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METHOD OF WORKING AND HEAT
TREATING CU-BE ALLOYSLouis L. Stott, Reading, Pa., assignor to Beryllium
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This invention relates to metallurgy and more particularly to an improved method of working and heat-treating alloys comprised mainly of copper but containing .3-3.0% beryllium. The invention is equally as applicable to the same copper-beryllium alloys also containing from small but effective amounts up to about 3.0% of at least one of the group of metals consisting of Ni, Co, Fe, Si, Ti, Zr, Mn, Al, Ag and P which when present in the alloy in total amount not in excess of 3% do not alter the basic age or thermal-hardening characteristics of the copper-beryllium alloy.

Heretofore in the art, in accordance with the disclosure of a prior U. S. Patent 1,975,113 to Masing et al., the above identified copper or copper base alloy is conditioned for mechanical deformation by heat-treating the same at a temperature and for a time interval which will bring about a solid solution of the beryllium content in the copper or copper base comprising the same and thereafter rapidly cooling, as by quenching, to atmospheric temperatures to preserve the solid solution thereby obtained. In this condition the alloy is relatively soft and ductile and may be mechanically deformed or machined to the desired final size, shape and configuration, with intermediate high temperature heat treatments to preserve in the final product this solid solution structure. The final product may be subjected to a final annealing and quench treatment at the same high temperatures above disclosed to effect a substantial elimination of all cold working effects developed during mechanical deformation, if desired, or alternatively may be heated to the age-hardening temperature without subjecting the alloy to the solid solution high temperature heating.

The age or thermal hardening treatment is accomplished by subjecting the final product to a temperature within the range 500-1000° F. (260-538° C.) at which the beryllium content in excess of the solubility limit at the temperature of treating separates out in the form of sub-microscopic particles of the so-called gamma phase. The separation of these submicroscopic particles in the alloy develops therein great hardness combined with high tensile strength. However, maximum hardness appears to be a function of a certain critical size and number of the hardening particles and an extension of the time of heating at any given temperature within this range will cause an apparent coalescence and growth of the hardening particles with consequent loss of hardness in the alloy. In most in-

stances this is undesirable especially in formed articles requiring in addition to hardness and tensile strength, relatively high endurance limits such as springs, diaphragms and the like articles which in their normal use are subjected to repeated stresses and strains.

One of the objects of the present invention is to provide a method of working and heat treating copper-beryllium or copper-beryllium alloys containing up to 3% of one or more of the group of metals above identified which are responsive to the same thermal hardening treatment applicable to the copper-beryllium alloy whereby an improved endurance limit may be obtained in the alloy. Another object is to provide material consisting of Cu-Be alloys of the solid solution age-hardening type having higher endurance limits with approximately the same hardness and tensile strengths than heretofore obtainable. Another object is to provide material consisting of Cu-Be alloys of the solid solution age-hardening type which is more suitable for use in the forming of articles such as springs, diaphragms and the like than heretofore provided.

Other objects and advantages will be apparent as the invention is more fully hereinafter disclosed.

In accordance with these objects I have discovered that a large increase in the endurance limit of the copper-beryllium alloys hereinabove described may be obtained by subjecting the alloy to prolonged heat-treatment at an age-hardening temperature at a point during its mechanical deformation process at which further deformation is required to obtain the desired final size, shape and configuration, the time of treatment at this temperature being sufficient to accomplish a sufficient degree of softening beyond the maximum hardness obtainable by heat-treatment at this temperature such that the subsequent cold working on the alloy to bring the alloy to desired final size, shape and configuration will bring the hardness or temper back to that desired in the alloy. In other words, I have found that by over-aging the alloy prior to its reaching desired final size, shape and configuration and thereafter cold working the over-aged alloy to desired final size, shape and configuration, the endurance limit of the alloy is improved over that obtainable by the heretofore practiced method of reducing the alloy to the desired final size, shape and configuration, heating to a high temperature to obtain a solid solution of the beryllium content of the alloy and thereafter age-hardening to

maximum hardness within the range 500-1000° F. (260-538° C.).

As one specific embodiment of the present invention I will describe the same as it has been applied to a copper-beryllium alloy consisting of 2.1% Be, balance substantially Cu except for incidental and unavoidable impurities. This alloy when heated within the range 760-810° C. will be converted entirely into its alpha phase which following quenching and reheating to within the range of temperatures below about 575° C. will break down into a mixture of alpha and gamma phases, the gamma phase being sub-microscopic in nature inducing hardening in the alloy. In the age-hardening treatment of this alloy for the purpose of the present invention, I have found whereas the over-aging of the alloy to re-soften the same requires a long period of hours at temperatures as low as 288° C. (550° F.) at temperature in the range 482-538° C. (900-1000° F.) only a few minutes is required. This permits a considerable saving of time in the practice of the present invention.

The degree of over-aging to be imparted to the alloy may be varied widely without departure from the present invention and will depend in part upon the Be content of the alloy and the maximum hardness which may be developed therein by heat treatment alone, and in part upon the extent and kind of final cold reduction to be applied to the alloy to obtain the desired final size, shape and configuration and also in part upon the final hardness and tension desired in the alloy. In general, I prefer to over-age the alloy to that degree which will permit the alloy to be subsequently cold worked to desired final size, shape and configuration and to develop therein as a result of the cold working a hardness approaching the maximum obtainable by heat-treatment alone. Alternatively, and particularly with the lower Be content alloys, I may cold work to a greater degree, or, and particularly with the higher Be content alloys, I may cold work to a lesser degree.

