

1

3,464,865

**PROCESS FOR TREATING COPPER  
BASE ALLOYS**

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No Drawing. Filed Apr. 11, 1967, Ser. No. 629,927

Int. Cl. C21d 7/14

U.S. Cl. 148—11.5

8 Claims

**ABSTRACT OF THE DISCLOSURE**

The instant disclosure teaches an improved practice for treating copper base alloys known as aluminum-bronze alloys to enable substantial increases in the cold rollability thereof, characterized by annealing, slowly cooling and cold rolling.

In accordance with United States Patent 3,297,497, certain improved aluminum-bronze alloys are disclosed and an improved process is taught for treating these alloys. The process of the foregoing patent is characterized by hot rolling the aluminum-bronze alloys at a temperature of from 1850° F. to 1000° F. followed by cold rolling at a temperature of below 500° F. After the cold rolling step, the foregoing patent teaches that the alloys may be annealed and cold rolled, with a plurality of annealing and cold rolling steps preferred.

The annealing and cold rolling steps are employed in accordance with the process of U.S. Patent 3,297,497 in order to obtain the desired gage material and the desired physical properties. It is highly desirable to provide a process which enables the greatest possible cold reduction without inordinate loss of physical properties. The advantages of greater cold reduction are significant in a commercial process. This will enable the reduction of production costs and the reduction of the number of anneals which are necessary.

Accordingly, it is a principal object of the present invention to provide a process for treating aluminum-bronze alloys.

It is an additional object of the present invention to provide a process as aforesaid which enables the increased cold rollability of aluminum-bronze alloys without inordinate loss of physical properties.

It is a still further object of the present invention to provide an improved annealing and cold rolling practice for aluminum-bronze alloys characterized by surprisingly increased cold rollability without inordinate loss of physical properties.

It is an additional object of the present invention to provide a process as aforesaid which is simple and convenient and readily amenable to commercial practices.

In accordance with the present invention, it has now been found that the foregoing objects and advantages may be readily obtained. The process of the present invention comprises:

(A) Providing an aluminum-bronze alloy in sheet form having a gage of at least 0.070" containing from 5 to 95% beta phase, balance alpha phase, said alloy consisting essentially of from 9.0 to 11.8% aluminum, from 1.0 to 5.0% iron, the balance essentially copper;

(B) Annealing said alloy at a temperature of from 1100 to 1500° F. for at least 15 minutes;

(C) Slowly cooling said alloy to a temperature of at least 1000° F. at a rate less than 100° F. per hour; and

(D) Cold rolling said alloy at a temperature below 500° F.

Throughout the present specification all percentages are percentages by weight.

The alloys of the present invention contain from 9.0

2

to 11.8% aluminum, from 1.0 to 5.0% iron and the balance essentially copper. The preferred iron content is from 3 to 4% and the preferred aluminum content is from 9.4 to 10.4%, optimally from 9.4 to 10.0%.

In addition, the alloys may contain from 0.05 to 5.0% of at least one additional element having a solid solubility in copper of less than 4.0% and which forms at least one intermetallic compound with aluminum. The total amount of the additional elements should be less than 10.0%. The additional element is preferably selected from the following group of elements, although the alloys are not necessarily limited to these elements: chromium; titanium; zirconium; molybdenum; columbium; vanadium and mixtures thereof in the preferred amounts set forth hereinbelow. Chromium, titanium, molybdenum, columbium, and vanadium are each preferably present in an amount of from 0.4 to 2.0%, and optimally in an amount of from 1 to 2%. Zirconium is preferably present in an amount of from 0.05 to 0.2% and optimally from 0.1 to 0.2%.

The additional element must, as discussed above, have limited solid solubility in copper and be an intermetallic compound former with aluminum. In addition, the additional element and/or intermetallic compounds formed should preferably form a dispersion in copper with limited solid solubility at temperatures up to 1800° F. The presence of this dispersion acts to prevent grain growth at high heat treatment temperatures.

The remainder or balance of the alloy is essentially copper, i.e., the alloy may contain incidental impurities or other materials which do not materially degrade the physical characteristics of the alloy. Examples of such elements which can be present include tin, zinc, lead, nickel, silicon, silver, phosphorus, magnesium, antimony, bismuth, and arsenic.

The reason it is difficult to obtain high cold reduction in the alloys of the present invention is the existence of a non-equilibrium iron-aluminum intermetallic compound (Fe<sub>3</sub>Al). It has been found that the precipitation of this compound can be prevented in accordance with the process of the present invention and better cold reductions attained.

The alloy is provided in plate or sheet form having a gage of at least 0.70". It is preferred to start with plate or sheet material having a thicker gage of at least 0.2" since the primary purpose of the present invention is to enable greater cold rollability, particularly at the heavier gages. It is noted that cold rollability may be defined as the amount of reduction in gage at which the first signs of edge cracking occur.

In order to provide the aluminum-bronze alloy in the plate or sheet form, the material may be cast by conventional commercial methods and hot rolled at a temperature of from 1850 to 1000° F. The process of the present invention may be performed on the as hot rolled plate or, if desired, the hot rolled plate may be cold rolled prior to the process of the present invention. Throughout the present specification, cold rolling should be performed at a temperature below 500° F. and preferably from 0 to 200° F.

In accordance with the process of the present invention, the plate or sheet product is annealed at a temperature of from 1100 to 1500° F. for a period of at least 15 minutes and preferably from 1 to 6 hours. It is preferred in accordance with the present invention to anneal the material at the higher end of the annealing temperature range, with the preferred range being from 1300 to 1400° F.

