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BERYLLIUM-COPPER ALLOYS

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This invention relates to beryllium-copper alloys, and especially to that general class of alloys in which the copper is the primary constituent, being present in amounts usually substantially greater than about 90% of the entire alloy.

Certain general properties of these alloys have been known for some time, including the high hardenability thereof, but various difficulties and disadvantages have been encountered with this general class of alloys. Some of these problems are discussed more in detail hereinafter, but it is here noted that, in general, the problems are met by the present invention by virtue of employing other metals in the alloy, in addition to the beryllium and copper. It should also be kept in mind that certain addition ingredients have already been proposed for use in copper-beryllium alloys, but that the particular ingredients chosen in accordance with the present invention and the proportions thereof accomplish specially improved characteristics, as will appear more fully hereinafter.

One of the problems which has been encountered in the development and use of the type of alloys here under consideration, is that it has been very difficult to secure uniformity of characteristics, especially hardenability, particularly when operating on any appreciable commercial scale.

Another difficulty which has been encountered in connection with the use of beryllium-copper alloys is that when such alloys have been employed for sand castings there has been a considerable tendency toward warpage and a development of objectionable surface cracks during hardening, which has seriously limited this use. The alloys of the present invention aid materially in overcoming these difficulties.

As another important object of the invention may be mentioned reduction in beryllium content, which is desirable because of the relatively high cost of beryllium, while at the same time obtaining physical and other characteristics which are not only equivalent to but, in some instances, superior to those of binary beryllium-copper alloys or ternary or quaternary alloys as heretofore proposed.

The present application is, in part, a continuation of my prior applications 219,999, filed July 19, 1938; 107,948, filed October 28, 1936; and 730,727, filed June 15, 1934, this last having issued February 18, 1936 as Patent No. 2,030,921.

Referring again to the problem of non-uniformity of characteristics, I have found that with beryllium-copper alloys in rolled form, a certain type of crystal structure is a very important factor in making possible uniformity of hardening by heat treatment. More particularly, as pointed out in application 107,948, the crystal structure should be homogeneous, and the addition ingredients should be so chosen, and they and the beryllium content should be present in such amounts, as to avoid as far as possible a heterogeneous crystal structure incorporating beta along with the alpha crystal forms.

As mentioned in said application 107,948, a homogeneous crystal structure and high physical properties are secured by the employment of beryllium from a trace up to about 2%, together with either or both of cobalt or silicon in an amount aggregating from about .1% to about 1%.

Still further, as mentioned in said application 107,948, especially desirable results are attained with an alloy containing the range of beryllium above indicated, together with both silicon and cobalt, the former being present in an amount about .2% and the latter in an amount about .4%. As indicated in the prior application, certain other constituents may also be added, so long as they are not of such a nature or present in such amounts as to impair the desired homogeneous crystal structure.

The general type of heat treatment which may effectively be used to harden alloys of the general class here involved is well known. Briefly, it includes quenching from a temperature between about 500° C. and 800° C. (for example, in the neighborhood of 750° C.) and subsequently reheating at temperatures between 250° C. and 500° C. Between the quenching and reheating, the alloys can also be cold worked.

With regard to the foregoing type of hardening treatment, the present invention is further of considerable benefit in making possible the attainment of substantially uniform hardness without necessitating the fine or accurate control of temperature and time of treatment, such as are required with binary beryllium-copper alloys.

As noted in application 730,727 as originally filed, improved results can also be secured by adding to beryllium-copper (the beryllium being present in an amount from a trace up to about 3%, preferably not more than 2.5%) certain other metals, notably silicon, silver, and to a lesser extent iron. In accordance with said application 730,727 (as filed) especially good results are obtained with alloys containing even as low as 1% beryllium, or thereabout, when there is added, for example, 5% silicon, or 5% silver.

The preferred ranges given in said application for these metals are—silicon from about .5% to about 7%, silver from about .5% to about 10%, and iron from about .5% to 2%. The original disclosure of said prior application also points out that more than one of these metals may be present, in which event they may each be present in an amount upwards of a trace, and preferably of a total content of from about .5% to about 10%.

Thus, with the beryllium content kept below the preferred upper limit of 2.5%, the copper would constitute upwards of 87.5%.

Said original disclosure of application 730,727 also brings out that the use of the specified metals in addition to the beryllium and copper aids in raising the recrystallization temperature so that re-softening during heat treatment is not so likely to occur.

Furthermore, with the homogeneous character of many of the alloys of this invention it is possible to employ more cold working, and as a result the invention makes possible greater use of cold working between anneals, this being of advantage since it avoids the necessity for repeated and expensive anneals between cold working steps.

In addition to affording the improvements relating to crystal structure and hardenability, as is pointed out in my prior application 219,999, the specific addition metal cobalt is particularly desirable since it provides high tensile strength and also higher electrical conductivity than with certain other additions, the latter property being important when the alloy is to be used for electrical contact or other similar parts, and the combination of the two properties in a single alloy being unusually advantageous for certain purposes, such as wire required to carry a high tensile load in addition to an electric current.

For the purposes emphasized in my prior application 219,999, the following ranges are preferred:

Be____from .5% to 2%
Co____from .1% to 1%
Cu____balance

In most instances the beryllium should be kept within from 1% to 2%, although for special purposes (notably castings) it may be carried up to as high as 2.5%.

The ranges of ingredients providing the best results for the general purposes mentioned in application 219,999 are as follows:

Be____from 1.25% to 2%
Co____from .2% to .5%
Cu____balance

A desirable alloy is as follows:

Be____2%
Co____.25%
Cu____balance

The cobalt addition is also particularly useful for sand castings which, with other alloys of this general type, have had a tendency to develop surface cracks during hardening treatment, the surface cracking being greatly reduced by the employment of cobalt. For these purposes, as is mentioned in application 219,999, ranges as follows should preferably be used:

Be____from 1.75% to 2.25%
Co____from .3% to 1%
Cu____balance

Castings from this alloy may be hardened to a very high degree.

As to conductivity, it is preferred to maintain the composition such that the electrical conductivity in the hardened condition equals at least 22% that of copper.

From the foregoing it will be seen that, as brought out in my prior applications, cobalt and silicon are of outstanding importance in improving various characteristics of beryllium-copper alloys, particularly hardenability, electrical conductivity and elongation, these ends being achieved with the use of a smaller amount of beryllium than would be required in a binary alloy for an equivalent degree of hardness.

The improvement in connection with uniformity of hardenability is especially noticeable when employing silicon and/or cobalt, the combination of silicon with cobalt, as mentioned in application 107,948, being especially advantageous with respect to the homogeneity of the crystal structure and uniformity of hardenability.

The addition of iron is also of importance, especially when employed in combination with silicon.

The silver addition is particularly suitable where the alloy is to be employed for special types of electrical parts, such as electrodes.

The cobalt addition is claimed in my copending application 219,999 above referred to.

To summarize the foregoing, it may be noted that ranges of metals given below may be employed in accordance with the invention.

Note first that the beryllium content, particularly for pieces to be rolled, should preferably be kept below about 2.5% and most desirably between an amount substantially greater than a trace and about 2%.

When silicon alone is used, the composition should be as follows:

Be____from a substantial amount above a trace up to about 2.5%
Si____from a substantial amount above a trace or about .1% to about 7%
Cu____balance

When cobalt is used in combination with silicon, the composition should be within the following ranges:

Be____from a substantial amount above a trace up to about 2.5%
Si____from a substantial amount above a trace or about .1% to about 7%
Co____from about .1% to about 1%
Cu____ balance

When employing both cobalt and silicon, it is desirable that the cobalt should be present in an amount about twice that of the silicon content. For instance, the following composition is effective:

Be____from a substantial amount above a trace up to about 2.5%
Si____.2%
Co____.4%
Cu____balance

Silicon and cobalt together produce good results when the combined content of the two equals from about .1% to about 1%.

Where iron is used alone, the composition may be as follows:

Be____from a substantial amount above a trace up to about 2.5%
Fe____from a substantial amount above a trace, or preferably from about .5%, up to about 2%
Cu____balance

If iron is used with certain other additions, for instance with silicon, the composition may be as follows:

Be____from a substantial amount above a trace up to about 2.5%
Si____from a substantial amount above a trace or about .1% to about 7%
Fe____from a substantial amount above a trace, or preferably from about .5%, up to about 2%
Cu____balance

In the last table above, it should be noted that the combined content of silicon and iron should preferably be within from .5% to about 10%. Still further, when some other metal, for instance silver, is used in combination with the iron and silicon, the total of the three should be kept within about .5% to about 10%.

Where silver is employed alone, the following composition may be used:

Be____from a substantial amount above a trace up to about 2.5%
Ag____from a substantial amout above a trace, and preferably from about .5%, to about 10%
Cu____balance

In the event that silver is used in combination with other metals, such as silicon or iron, the ranges above indicated for these metals may be employed, and the total content of the group should again be kept within about .5% to about 10%.

In all tables above and also in various of the claims, it will be understood that where the copper content is referred to (for instance—"Cu—balance") it is intended to include small amounts of other ingredients and/or characteristic impurities, so long as they do not materially alter the characteristic properties of the alloys.

What I claim is:

1. An alloy composed of the following ingredients in the proportions indicated:

Be____from a substantial amount above a trace up to about 2.5%
Si____from a substantial amount above a trace or about .1% to about 7%
Cu____balance

2. An alloy composed of:

Be____from a substantial amount above a trace up to about 2%
Si____from about .1% to about 1%
Cu____balance

3. An alloy composed of:

Be____about 2%
Si____from about .1% to about 1%
Cu____balance

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