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ALUMINUM BRONZE ALLOY HAVING IMPROVED RESISTANCE TO INTERGRANULAR OXIDATION BY THE ADDITION OF SILVER

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This invention relates to an aluminum bronze alloy having increased resistance to intergranular oxidation when subjected to stress in a hot water or steam atmosphere.

It is well known that almost all copper-base alloys, when stressed in certain corrosive media, are subject to a particular species of oxidation, generally termed intergranular oxidation by those skilled in the art. The term intergranular oxidation refers to the spontaneous cracking of a metal subjected to contact with a corrodent and to residual or applied stresses. This invention involves an improvement of the characteristics of aluminum bronze alloys which have been found to be subject to intergranular oxidation when stressed in media containing hot water and steam.

It has been found that the oxidation or fracture of an aluminum bronze alloy under the action of stress and a hot water or steam corrodent, follow paths which are intergranular in nature. It is believed that the reason for this intergranular type of attack is that aluminum atoms are in a higher concentration in the grain boundary than in the grains. This is probably because aluminum atoms have a negative elastic energy interaction with dilated grain boundary regions; therefore the larger aluminum atoms become segregated in the grain boundary and are subject to oxidation.

The present invention is based on the discovery that the resistance of an alpha-phase aluminum bronze alloy to intergranular oxidation when subjected to a steam or hot water atmosphere can be increased by the addition of small amounts of silver to the alloy. This is particularly true where the amount of silver is maintained within a specific ratio to the aluminum content in the alloy.

More specifically, the aluminum to silver weight ratio should be about 35 to 1. It has been found that aluminum bronze alloys containing the above aluminum to silver ratio is much more resistant to intergranular oxidation when stressed in hot water and steam because silver atoms, being larger than aluminum atoms, have a larger negative elastic energy interaction with dilated grain boundary regions than aluminum atoms, and therefore tend to replace aluminum atoms in the grain boundary. It is probably because of the low heat of formation of the oxides of silver that the grain boundaries of the aluminum bronze alloys containing silver show unusual resistance to intergranular attack when stressed in steam and hot water media.

It has been found that it is necessary to make the improved alloy with a certain critical ratio of silver to the aluminum content. This is believed due to the additional theoretical consideration of the configurational entropy contributed by the aluminum and silver atoms. In effect, this means that the smaller the concentration of a particular solute atom, the more difficult it will be for it to segregate to a grain boundary. The silver atoms compete with aluminum atoms for grain boundary locations and the ability to create a grain boundary resistant

to oxidation depends on holding the aluminum to silver content in certain critical ratios.

Silver has been used as a minor addition to copper and copper-base alloys in a great number of instances. However, the use of silver in alloying with copper in the previous art has not specified or contemplated the use in aluminum bronze alloys in a definite ratio to the aluminum content to substantially prevent intergranular attack when stressed in hot water and steam environs. Silver has been used in prior art mainly in conjunction with copper to improve the mechanical properties of conductivity alloys and the recrystallization characteristics of copper. In contrast, this invention relates to an alpha-phase aluminum bronze alloy, with greatly improved resistance to intergranular oxidation when stressed in hot water and steam media through the use of a specific aluminum to silver ratio. In this invention, the physical and electrical properties of the improved aluminum bronze have been found to be substantially the same as those for the usual aluminum bronze not containing the silver.

According to the invention the general composition range, by weight, of the alloy is as follows:

Aluminum	5.0 to 8.0%.
Iron	1.6 to 2.9%.
Silver	In a weight ratio of 1 part silver to 23 to 44 parts of aluminum.
Copper	Balance.

The controlled preferred compositional range of the alloy to which the silver is added is as follows:

Aluminum	6.00 to 6.75%.
Iron	2.00 to 2.40%.
Silver	In a weight ratio of 1 part silver to 33 to 38 parts of aluminum.
Copper	Balance.

A specific illustration of the alloy having a small amount of silver and falling within the above ranges is as follows, in weight percent:

	Percent
Aluminum	6.25
Iron	2.08
Silver	0.18
Copper	91.49

In addition to the ratio between the aluminum and silver, it has been found that the most desirable properties are obtained in the alloy when the iron content is maintained at a 1 to 3 ratio to the aluminum content. The iron is employed as a grain stabilizer and also acts to increase the strength of the alloy, particularly at higher temperatures. The 1 to 3 ratio between the iron and aluminum provides the alloy with the most desirable grain refining characteristics and mechanical properties.

In addition, other metals such as nickel and manganese may be employed in the alloy in amounts up to about 0.25% to add to the mechanical properties of the alloy, if desired.