After the annealing step, the material is critically slowly cooled to a temperature of 1000° F. at a rate slower than 100° F. per hour, and preferably slower than 50° F. per hour. If desired, the slow cooling may be continued below 1000° F., but no particular advantage is had thereby. Also,

if desired, the slow cooling rate may be slower than 50° F. per hour. This slow cooling step is necessary in order to prevent the iron dissolved at elevated temperatures from precipitating as the non-equilibrium Fe<sub>3</sub>Al intermetallic compound.

After slow cooling step, the material is cold rolled as desired. A plurality of annealing and cold rolling cycles may be performed depending on particular gage requirements, with from 2 to 5 cycles of annealing and cold rolling being preferred.

In accordance with the present invention, it is preferred to heat the material to the annealing temperature at a rate faster than 200° F. per hour. It is still more preferred to use a still faster heat-up rate of faster than 100° F. per minute.

It has been found in the practice of the process of the present invention that progressively lower annealing temperatures should be used during progressive annealing cycles. This results in preferred physical properties.

Subsequent to the cold rolling step or steps of the present invention the material may be formed or brazed in accordance with conventional practices.

The alloy has a uniformly fine metallographic grain structure with a particle size less than 0.065 mm., and generally less than 0.040 mm. The alloys of the present invention possess properties which are unexpected and surprising in alloys of this type, especially with regard to strength and ductility. For example, tensile strengths, ranging from 120,000 to 160,000 p.s.i. and yield strengths from 60,000 to 80,000 p.s.i. (0.2 percent offset) may be developed in combination with elongations ranging from 12 to 9 percent. The electrical conductivities are good for alloys of this type, ranging from 10 to 16 percent IACS. In addition, modifications of the present invention improve the properties still further. For example, tempering increases the yield strength considerably, e.g., to from 60,000 to 110,000 p.s.i., at the expense, however, of ductility. In another modification consisting of cold rolling the alloy following an annealing operation, yield strength values as high as 115,000 p.s.i. and higher may be achieved together with tensile strengths as high as 148,000 p.s.i.

The present invention and the improvements resulting therefrom will be more readily understandable from a consideration of the following illustrative examples.

#### Example I

Alloys containing 9.7% aluminum, 4.0% iron, balance essentially copper, were prepared from a charge of cathode copper, aluminum-iron master alloy and commercial purity aluminum in the form of commercial size DC cast bars.

The alloy was hot rolled in the temperature range of from 1600 to 1300° F., using a thirteen (13) pass schedule, in reducing the gage from 5" to 0.25".

#### Example II

Following hot rolling, the alloy of Example I was annealed at 1150° F. for 5 hours, followed by a water quench to room temperature. The material was then cold rolled and it was found that the material could be cold rolled 40% to the start of edge cracking.

#### Example III

The alloy of Example I following hot rolling was treated in the following manner: The material was cold rolled 29% followed by annealing at 1150° F. for 5 hours, with a heat-up rate to annealing temperature of about 100° F. per minute. The material was then water quenched to room temperature and cold rolled. It was found that the material could be cold rolled 30%.

#### Example IV

The material of Example I following the treatment of Example I was treated in the following manner: The material was cold rolled 29% followed by annealing at 1375° F. for 5 hours, with a heat-up rate to annealing

temperature of about 150° F. per hour. After annealing the material was slowly cooled to 1000° F. at a rate of about 50° F. per hour followed by water quenching to room temperature. The material was then cold rolled, with a cold rollability value of 52% being obtained. This cold rollability value should be sharply contrasted to the lower cold rollability obtained in Examples II and III.

#### Example V

The procedure of Example IV was repeated with the exception that the material was rapidly heated to annealing temperature at a rate of approximately 100° F. per minute. In this case, a cold rollability value of 58% was obtained.

#### Example VI

The procedure of Example IV was repeated with the following exceptions: The annealing temperature was 1450° F. for 24 hours. In this case the cold rollability was 55%.

#### Example VII

The procedure of Example VI was repeated except that the material was held at temperature for 43 hours. In this case the cold rollability value was 55%.

This invention may be embodied in other forms or carried out in other ways without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered as in all respects illustrative and not restrictive, the scope of the invention being indicated by the appended claims, and all changes which come within the meaning and range of equivalency are intended to be embraced therein.

What is claimed is:

1. A process which comprises:

- (A) providing an aluminum-bronze alloy in sheet form having a gage of at least 0.070" containing from 5 to 95% beta phase, balance alpha phase, said alloy consisting essentially of from 9.0 to 11.8% aluminum, from 1.0 to 5.0% iron, the balance essentially copper;
- (B) annealing said alloy at a temperature of from 1100 to 1500° F. for at least 15 minutes;
- (C) slowly cooling said alloy to a temperature of at least 1000° F. at a rate less than 100° F. per hour; and
- (D) cold rolling said alloy at a temperature below 500° F.

2. A process in accordance with claim 1 wherein the iron is present in an amount from 3 to 4%.

3. A process in accordance with claim 1 wherein said material is annealed at a temperature of from 1300 to 1400° F. for from 1 to 6 hours.

4. A process according to claim 1 wherein said alloy is slowly cooled to a temperature of at least 1000° F. at a rate of less than 50° F. per hour.

5. A process according to claim 1 wherein from 2 to 5 cycles of annealing, slow cooling and cold rolling are performed.

6. A process according to claim 1 wherein said material is heated to annealing temperature at a rate faster than 200° F. per hour.

7. A process according to claim 6 wherein the material is heated to annealing temperature at a rate faster than 100° F. per minute.

8. A process according to claim 5 wherein each succeeding annealing step is conducted at a lower temperature.

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