3,117,002
Patented Jan. 7, 1964

3,117,002

ALUMINUM BRONZE ALLOY HAVING IMPROVED WEAR RESISTANCE BY THE ADDITION OF COBALT, CHROMIUM, AND MANGANESE

John F. Klement, Milwaukee, Wis., assignor to Ampco Metal, Inc., Milwaukee, Wis., a corporation of Wisconsin

No Drawing. Filed Feb. 16, 1960, Ser. No. 8,941
6 Claims. (Cl. 75—162)

This invention relates to an aluminum bronze alloy and more particularly to an aluminum bronze alloy having improved toughness and wear resistance.

Aluminum bronze alloys have for years been used as dies for forming and drawing operations for a large group of sheet and plate alloys, such as stainless steel, aluminum, nickel, titanium, mild steel and some copper base alloys. Aluminum bronze alloys used in die applications possess the properties of good corrosion resistance, wear resistance and non-galling against many wrought materials.

The aluminum bronze alloys which in the past have shown the optimum properties for deep drawing dies are those that contain approximately 14% aluminum, a small amount of iron and the balance copper. An alloy of this type has good corrosion resistance and non-galling properties. However, under heavy use in die applications, it wears undesirably fast so that close dimensional tolerances cannot be maintained because of the wear that occurs on the die surface.

The present invention is directed to an aluminum bronze alloy which has the non-galling properties characteristic of alumium bronze alloys and has improved corrosion resistance, toughness and wear resistance as well as having a high uniform hardness. This is accomplished by the additional of small amounts of cobalt, manganese and chromium to the alloy which completely eliminates the tendency of the alloy to form the eutectoid. The addition of cobalt, manganese and chromium in controlled amounts also makes the alloy more homogeneous in the distribution of the alloy phases and intermetallic compounds formed during solidification and heat treatment and also promotes uniform controlled grain size.

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

	Percent
Aluminum	14.25–20.0
Iron	1.0–7.0
Cobalt	0.475–6.0
Manganese	2.3–8.8
Chromium	0.475–6.0
Copper	Balance

To provide the most desirable metallurgical structure, the iron should be present in the weight ratio of 0.2 to 1.0 part of iron per 3 parts of aluminum, and the combined total of cobalt, chromium and manganese should be present in the weight ratio of 1 to 2 parts per 3 parts of aluminum. In addition, the combined total of cobalt and chromium should be present in the weight ratio of 1 part of the total of cobalt and chromium to 1 to 2 parts of manganese.

The alloy having the above range of chemistry has a tensile strength of about 65,000 to 105,000 p.s.i., a yield strength of 65,000 to 80,000 p.s.i., an elongation in two inches up to 3.0% and a Rockwell C hardness in the range of 25 to 55.

Specific illustrations of the composition of the alloy

falling within the above range are as follows in weight percent:

	No. 1	No. 2
Aluminum	20.0	14.75
Iron	7.0	4.5
Cobalt	1.5	2.0
Manganese	8.8	2.5
Chromium	2.5	0.5
Copper	60.2	75.75

The above alloy compositions can be cast eight statically or centrifugally to produce a fine grained tough structure.

The alloy of the invention has greatly improved wear resistance over that of an ordinary aluminum bronze alloy and this increase in wear resistance is unexpected since the hardness of the alloy is substantially the same as the hardness of an aluminum bronze alloy having similar proportions of aluminum and iron, but not containing the cobalt, manganese and chromium. In addition to the greatly improved wear resistance, the addition of chromium aids in increasing the corrosion resistance of the alloy. The machineability, at the lower chromium contents, is substantially increased over that of the ordinary aluminum bronze alloy not containing the cobalt, manganese and chromium additions.

The metallographic structure of the alloy consists essentially of gamma two phase which is uniformly distributed in a matrix of beta. Intermetallic compounds composed of iron, aluminum, copper, cobalt, manganese and chromium exists in small particles of uniform size and shape. Because of the method of casting and the inoculant used, the intermetallic compounds are uniformly distributed throughout the cast section. It is believed that these intermetallic compounds which are dispersed throughout the metallographic structure are primarily responsible for the improved wear resistance of the alloy.

