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ALUMINUM BRONZE ALLOY CONTAINING IRON AND COBALT AND METHOD OF HEAT TREATING THE SAME

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This invention relates to an aluminum bronze alloy and more particularly to an aluminum bronze alloy containing iron and cobalt and to a method of heat treating the same.

Duplex phase aluminum bronze alloys containing from 9% to 12% aluminum and 2% to 5% iron have excellent corrosion resistance and good physical properties and have wide application for use as gears, bushings, guides and the like. The present invention is directed to a duplex phase aluminum bronze alloy containing small additions of cobalt and having improved physical properties which are brought about by a novel heat treatment.

The alloy of the invention has the following general composition by weight:

	Percent
Aluminum	9.0–12.0
Iron	2.0–5.0
Cobalt	0.01–1.9
Copper	Balance

A preferred analysis of the alloy of the invention is as follows:

	Percent
Aluminum	9.7–10.7
Iron	3.1–3.7
Cobalt	0.3–0.4
Copper	Balance

To provide the most desirable metallurgical structure, the iron should be present in a weight ratio of 7 to 13 parts of iron per part of cobalt with a ratio of about 10 parts of iron to one part of cobalt being preferred, and the aluminum should be present in the weight ratio of 24 to 36 parts by weight of aluminum per part of cobalt, with about 29 parts of aluminum to one part of cobalt being preferred.

A specific illustration of an alloy falling within the above general range of composition is as follows in weight percent:

	Percent
Aluminum	10.40
Iron	3.40
Cobalt	0.35
Copper	85.85

In preparing the alloy, the metals used should be of high quality. Electrolytic or wrought fire-refined copper, high purity aluminum, low carbon iron and high purity cobalt are preferred to be used. It has also been found that the best method of obtaining the desired uniformity in the alloy is by using a double melting procedure whereby a pre-alloy is made. One of the most satisfactory pre-alloys is an alloy consisting of approximately 60% aluminum, 19% iron, 19% copper and 2% cobalt.

In the melting procedure employed in making the pre-alloy, copper, along with the iron and cobalt, is placed into the crucible and melting begun. When the copper starts to melt, the iron is slowly dissolved into the copper during that period when aluminum is added to form an exothermic reaction which helps to dissolve the higher melting point cobalt. This pre-alloy is then cast in ingot form and then is ready to use for the final alloy.

The final alloy is made by intermixing a predetermined percentage of the pre-alloy and copper. With the specific

pre-alloy composition mentioned above, about 18.25 pounds of this pre-alloy are mixed with 81.75 pounds of copper to provide the final alloy.

The cast alloy is subjected to a heat treatment to improve the physical characteristics of the alloy. According to the specific heat treatment, the alloy is initially heated at any desired heating rate to a temperature above 1500° F. and generally in the range of 1500° F. to 1650° F., with a temperature of about 1625° F. being preferred. The alloy is held at this temperature until a uniform distribution of heat is obtained. The alloy is then quenched from this temperatures at a rate faster than 500° F. per hour, as can be obtained by water quenching, to a temperature below 500° F. and the beta structure is retained by the quench.

After the quench the alloy is reheated at any desired rate to a drawing temperature in the range of 1025° F. to 1250° F., and preferably about 1125° F., and maintained at this temperature for a period of time longer than ½ hour per one inch of section thickness. The draw serves to precipitate acicular alpha.

The alloy is then quenched from the drawing temperature at a rate faster than 200° F. per hour to a temperature below 500° F. and subsequently reheated at any desired heating rate to an aging temperature in the range of 500° F. to 700° F., and preferably about 600° F. The alloy is maintained at this aging temperature for a period longer than one-half hour per one inch of section thickness and is subsequently cooled, either by air cooling or quenching, to room temperature.

The aging tends to cause the precipitation of cobalt compounds in the alloy which increases the yield strength of the heat treated alloy.

As an alternate method of heat treatment, the alloy can be initially heated to a temperature above 1500° F. and generally in the range of 1500° F. to 1650° F. at any desired rate and after the alloy has obtained a uniform distribution of heat, it is quenched in a molten salt bath having a temperature in the range of 800° F. to 1250° F. and preferably about 1100° F. This quenching treatment tends to precipitate the acicular alpha in the metallographic structure of the alloy.

Following this initial quench, the alloy is then transferred to a second salt bath having a temperature in the range of 400° F. to 800° F. and preferably about 600° F. The alloy is maintained in this second salt bath for a period of time sufficient to bring about a uniform distribution of temperature and generally a time longer than ½ hour per one inch of section thickness. This second quenching treatment at about 600° F. serves to age the alloy and increases the yield strength by a process which is not fully understood.

After the alloy has been subjected to the second salt bath quench, it is cooled to room temperature at any desired cooling rate.

The alloy heat treated by either of the above-mentioned heat treatments will have a tensile strength in the range of 100,000 to 120,000 p.s.i., a yield strength in the range of 45,000 to 70,000 p.s.i., an elongation in two inches of 5% to 30%, and a Brinell hardness in the range of 190 to 240.

As an example, an alloy containing 10.4% aluminum, 3.4% iron, 0.35% cobalt and 85.85% copper was initially heated to a temperature of 1625° F. and maintained at this temperature for 1 hour. The alloy was then water quenched and subsequently reheated to a temperature of 1200° F. and maintained at this temperature for 2 hours. The alloy was then again water quenched and subsequently reheated to 600° F. and maintained at this temperature for 2 hours. The alloy was then air cooled to room temperature to complete the heat treatment.

This alloy, after heat treatment, had a tensile strength

of 118,000 p.s.i., a yield strength of 62,000 p.s.i., an elongation in two inches of 20%, and a Brinell hardness of 210.

