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METHOD OF SURFACE HARDENING BERYLLIUM-COPPER ALLOYS AND ARTICLES COMPRISED THEREOF

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This invention relates to metallurgy and more particularly to metal working and heat-treating and has for its object the provision of an improved method of working and heat-treating beryllium-copper alloys of the cold workable-precipitation hardenable type to produce a final metal product having a tough and ductile core or body portion with a selected or desired portion of the surface area thereof hardened to the desired degree.

Another object is to provide articles such as pin punches, chisels, gears, wrenches, nuts, bolts, and the like articles, comprised of cold workable-precipitation hardenable beryllium-copper alloys, wherein the working surface of the article is hardened to the desired degree and is backed by relatively softer, tougher and more ductile metal.

Still another object is to provide a method of selectively hardening the working face or surface of articles comprised of cold workable-precipitation hardenable beryllium-copper alloys.

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

In accordance with these objects I have discovered that by converting the heretofore well known cold workable solid solution alpha crystal structure of the cold workable-precipitation hardenable beryllium copper alloys to a heterogeneous crystal structure consisting of recrystallized alpha with agglomerated and spheroidized gamma particles substantially uniformly dispersed therethrough, as described and claimed in my copending application, filed July 31, 1942, bearing Serial No. 453,039, which application is assigned to the same assignee as the present application, and subsequently subjecting the surface of the alloy or that portion of the surface which is desired to be hardened to a solution anneal heat-treatment followed by rapid cooling and later to heat-treatment within the precipitation hardening temperature range, the surface portion of the alloy so treated may be hardened to the extent and degree desired, within the hardening characteristics of the alloy, without altering the tough and ductile characteristics of the main mass of the alloy, thereby markedly improving the physical character of the alloy or article comprised of the alloy in its contemplated service use.

Cold workable-precipitation hardenable beryllium-copper alloys within the scope of the present invention consist principally of copper and contain a beryllium content not substantially in excess of that amount that may be placed in solid solution in the alloy upon extended heat-treatment at a temperature within the range 1400–1500° F. Where the alloy is essentially a binary alloy of beryllium and copper, the beryllium percentage normally is within the range 1 to 3%, and preferably approximates 2%. A relatively large number of other metals and some metalloids may be added to the binary beryllium copper alloy in small percentages without substantially suppressing the essential phase change reactions upon which the cold workability and the precipitation hardening of the binary alloy is predicated and all such poly- or multi-component alloy systems including copper as a base and beryllium as the precipitation hardening constituent are within the scope of the present invention.

As a specific embodiment of the present invention, but not as a limitation of the same, the invention will be described as it has been adapted to the treatment of an article, such as a pin punch, comprised of an essentially binary alloy of copper and beryllium containing 1.85% Be. This binary alloy is one most common in the art and pin punches comprised of this alloy are greatly in demand because of their non-sparking properties.

Heretofore, however, under the standard hardening practice wherein the entire mass of the article is subjected to a solution anneal heat-treatment followed by rapid cooling to retain the substantially pure alpha structure obtained and is then subjected to a precipitation hardening heat-treatment at a temperature approximating 600–750° F., the time at temperature during the precipitation hardening had to be extended or prolonged to a time interval required to obtain a re-softening of the alloy from the maximum hardness of about C–40 to a hardness within the range C–28 to C–34, for the reason that where the entire body or mass of the article is hardened to the maximum hardness of C–40, the article is likely to break or chip when struck sharply or not squarely. As is well recognized in the art, the precipitation hardening reaction in beryllium copper alloys is essentially a time-temperature reaction and at any given temperature within the precipitation hardening temperature range, requires a determined time interval to initiate with maximum hardness being first obtained, which on continued heating at the same temperature gradually falls to a lower value. Ordinarily, for example, a beryllium copper alloy (Be. 1.85–2.0%) in the solution anneal condition (alpha structure) requires heating at temperatures in the range approximating 600–750° F. for a period of time of about 2 hours

before precipitation hardening initiates and for a time interval approximating 8 hours to obtain a softening of the hardened piece from the maximum hardness of C–40 to the desired hardness of C–30 (C–28–C–34).

Another disadvantage of the prior practice is that prior to such hardening heat treatment, the alloy must be solution annealed at temperatures within the range 1400–1500° F. for a time interval as long as three (3) hours and cooled rapidly to atmospheric temperatures before the alloy is in condition for such hardening heat-treatment.

In accordance with the present invention all of these disadvantages are eliminated and the alloy, at the conclusion of the forging operation wherein it is shaped to the article, such as a pin punch, is subjected to a heat treatment at a temperature within the range 900–1050° F. (preferably about 1000° F.) for a time interval approximating 2 to 8 hours in accordance with the invention of my co-pending application above identified, to impart thereto the thermally stabilized heterogeneous crystal structure consisting of recrystallized alpha and substantially agglomerated and spheroidized gamma phases, following which the alloy is cooled, preferably slowly, to atmospheric temperatures. This initial treatment governs the final body hardness or toughness which may be varied from B–76 up to C–36 (not the working face hardness).