In order to obtain optimum properties, the metals used for the alloy should be of high quality. Electrolytic or wrought fire refined copper, high purity aluminum, low carbon iron and high purity cobalt, manganese and chromium 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 has approximately 40% aluminum, 15% copper, 15% iron, 10% chromium, 10% manganese and 10% cobalt.

The melting procedure employed in making the pre-alloy is such that some copper, along with the iron, chromium, maganese and cobalt, is placed into the crucible and melting begun. When the copper starts to melt, the iron and other additives are 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 and chromium additions. This pre-alloy is then cast into ingot form and is ready to use for the final alloy.

The final alloy is made by intermixing a predetermined percentage of the pre-alloy and copper plus what other elements are needed to satisfy the desired chemical range. A deoxidizer is added to this alloy in the molten state in the furnace to reduce the oxides and purge the metal of soluble gases. These deoxidizers can include the compounds of boron, phosphorus, magnesium and lithium. Deoxidizers of the gas type can also be used.

This can include volatile chlorides or any of the inert gases. The dry type deoxidizers are added in quantities of approximately 4 ounces per 100 pounds of metal, and the gas type deoxidizers are passed either through or over the molten metal for a period of five minutes. Removal of the oxide particles is of particular importance because of their abrasive and adverse effect on the wear resistant properties of the alloy.

Alternately, instead of employing a pre-alloy, the chromium, manganese and cobalt metals or alloys can be added directly to a molten aluminum-iron-copper alloy.

To establish complete uniformity of the microstructure and hardness, the alloy is heat treated at an elevated temperature in the temperature range of 1050° F. to 1400° F., such as about 1150° F. Small castings of simple shapes of this alloy can be placed directly into the heat treating furnace at temperature. Large massive castings or intricate shapes are preheated in the furnace at about 400° F. until the section reaches uniform temperature and then are heated directly to the elevated temperature. The castings are held at a temperature in the range of 1050° F. to 1400° F. for one hour plus one-half hour per inch of section thickness greater than one inch, up to a maximum of two and one-half hours at temperature.

After the required soaking time at the elevated temperature, the alloy is cooled at a rate faster than about 20° F. per hour per one inch of section thickness. This rate is conveniently obtained by fan air cooling.

Internal stresses created within castings during machining or other finishing operations, during weldments or from metal overlays on base metals, are usually removed depending on the future application of the part. These stresses are removed by a stress relief heat treatment. The usual commercial aluminum bronze alloys cannot generally be stress relieved at a temperature in the range of 650° F. to 1050° F. due to eutectoid formation that occurs at this temperature range. Furthermore, a stress relief at temperatures above 1050° F. frequently causes distortions and further stresses in the usual commercial aluminum bronze alloy during the rapid cooling to room temperature. Stress relief at temperatures lower than 650° F. takes considerable time and often the most severe stresses remain.

In contrast to this, the alloy of the invention can be stress relieved within the temperature range of 650° F. to 1050° F. without embrittlement due to the eutectoid structure. An optimum stress relief temperature for the present alloy, based on the severity of the internal stresses and geometry of the article, can be selected in the range of 650° F. to 1050° F. to obtain a reasonable holding time in the furnace, such as one to two hours per 2 inches of section, and to prevent distortions and micro stresses during cooling. The article is then cooled slowly to room temperature.

The alloy can be used to produce articles for wear resistant applications in drawing and forming operations. The articles may take the form of deep drawing dies, hold down dies, wear guides, forming rolls, skids, slides, etc.

The alloy can also be extruded into weldrods or weld wire. The alloy in the form of coated or uncoated weldrod can be overlaid on a base metal by metal spraying or other welding methods, such as heli-arc, metal-arc, carbon-arc, etc., to obtain a corrosion resistant wear surface. The metal overlay can be given a stress relief treatment at temperatures in the range of 650° F. to 1150° F. and cooled slowly to room temperature.