An alloy of similar composition but without the addition of cobalt and not subjected to the heat treatment of the invention has a tensile strength of 90,000 p.s.i., a yield strength of 50,000 p.s.i., an elongation in two inches of 5% and a Brinell hardness of 200. This comparision shows that the addition of cobalt with the specific heat treatment of the invention substantially increases the tensile and yield strength and also improves the elongation or ductility of the alloy.

The heat treated alloy can be used to produce articles such as gears, shafts, wear strips, guides and the like. The alloy can also be extruded to weld rods or weld wire. The alloy in the form of coated or uncoated weld rod can be overlaid on a base metal by metal spraying or other welding methods such as heliarc, metal arc, carbon arc, or the like, to obtain a corrosion resistant, wear resistant, aluminum bronze surface.

Various modes of carrying out the invention are contemplated as being within the scope of the following claims particularly pointing out and distinctly claiming the subject matter which is regarded as the invention.

I claim:

1. An aluminum bronze alloy, consisting essentially of 9.0% to 12.0% aluminum, 2.0% to 5.0% iron, 0.01% to 1.9% cobalt and the balance copper, said alloy having a metallographic structure consisting of beta, cobalt-containing intermetallic compounds and acicular alpha and having a tensile strength in the range of 100,000 to 120,000 p.s.i., a yield strength in the range of 45,000 to 70,000 p.s.i., an elongation in two inches of 5% to 30%, and a Brinell hardness in the range of 190 to 240.

2. An aluminum bronze alloy, consisting essentially of 9.7% to 10.7% aluminum, 3.1% to 3.7% iron, 0.3% to 0.4% cobalt and the balance copper, said alloy having a metallographic structure consisting of beta, cobalt-containing intermetallic compounds and acicular alpha and having a tensile strength in the range of 100,000 to 120,000 p.s.i., a yield strength in the range of 45,000 to 70,000 p.s.i., an elongation in two inches of 5% to 30%, and a Brinell hardness in the range of 190 to 240.

3. A method of heat treating an aluminum bronze alloy to improve the physical properties thereof, comprising the steps of heating an aluminum bronze alloy consisting essentially of 9.0% to 12.0% aluminum, 2.0% to 5.0% iron, 0.01% to 1.9% cobalt and the balance copper to a temperature above 1500° F. and below the melting point of the alloy, maintaining the alloy at this temperature for a period of time sufficient to obtain a uniform distribution of heat throughout the alloy, quenching the alloy from said temperature, reheating the alloy to a temperature in the range of 1025° F. to 1250° F., maintaining the alloy at a temperature within said last named range for a period of time longer than one-half hour per one inch of section thickness, quenching the alloy from a temperature in said last named range, reheating the alloy to a temperature in the range of 500° F. to 700° F., maintaining the alloy at a temperature in said last named range for a period of time longer than one-half hour per one inch of section thickness, and cooling the alloy to room temperature.

4. A method of heat treating an aluminum bronze alloy consisting essentially of 9.0% to 12.0% aluminum, 2.0% to 5.0% iron, 0.01% to 1.9% cobalt and the balance copper to improve the physical properties thereof, comprising the steps of heating the alloy to a temperature in the range of 1500° F. to 1650° F., holding the alloy at

said temperature to obtain a uniform distribution of heat throughout the alloy, quenching the alloy from said temperature at a rate faster than 500° F. per hour, reheating the alloy to a drawing temperature in the range of 1025° F. to 1250° F., maintaining the alloy at a temperature within said last named range for a period of time longer than one-half hour per one inch of section thickness, quenching the alloy from the drawing temperature at a rate faster than 200° F. per hour to a temperature below 500° F., reheating the alloy to an aging temperature in the range of 500° F. to 700° F., maintaining the alloy at a temperature within said last named range for a period of time longer than one-half hour per one inch of section thickness, and cooling the alloy to room temperature.

5. A method of heat treating an aluminum bronze alloy to improve the physical properties thereof, comprising the steps of heating an aluminum bronze alloy consisting essentially of 9.0% to 12.0% aluminum, 2.0% to 5.0% iron, 0.01% to 1.9% cobalt and the balance copper to a temperature in the range of 1500° F. to 1650° F., maintaining the alloy at said temperature for a sufficient period of time to maintain a uniform distribution of heat through said alloy, quenching the alloy in a bath of molten material having a temperature in the range of 800° F. to 1250° F., maintaining the alloy in said bath for a period of time sufficient to obtain a uniform distribution of heat throughout the alloy, transferring the alloy to a second bath containing a molten material having a temperature in the range of 400° F. to 800° F., maintaining said alloy in said second bath for a period of time sufficient to bring about a uniform distribution of heat throughout the alloy, and cooling the alloy to room temperature.

6. A method of heat treating an aluminum bronze alloy to improve the physical properties thereof, comprising the steps of heating an aluminum bronze alloy consisting essentially of 9.0% to 12.0% aluminum, 2.0% to 5.0% iron, 0.01% to 1.9% cobalt and the balance copper to a temperature in the range of 1500° F. to 1650° F., maintaining the alloy at this temperature for a period of time sufficient to obtain a uniform distribution of heat throughout the alloy, quenching the alloy at a rate faster than 500° F. per hour to a temperature below 500° F., reheating the alloy to a temperature in the range of 1025° F. to 1250° F., maintaining the alloy at a temperature within said last named range for a period of time longer than one-half hour per one inch of section thickness, quenching the alloy from a temperature in said last named range at a rate faster than 200° F. per hour to a temperature below 500° F., reheating the alloy to a temperature in the range of 500° F. to 700° F., maintaining the alloy at a temperature in said last named range for a period of time longer than one-half hour per one inch of section thickness, and cooling the alloy to room temperature.

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