.

The chief function of the cobalt and nickel appears to be that of producing a strong, tough, heat resisting matrix for the carbides of the chromium group or other group of metals. Neither cobalt or nickel possesses the affinity for carbon, that is possessed by chromium or tungsten for example, so that it is probable that there is little or no carbide of either cobalt or nickel in my alloys.

The amount of carbon by weight in my alloys is comparatively slight, say 1.50% but the proportion of carbide by volume may be as high as 20 to 25% of the entire alloy. This follows from the great differences in specific gravity of carbon and the metals with which it combines to form carbide. In view of this large content of non-metallic compounds the composition of the matrix is of the utmost importance. It will also be evident that since these alloys may be regarded as a mass of carbide crystals embedded in a strong, tough, heat resisting matrix, a variety of carbides may be used with a matrix having as its basal constituents both cobalt and nickel.

These carbides are soluble to a certain extent in the molten alloy so that unless the carbon content exceeds certain limits depending upon the nature and proportion of the metals forming the alloy, the latter on cooling will not contain free carbide crystals but only carbide in solid solution. While carbide in solid solution has a hardening effect it is not the desired abrasive hardness which results from the presence of free carbide crystals. The carbon content of the alloy should, therefore, be high enough to provide a substantial proportion of free carbide crystals in the alloy.

Ordinarily, alloys made in accordance with this invention will consist of cobalt, nickel, chromium and tungsten with a small amount of carbon.

The percentage of these metals will usually be within the following limits:

	Per cent.
Cobalt.....	25 to 40
Nickel.....	10 to 20
Chromium.....	25 to 35
Tungsten.....	15 to 35

The total amount of cobalt and nickel should be between 35 and 65%.

In certain cases a wider range of proportions may be employed such as those lying with the following percentages:

	Per cent.
Cobalt.....	10 to 45
Nickel.....	7 to 30
Chromium.....	20 to 45
Tungsten.....	10 to 45

The total amount of cobalt and nickel should be between 30 and 70%.

As an example of a suitable alloy falling within the above limits the following may be given:

	Per cent.
Cobalt.....	27
Nickel.....	14
Chromium.....	31
Tungsten.....	28

If desired the quantity of cobalt may be decreased and that of the nickel increased correspondingly. At the same time it is desirable to increase the proportion of chromium group metals as increasing the nickel content tends to soften the alloy. This is exemplified by the following:

	Per cent.
Cobalt.....	10
Nickel.....	25
Chromium.....	35
Tungsten.....	30

Conversely if the cobalt is increased and the nickel is decreased a smaller proportion of chromium group metals are required.

Thus:

	Per cent.
Cobalt.....	36
Nickel.....	10
Chromium.....	32
Tungsten.....	22

In some instances only one metal of the chromium group may be used, as in the case of the following alloy:

	Per cent.
Cobalt.....	45
Nickel.....	15
Tungsten.....	40

In addition to the metallic constituents mentioned above a hardening element should be added. Usually this will be carbon although other elements, more particularly silicon, have a hardening effect. Many metallic silicides are as hard if not harder than the corresponding carbides.

Usually the amount of carbon in the alloy

will be between 1 and 2.5%, for example around 1.5% although in some cases it may be as low as 0.5% or as high as 3.5%. It is desirable on the one hand to have enough carbon to produce free carbide crystals and on the other hand not enough to cause the formation of particles of graphitic carbon throughout the alloy, as the presence of graphitic carbon greatly reduces the strength of the alloy.

As a given weight of chromium, for example, will combine with a much larger weight of carbon than will the same weight of tungsten the amount of carbon which may be added before free graphitic carbon is formed in the alloy will depend upon the nature and proportions of the metals composing the alloy.

The carbon is most readily and accurately added as a carbide, such as the carbide of one of the metals forming the alloy as chromium.

In addition to a hardening element it is frequently advisable to use a de-oxidizer such as aluminum or boron. Further the hardening element and de-oxidizer may to advantage be added simultaneously in the form of boron carbide.

While my alloys consist essentially of the above metallic and non-metallic ingredients it will be understood that the addition or presence as impurities of small quantities of other metals, etc., such as iron, manganese or the like, will not change the general characteristics of my alloys.

In the process of forming the alloy the several ingredients in proper proportion are placed in a crucible preferably together with some readily fusible material, such as glass, which will form a protecting layer over the alloy and so prevent oxidation. Preferably the metals are placed in the crucible in the order of their fusibility and specific gravity.

Cobalt m. p.....	1490° C.	Sp. gravity....	8.72
Nickel m. p.....	1452° C.	Sp. gravity....	8.70
Chromium m. p.....	1505° C.	Sp. gravity....	6.92
Tungsten m. p. above.....	3000° C.	Sp. gravity....	18.70

The cobalt, nickel and chromium are placed at the bottom of the crucible and then the tungsten placed on top so that when the first named metals melt the tungsten may sink by gravity through the molten mass and in so doing be alloyed therewith.

The temperature employed for fusing the constituents may be from 1750° to 1950° C. according to conditions. As these alloys do not respond to heat treatment, as does steel, at least at a temperature below 1100° C. the alloy must be formed into the desired shape by casting and then grinding instead of by forging.