In accordance with the invention, the alloy of the present specific embodiment may be worked down from the billet stage to a wire size approximating .080 inch diameter in the manner as heretofore practiced in the art, with all annealing heat treatments on the alloy conducted at temperatures above about 1450° F. followed by a quenching.

At the size .080 inch, I subject the wire to an anneal at temperatures approximating 980-1000° F. (526-538° C.) to over-age the alloy beyond the point of maximum hardness and thereafter cold reduce the diameter of the over-annealed wire to about .040 inch. The anneal at 980-1000° F. is what is known in the art as a "strand anneal" and is conducted as a continuous operation with each succeeding length of the wire being subjected to the maximum heating for a relatively short time interval. The maximum hardness obtainable in this alloy by age-hardening to precipitate out the gamma phase approximates 112 Rockwell B at a tensile strength of about 185,000 p. s. i. Where a 75% reduction in area is to be subsequently made on wire of the alloy, I prefer to over-age to a hardness of about 95-100 Rockwell B or to a tensile strength of about 100,000-110,000 p. s. i. The 75% reduction in area given to this material will increase the hardness to about 109-111 Rockwell B at a tensile strength of about 175,000-185,000 p. s. i.

Fatigue trials on the wire thus obtained indi-

cate that the endurance limit is at least 25% greater than wire of approximately similar composition and size which was drawn to final size and given the usual final age-hardening treatment to maximum hardness.

The higher endurance limit product of the present invention is of especial advantage in the manufacture of products which in service use are to be subjected to flexing stresses and strains, such as diaphragms and springs in both helical and flat form. The subsequent cold working of the over-aged alloy introduces tension in the alloy which is advantageous in the forming of the spring and highly desirable for some spring types and unobtainable heretofore due to the fact that the heat hardening treatment usually was applied subsequent to forming.

In the specific embodiment given, one skilled in the art will recognize that many modifications of the degree of over-aging and the degree of subsequent cold working may be made without essential departure from the present invention. The degree of over-aging should be regulated relative to the degree of cold working subsequently to be imparted so as to produce a final over-aged and cold worked product having the desired physical characteristics enabling it to be formed into the article desired. Preferably, I over-age to such a degree that the subsequent cold working will restore to the metal a hardness approaching the maximum hardness obtainable by age-hardening alone, as the amount of tension in the material incident to this degree of cold working has been found to be most favorable for the forming of the material into articles, such as springs, for example, requiring initial tension. However, I am not to be construed as being limited to this preferred practice.

Whereas the present invention has been described hereinabove as it has been applied to one specific alloy of the group of alloys to which it is applicable, it is not to be limited thereby, as it is believed apparent to one skilled in the art that the method is equally as well adapted for use with any of the well recognized age-hardening type Cu-Be alloys which are known in the art as containing .3-3.0% Be and as permissively containing from small but effective amounts up to 3% of one or more of the metals of the group consisting of Ni, Co, Fe, Ti, Zr, Mn, Al, Si, Ag and P to reinforce, stabilize or to accentuate the hardening effect of the beryllium content of the alloy, such as, for example, the following alloys:

- (a) 1.85% Be; .50% Co; balance principally Cu
- (b) 2.21% Be; .3% Ni; balance principally Cu
- (c) 1.75% Be; .40% Co; .20% Si; balance principally Cu
- (d) .45% Be; 2.6% Co; balance principally Cu
- (e) 1.25% Be; balance principally Cu

Having broadly and specifically described the present invention and given one specific embodiment of the same, all departures and modifications of the same are contemplated as may fall within the scope of the following claims:

What I claim is:

1. The method of producing a spring wire from an age-hardenable and cold-workable copper base alloy containing from .3-3.0% Be balance mainly copper which comprises mechanically deforming the alloy to wire form of a size materially larger than the desired final size, heating the same to an age-hardening temperature within the range 482-538° C. for a time interval

at least sufficient to over-age the said alloy to a degree producing a hardness materially less than the maximum hardness obtained at the temperature of heating, and then strain hardening the material by mechanically deforming the wire at a cold working temperature to the desired final size, the extent of said strain hardening being approximately that required to increase the hardness of the overaged alloy to a value approximating the maximum hardness value obtainable on heating to said age hardening temperature.

2. The method of forming high endurance limit spring material from an age-hardenable and cold-workable copper base alloy containing from .3-3.0% Be and not over 3.0% of other alloy constituents, which comprises heat-treat-

ing the alloy to a beta-solutioning temperature within the range 760-810° C. for a time interval at least sufficient to produce a crystal structure capable of being cold worked, rapidly cooling the same to preserve said structure, mechanically deforming said alloy into wire form at a cold working temperature, heat-treating the alloy at an age-hardening temperature within the range 482-538° C. for a time interval at least sufficient to harden the same to its maximum hardness and for an additional time interval effective to soften the said material from this maximum hardness, and thereafter strain hardening the material by again mechanically deforming the material at a cold working temperature to a wire form of lesser diameter.

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