Age hardening metals such as silicon, beryllium and the like should be avoided in the present alloy. Nickel, if used alone in the aluminum-iron copper alloy of the invention, will not age harden, but if a combination of metals such as silicon and nickel is used, the combination will age harden when the alloy is heated during welding, forming, or the like to form nickel silicides. The nickel silicides are extremely brittle and tend to precipitate and gather at the grain boundaries. This tendency of the age hardening precipitate to gather at the grain boundary is believed to prevent the silver from gathering

at the grain boundaries and in effect destroys the purpose of the silver addition. The age hardening precipitates can be removed by a solution quench from over 1600° F., but a heat treatment such as this is not possible with a finished or fabricated article because the dimensional tolerances of the article will be destroyed by the heat treatment. Therefore, age hardening constituents should be avoided in the present alloy.

The alloy is formed by initially preparing a pre-alloy of copper, aluminum and iron. This pre-alloy is then alloyed with additional copper and silver and cast. It is preferred not to add the silver to the pre-alloy because a portion of the silver would be lost by oxidation during melting and additional quantities of silver would have to be employed to hold the concentration of the same within the desired limits.

The present alloy can be readily fabricated into the form of rod, sheet, plate, tube, etc. or can be used as a weld deposit. The alloy can be made to provide a yield strength from 20,000 p. s. i. to 90,000 p. s. i., a tensile strength of 40,000 p. s. i. to 120,000 p. s. i. and an elongation in 2 inches of 1% to 60%, depending on the alloy composition, the method of fabrication employed and the heat treatment used. For example, an alloy having 6.75% aluminum, 2.10% iron, 0.12% silver and the balance copper, in the form of ⅜ inch thick plate, can be hot rolled and annealed to give a tensile strength of 80,000 p. s. i., a yield strength of 42,000 p. s. i., an elongation in 2 inches of 38% and a Brinell hardness of 150.

The same alloy in the form of cold drawn ¾ inch diameter rod has a tensile strength of 85,000 p. s. i., yield strength of 55,000 p. s. i., an elongation in 2 inches of 30% and a Brinell hardness of 165.

The alloy has high resistance to intergranular fracture resulting from oxidation at the grain boundaries. For example, the alloy will resist intergranular fracture for at least 2000 hours when stressed from 20,000 to 50,000 p. s. i. in a steam or hot water atmosphere at temperatures from 180° F. to 500° F. In some cases the alloy has been stressed for 8000 hours under the above conditions without failure.

As an example of the increased resistance of the alloy to intergranular oxidation when stressed in a hot water or steam atmosphere, a specimen of an alloy containing 6.75% aluminum, 2.10% iron, 0.12% silver and the balance copper was stressed beyond the yield strength by deflection bending in a medium consisting of a mixture of a 5% solution of acetic acid and a 8% solution of sulphuric acid at a temperature of 350° F. The specimen did not fail in 1000 hours of testing.

A second specimen having a similar composition, but without the silver addition, was stressed under identical conditions and failed after 50 hours of testing.

The present invention provides an aluminum bronze alloy that has greatly improved resistance to intergranular oxidation when stressed in steam and water atmospheres. The term "steam" is intended to include gaseous mixtures of steam and other vapors and the term "hot water" is intended to include heated aqueous solutions of salts, acids or bases and other materials containing water or moisture as an ingredient.

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 having increased resistance to intergranular oxidation when subjected to stress in a hot water or steam atmosphere, consisting essentially by weight of: about 5.0 to 8.0% aluminum; about 1.6% to 2.9% iron; silver in a weight ratio of 1 part silver to 23 to 44 parts of aluminum; and the balance substantially copper.

2. An aluminum bronze alloy having increased resistance to intergranular oxidation when subjected to stress in a hot water or steam atmosphere, consisting essentially by weight of: about 6.00% to 6.75% aluminum; about 2.00% to 2.40% iron; silver in a weight ratio of 1 part silver to 33 to 38 parts of aluminum; and the balance substantially copper.

3. An aluminum bronze alloy having increased resistance to intergranular oxidation when subjected to stress in a hot water or steam atmosphere, consisting essentially of, by weight: about 5.0% to 8.0% aluminum; iron in a weight ratio of about 1 part iron to about 3 parts aluminum; silver in a weight ratio of 1 part silver to 23 to 44 parts of aluminum; and the balance substantially copper, said silver segregating in the grain boundaries of the alloy and restricting the oxidation of said alloy at said grain boundaries.

4. An aluminum bronze alloy having increased resistance to intergranular oxidation when subjected to stress in a medium containing hot water or steam, consisting essentially of, by weight: about 6.00% to 6.75% aluminum; iron in a weight ratio of about 1 part iron to about 3 parts aluminum; silver in a weight ratio of 1 part silver to 33 to 38 parts of aluminum; and the balance substantially copper.

5. An aluminum bronze alloy, consisting essentially of, by weight: 6.25% aluminum; 2.08% iron; 0.18% silver; and the balance copper, said alloy having a high concentration of silver in the grain goundaries to thereby increase the resistance of the alloy to intergranular oxidation when subjected to stress in a medium containing hot water or steam.

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