Following this heat treatment the alloy or article consisting of the alloy is heated over the surface area thereof, which is desired to be hardened and for a desired depth interiorly from the surface to a temperautre within the range 1400–1500° F. for a relatively short time interval at least sufficient to obtain re-solution of the gamma phase in the heterogeneous structure of this heated area. The conversion of this heterogeneous alpha-gamma structure to substantially pure alpha (solid solution) structure is of an entirely different order than is the conversion of other structures of Be.Cu alloys, requiring but a fraction of the time interval usually necessary with these other structures. The heated portion of the alloy is then cooled rapidly, as by quenching and the entire mass of the alloy is subjected to precipitation hardening heat treatment for the time interval required to obtain the desired hardness, within the characteristic hardness range of the alloy.

It is believed apparent that that portion of the alloy which has not been subjected to the solution anneal temperature will remain unaffected by subsequent heating at a temperature within the precipitation hardening range, as the precipitation hardening temperature range is below the temperature of heating employed in obtaining the heterogeneous crystal structure previously imparted thereto and that only that portion of the alloy which has been subjected to the solution anneal temperature (1400–1500° F.) will undergo precipitation hardening.

Due to the high thermal conductivity of copper beryllium alloys the surface heating of the alloy or of any given portion of an alloy must be closely controlled to regulate the depth of heating. Fortunately, however, the gamma phase constituent of the heterogeneous structure re-dissolves readily in the surrounding alpha phase as the temperature of heating approximates 1450° G. and in most instances the time interval of heating to obtain a conversion of the heterogeneous structure to a substantially pure alpha (precipitation-hardenable) phase is a matter of seconds, instead of hours as is usually the case with other mixed phases of the alloy.

This enables me to employ induction heating, flame impact heating, and other types of heating wherein the heat energy is applied directly onto the surface of a metal body for conduction interiorly. As the particular mode of heating forms no part of the present invention and, per se, is old and well known in the art, it is believed unnecessary to a proper understanding of the present invention to describe the same.

With respect to the pin punch article referred to above, this article consists of an elongated body part either square, round or hexagonal in cross-section having one end thereof tapered to a point of various diameters, depending upon the size of the punch and normally its contemplated field of use. The length of the article varies widely. In such an article the pointed end for an extended distance towards the body portion is the only section thereof normally required to be of maximum hardness. The remainder of the tool should be relatively tough and ductile to absorb the blows of a hammer. By hardening the pointed end of the pin punch in accordance with the present invention after imparting to the entire body portion the heterogeneous structure of my prior invention, an improved pin punch product results. For example, the pointed end for an extended distance towards the body portion may be hardened to a hardness of C–42 leaving the body portion consisting of the heterogeneous structure at a hardness of B–82. This, for example, may be obtained by heating the punch for 2 hours at 980° F. cooling slowly, heating the pin end of the punch rapidly in an open flame to 1450° F. for only a few seconds, quenching, and then heat treating the entire punch for 2½ hours at 600° F. The main body of the punch consisting at it does of the heterogeneous structure is unaffected by the last heating at 600° F.

As a second example of the present invention, the gear teeth of worm or spur gears may preferentially be hardened or the surface areas of the same only may be preferentially hardened, so that the body portion of the gear retains the tough and ductile characteristics of the heterogeneous structure imparted thereto in accordance with my prior invention.

The preferential hardening of the wearing or engaging surfaces of gears leaving the body of the gear tough and ductile is of great importance in the art and heretofore has not been possible by any prior heat treatment process. The principal advantage to be gained by the present invention is the provision of a hard tough wearing or engaging surface backed by tough but ductile metal which is deformable under pressure. This provides for the self-adjusting of the gear to slight irregularities in meshing engagement that otherwise would put such a strain on the gear as to cause the gear tooth to break off necessitating replacement. Moreover, the present invention provides a means for obtaining the maximum hardness available in any given alloy at the surface where such hardness and wear resistance is desired which heretofore has not been possible.

By similarly treating the jaws of wrenches of all types to surface harden the wearing faces to the maximum degree obtainable while retaining a tough but ductile backing metal underlying the same and throughout the remainder of the wrench, a greatly improved and longer lived wrench is obtained.

Finally, in the case of nuts and bolts, it is ex-

ceedingly important that the engaging threads be hard and wear resistant while the body of the nut or bolt be relatively tough and resistant to torsional stresses, a condition not obtained by prior art practices of hardening the articles uniformly throughout its cross-section. By the practice of the present invention this desirable condition may be imparted to these articles.

In the case of articles comprised of beryllium copper alloys which are provided with a cutting edge, such as chisels, and articles, such as hammers, which are provided with a hard, impact resisting surface, the practice of the present invention provides a means of obtaining greatly superior products as one skilled in the art will perceive.

In view of the above disclosure, it is believed apparent that the invention may be widely varied without essential departure therefrom and adapted to the heat-treating of a large variety of metal articles comprised of cold workable-precipitation hardenable beryllium copper alloys, and all such modifications and adaptations are contemplated as may fall within the scope of the following claims.

What I claim is:

1. The method of treating beryllium copper alloys of the cold workable and precipitation hardenable type, which comprises heat treating the alloy to produce therein a heterogeneous crystal structure consisting of a mixture of the alpha and gamma phases with the gamma phase dispersed throughout the alpha phase and in a substantially agglomerated and spheroidized condition and then heating at least a portion of the alloy from the surface inwardly to a temperature at least sufficient to effect a conversion of the said heterogeneous structure to a desired depth to substantially pure alpha, quenching the said heated portion and reheating the alloy to a temperature within the precipitation hardening temperature range for the said alloy for a time interval at least sufficient to obtain precipitation hardening of the reheated portion to the hardness desired within the hardness range obtainable in the alloy.

2. The method of treating beryllium copper alloys of the cold workable-precipitation hardenable type to obtain surface hardening thereof, which comprises heat treating the alloys at a temperature within the range 900–1100° F. for a time interval at least sufficient to obtain a conversion of the crystal structure thereof into a heterogeneous crystal structure consisting of the alpha and gamma phases with the gamma phase distributed throughout the alpha phase in an agglomerated and spheroidized condition, then heating the alloy from the surface inwardly over the area thereof desired to be hardened to a temperature within the range 1400–1500° F. for a time interval at least sufficient to convert the said heterogeneous structure at the surface of the alloy over the area being heated and for a limited depth underlying the said surface to a solid solution pure alpha structure, quenching the said heated area and reheating the alloy to a temperature within the precipitation hardening temperature range of the alloy for a time interval required to effect precipitation hardening of the said alpha structure.

3. The method of treating pin punches comprised of a precipitation hardenable beryllium copper alloy which comprises heat-treating the punch at a temperature within the range 900–1100° F. for a time interval at least sufficient to convert the crystal structure of the alloy into a heterogeneous structure consisting of mixed alpha and gamma phases with the gamma phase in an agglomerated and spheroidized condition distributed throughout the alpha phase, heating the pin end of said punch from the surface inwardly and for a distance toward the shank thereof to a temperature within the range 1400–1500° F. for a time interval at least sufficient to convert the said heterogeneous structure of the said pin end at least at the surface thereof into a solid solution alpha structure, quenching the heated portion of the punch and reheating the punch to a temperature within the precipitation hardening range for a time interval sufficient to obtain precipitation hardening of the said solid solution alpha structure.

4. The method of treating gears comprised of cold workable-precipitation hardenable beryllium copper alloys to obtain a gear having relatively hard wear-resistant gear teeth surfaces backed by a relatively though and ductile metal matrix underlying the same and extending into the body portion of the gear which comprises heating the gear to a temperature within the range 900–1100° F. for a time interval at least sufficient to obtain a conversion of the crystal structure to a heterogeneous structure consisting of a mixture of the alpha and gamma phases with the said gamma phase in agglomerated and spheroidized condition distributed throughout the alpha phase, heating the wearing and engaging surfaces of the gear teeth to a temperature within the range 1400–1500° F. for a time interval at least sufficient to convert the said heterogeneous structure of the said surface to solid solution alpha, quenching the heated portion and reheating the gear to a temperature within the precipitation hardening range of the alloy for a time interval sufficient to obtain the precipitation hardening of the said alpha structure.

5. The method of treating tools provided with a cutting edge and comprised of a cold workable-precipitation hardenable beryllium copper alloy to obtain a cutting edge hardness of the maximum degree superposed upon a relatively tough and ductile backing matrix, which comprised heating the entire tool to a temperature within the range 900–1100° F. for a time interval at least sufficient to convert the crystal structure of the alloy to a heterogeneous structure consisting of mixed alpha and gamma phases with the gamma phase in agglomerated and spheroidized condition distributed throughout the alpha phase, locally heating the cutting edge of said tool from the surface inwardly to a temperature within the range 1400–1500° F. for a time interval at least sufficient to convert the heterogeneous structure of the cutting edge for an extended distance inwardly to the precipitation hardenable solid solution alpha phase, quenching the heated portion of the tool and reheating the tool to a temperature within the precipitation hardening temperature range for a time interval sufficient to precipitation harden the said alpha phase.

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