To obtain the best results molds made of sand should not be employed since, using such molds, even if brushed over with graphite powder, the bars are apt to be full of blow holes and too soft to make good

lathe tools. Preferably the molds are constructed of graphite although cast iron may be used for this purpose if the surface is treated before use to prevent the hot metal adhering thereto. Such treatment may consist either in treatment with sulphuric acid or coating with carbon by the application of a smoky flame thereto.

Graphite is, however, much superior to cast iron as a material for molds. In the first place it is much easier to machine graphite than cast iron so that molds for casting special sizes and shapes can be more readily made. Then again, cast iron molds have to be repeatedly treated with sulphuric acid solution since the effect of the treatment soon wears off.

Further, cast iron molds, especially for small sizes of bars, chills the metal too rapidly. This chilling makes the bars hard, and, while hardness is a desideratum, it should be uniform throughout the bar and chilling makes the outer layers harder than the center.

Now graphite has a lower specific heat per unit volume and also a much lower heat conductivity than cast iron. Consequently the rate of abstraction of heat from the cooling metal is far less in the case of graphite than in the case of iron molds.

I have also found that the hardness of bars cast with the above alloys vary according to the rate at which they cool so that a small bar, which necessarily cools more rapidly than a large one, is, other conditions being the same, harder. On the other hand, increasing the carbon content of the alloy increases its hardness. It has further been found that heat treatment of the alloy after casting does not appreciably change its hardness so that the alloy may be termed "self-hardening".

To secure the best results it is necessary to hit the happy mean between too great hardness, which means brittleness, and liability to flake or chip, and too little hardness, which means that a tool made therefrom will be too soft to cut for the desired length of time or to cut hard metals.

This I accomplish by the present invention by varying the amount of hardening element, such as boron carbide, added with varying dimensions of the bar to be cast.

For example, for a $\frac{1}{4}$ inch bar 0.56% boron carbide may be used to advantage; for a $\frac{3}{8}$ inch bar 0.85%; and for a $\frac{1}{2}$ inch bar 0.97%.

By so varying the content of boron carbide the sum of the hardness due to chilling and the hardness due to the hardening element is maintained substantially uniform irrespective of the size of the bar cast.

If on casting a trial bar from any given melt the alloy appears to be too soft, small

additions of tungsten may be added to the crucible to give the requisite hardness.

The above mentioned quantities of carbon, added as boron carbide, are considerably lower than the desired carbon contents of the bars for the reason that not only do the constituent commercial metals contain small amounts of carbon but also larger amounts of carbon are picked up from the crucible in which the alloy is made, if an unlined graphite crucible be employed.

As a result of the picking up of carbon from the crucible it is desirable to avoid heating the metal to too high a temperature or for too long a time in the crucible. Further, when remelting scrap along with a proportion of new metal the quantity of boron carbide added should be decreased to allow for the carbon already in the scrap.

I am aware that the proportions of the constituents of the alloys and numerous details of the method of manufacture of such alloys and tools therefrom may be varied through a wide range without departing from the spirit of this invention, and I do not desire limiting the patent granted, otherwise than as necessitated by the prior art.

I claim as my invention:

1. An alloy containing nickel and cobalt, not varying, jointly, widely from 40 per cent of the total, each being present in substantial amount; chromium and tungsten, each not varying widely from 30 per cent of the total; and carbon, in appreciable amount.

2. An alloy containing nickel about 14 per cent, cobalt about 27 per cent, chromium about 31 per cent, tungsten about 28 per cent and carbon about 1.25 per cent.

3. An alloy in which nickel and cobalt constitute about 40 per cent, chromium and tungsten each about 30 per cent, and carbon about 1 per cent.

4. A high speed tool composed essentially of 10 to 45% cobalt, 7 to 30% nickel, and 0.5 to 3.5% carbon, the remainder of the alloy consisting chiefly of a metal capable of forming a hard carbide.

5. An alloy comprising 10 to 45% cobalt, 7 to 30% nickel, and 0.5 to 3.5% carbon, the remainder of the alloy consisting chiefly of metal capable of forming hard carbide.

6. An alloy for high speed tools comprising 25 to 40% cobalt, 10 to 20% nickel, 25 to 35% chromium, 15 to 35% tungsten and 1.0 to 2.5% carbon.

7. The method of forming alloys of a metal having the properties of nickel or cobalt, chromium and tungsten comprising placing the first metal and chromium into the crucible as a lower layer, then placing the tungsten on top as an upper layer and heating the crucible to a temperature suffi-

cient to melt the first metal and chromium and alloy the tungsten therewith.

8. A cast high speed tool of controlled hardness and composed essentially of 10 to 45% cobalt, 7 to 30% nickel, 0.5 to 3.5% carbon and the remainder thereof being chiefly of a metal capable of forming a hard carbide, the proportion of carbon varying (within the limits set forth) proportionally as the cross-sectional area of the tool.
9. A cast high speed tool of controlled hardness comprising 25 to 40% cobalt, 10 to 20% nickel, 25 to 35% chromium, 15 to 35% tungsten and 1.0 to 2.5% carbon, the proportion of carbon being proportional within the limits set forth to the cross sectional area of the tool.

In testimony whereof I have hereunto subscribed my name.

PERCY C. CHESTERFIELD.