It has been found that the addition of cobalt, manganese and chromium in controlled ratios to each other and in controlled ratios to aluminum greatly improves the toughness, corrosion resistance and wear resistance of the aluminum bronze alloy and eliminates the tendency for eutectoid embrittlement. As the alloy of the invention will not form the embrittling eutectoid structure, more alloying elements can be incorporated in the alloy for a given hardness to thereby obtain increased wear resistance.

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 14.25% to 20.0% aluminum, from 1.0% to 7.0% iron, from 2.3% to 8.8% manganese, from 0.475% to 6.0% cobalt, from 0.475% to 6.0% chromium and the balance being substantially copper, said alloy being characterized by having excellent corrosion resistance and having improved toughness and wear resistance.

2. An aluminum bronze alloy having improved wear resistance, toughness and machineability, consisting essentially of from 14.25% to 20.0% aluminum, 1.0% to 7.0% iron, from 2.3% to 8.8% manganese, 0.474% to 6.0% cobalt, 0.475% to 6.0% chromium and the balance substantially copper, said alloy being characterized by a tensile strength in the range of 65,000 to 105,000 p.s.i., a yield strength in the range of 65,000 to 80,000 p.s.i., an elongation in two inches of up to 2.5%, and a hardness in the range of 25 to 55 Rockwell C.

3. An aluminum bronze alloy having improved toughness and wear resistance, consisting essentially of 14.75% aluminum, 4.5% iron, 2.5% manganese, 2.0% cobalt, 0.5% chromium and 75.75% copper.

4. An aluminum bronze alloy having improved toughness and wear resistance, consisting essentially of 14.25% to 20% aluminum, from 1.0% to 7.0% iron, from 2.3% to 8.8% manganese, from 0.475% to 6.0% cobalt, from 0.475% to 6.0% chromium, and the balance being substantially copper, said iron being present in the weight ratio of 0.2 to 1.0 part of iron per 3 parts of aluminum, the combined total of said cobalt, chromium and manganese being present in the weight ratio of 1 to 2 parts of said combined total per 3 parts of aluminum and the combined total of said cobalt and chromium being present in the weight ratio of 1 part of the total of cobalt and chromium to 1 to 2 parts of manganese.

5. A drawing die characterized by having excellent corrosion resistance, a hardness in the range of 25 to 55 Rockwell C and improved wear resistance, said die being fabricated from an aluminum bronze alloy consisting essentially of 14.25% to 20% aluminum, from 1.0% to 7.0% iron, from 2.3% to 8.8% manganese, from 0.475% to 6.0% cobalt, from 0.475% to 6.0% chromium, and the balance being substantially copper, said iron being present in the weight ratio of 0.2 to 1.0 part of iron per 3 parts of aluminum, the combined total of said cobalt, chromium and manganese being present in the weight ratio of 1 to 2 parts of said combined total per 3 parts of aluminum and the combined total of said cobalt and chromium being present in the weight ratio of 1 part of the total of cobalt and chromium to 1 to 2 parts of manganese.

6. An aluminum bronze welding electrode consisting essentially of 14.25% to 20% aluminum, from 1.0% to 7.0% iron, from 2.3% to 8.8% manganese, from 0.475% to 6.0% cobalt, from 0.475% to 6.0% chromium, and the balance being substantially copper.

References Cited in the file of this patent

UNITED STATES PATENTS

2,007,430	Maas	July 9, 1935
2,979,397	Klement	Apr. 11, 1961

FOREIGN PATENTS

537,404	Great Britain	June 20, 1941
808,800	Great Britain	June 21, 1957

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,117,002 January 7, 1964

John F. Klement

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 35, for "additional" read -- addition --; column 2, line 11, for "eight" read -- either --; column 4, line 20, for "0.474%" read -- 0.475% --.

Signed and sealed this 9th day of June 1964.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents