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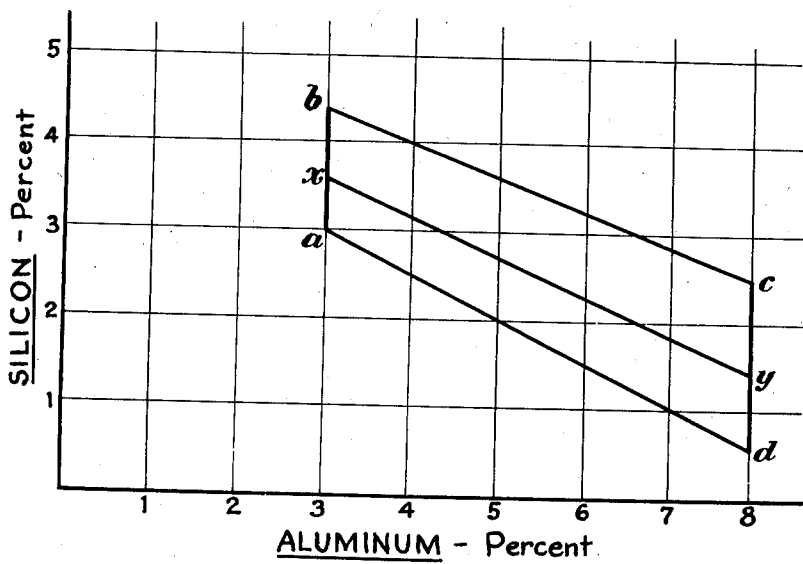
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COPPER ALLOY

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ZIRCONIUM .01-1.0 Percent
Remainder Substantially COPPER



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COPPER ALLOY

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8 Claims. (Cl. 75-160)

This invention relates to metallic alloys and particularly to non-ferrous alloys consisting primarily of copper.

Heretofore metallic alloys have been made consisting primarily of copper and containing small quantities of aluminum and silicon. Such aluminum silicon bronzes in general have high tensile strength and hardness combined with corrosion resistance and are widely used for a variety of purposes. It is a purpose of this invention to improve upon aluminum silicon bronze alloys of the character referred to.

According to this invention, aluminum silicon bronzes of the character herein defined are improved by the addition thereto of zirconium as an alloying metal. I have found that, by the addition to such silicon aluminum bronzes of small amounts of zirconium, i. e., about 1% by weight or less, a marked improvement in tensile strength is obtained while at the same time markedly improving the machinability of the alloy. It is also significant that these improvements are obtained without impairing the ductility of the alloy.

The property of machinability is important in connection with non-ferrous alloys such as aluminum silicon bronzes which are used in the fabrication of articles, parts, etc., by a machining operation. The property of machinability is well recognized in the art and involves such factors as ease and rapidity of cutting, excellence of finish, etc. Improvement in the machinability of an alloy results in increased life of the machine used for machining it and expedites the machining operation.

In Technical Publication No. 454 of The American Institute of Mining and Metallurgical Engineers, I have described a machine and method which may be used for determining a value that is indicative of the machinability of a specimen of metal or alloy. According to the test described, the work done to remove a given volume of metal under standard test conditions is determined by means of a cutter moving with a weighted pendulum. Details as to the test may be found in the aforesaid article. The machinability is expressed in foot pounds per cubic inch of metal removed.

The practical importance of high tensile strength, of course, is obvious. The attainment of improved tensile strength is in itself of great utility. As aforesaid, according to this invention, the tensile strength of aluminum silicon bronze has been markedly improved. Moreover, as also mentioned above, the machinability of the alloy has also been markedly improved. This unusual

combination of valuable characteristics has been attained according to this invention.

As aforesaid, the new alloy of this invention comprises aluminum, silicon, and zirconium, the balance of the alloy consisting substantially of copper. The amount of aluminum may vary from substantially 3% by weight to substantially 8% by weight. The amount of silicon may vary from substantially 0.6% by weight to substantially 4.4% by weight. The improvements of this invention are attained by incorporating zirconium in the aluminum, silicon, copper alloy. Even as little as 0.01% by weight of zirconium effects an increase in tensile strength and also an improvement in machinability although the effect on these properties is more substantial when .05% by weight of zirconium is present. When 0.1% by weight of zirconium is present the effect on both of these properties is very pronounced. Preferably, I employ about .3% to about .4% by weight of zirconium, although about .2% by weight gives results nearly as good. The amount of zirconium that is used may be further increased, but the further improvement in tensile strength and machinability therefrom is only slight by using amounts in excess of about .4%. About 1.0% of zirconium is the maximum that I ordinarily employ in my new alloy.

In formulating my new alloy, I preferably adjust the amount of silicon that is used depending upon the amount of aluminum that is employed. This relationship is indicated in the accompanying drawing showing coordinate rectilinear axes, one of which is percent aluminum and the other of which is percent silicon. On the drawing, there are coordinate points *a*, *b*, *c* and *d* as follows:

- (a) 3% aluminum; 3% silicon
- (b) 3% aluminum; 4.4% silicon
- (c) 8% aluminum; 2.5% silicon
- (d) 8% aluminum; .6% silicon

The amount of aluminum and silicon that I regard as constituting good practice is substantially on or within the quadrilateral determined by the points *a*, *b*, *c* and *d*. The relationship may also be expressed in substantially the same way by stating that the amount of aluminum that is used is substantially 3% to substantially 8%, and the amount of silicon varies directly from between substantially 3% and substantially 4.4% for an aluminum content of substantially 3% to between substantially .6% and substantially 2.5% for an aluminum content of substantially 8%.

In ordinary commercial practice, I prefer to

hold the amount of silicon within somewhat narrower limits, depending upon the amount of aluminum that is used. On the drawing are shown coordinate points x and y which are as follows:

- (x) 3% aluminum; 3.6% silicon
(y) 8% aluminum; 1.4% silicon

I prefer to employ aluminum within the limits 3% to 8% and an amount of silicon that is within substantially $\frac{1}{2}\%$ of any coordinate point on the line determined by the coordinate points x and y . Or, expressing substantially the same relationship in other words, the amount by weight of aluminum is substantially 3% to substantially 8% and the amount of silicon varies directly between substantially 3.1% and substantially 4.1% for an aluminum content of substantially 3% to between substantially 1.9% and substantially 2.9% for an aluminum content of substantially 8%.

By way of example, an alloy made according to this invention and suitable for fabrication into rods for screw machine work or forging, or for casting, has the following composition by weight:

Aluminum	Per cent
-----	6.5 to 7
Silicon	-----
-----	1.5 to 2.2
Zirconium	-----
-----	.2 to .4
Copper	-----
-----	Balance

In order that the improvements afforded by the use of zirconium according to this invention may be more apparent, the following tests may be cited by way of illustration. The new alloy embodying this invention and which was the subject of the test had the following composition by weight:

	Per cent
Aluminum	-----
-----	6.52
Silicon	-----
-----	2.11
Zirconium	-----
-----	.35
Copper	-----
-----	90.88

The alloy was hot rolled and annealed for two hours at 550° C. The alloy, when tested for tensile strength according to the standard A. S. T. M. tensile strength test (a $\frac{3}{8}$ " specimen was used), had a tensile strength of 94,450 pounds per square inch. The specimen exhibited a per cent. elongation (in two inches) of 31.5% and a reduction of area of 45%, showing that the alloy has good ductility.

When an alloy of similar composition but without the zirconium was prepared and tested in the same way, the tensile strength was about 86,000 pounds per square inch. It is apparent from the foregoing that the addition of the .35% of zirconium increased the tensile strength of the alloy by about 8,450 pounds per square inch.

Specimens of the new alloy having the composition above mentioned were tested on the machinability testing machine described in Technical Publication No. 454 of The American Institute of Mining and Metallurgical Engineers mentioned hereinabove. This testing machine showed the machinability of the new alloy to be 12,965 foot pounds per cubic inch of metal removed. When a specimen of an alloy of similar composition but without the zirconium was tested in a similar way, the machinability was found to be 13,900 foot pounds per cubic inch of metal removed. In other words, with the new alloy, the foot pounds of work required to remove a cubic inch of metal were reduced by approximately 1000 foot pounds, indicating a very marked improvement in machinability.

The addition of the zirconium to the alloy did not have any substantial effect on ductility. Thus, in testing the new alloy above mentioned, including zirconium, and the same alloy similarly prepared but without zirconium, the per cent. elongation and reduction in area remained substantially the same. Moreover, the hot working properties and the age hardening properties of the alloy are not substantially changed by the addition of the zirconium.

In connection with the foregoing examples and tests of specimen alloys, it is to be understood that they have been mentioned in order to exemplify this invention and in order to indicate improvements which are readily attainable in the practice of this invention. It is to be understood, however, that within the limits of composition above mentioned, the specific properties of the alloy will vary somewhat while still obtaining the benefits of the improvements which this invention affords.

The alloy of this invention is useful for a wide variety of purposes, and is of special advantage in the fabrication of parts and articles of high strength which are machined to desired dimensions. A product of particular utility is metallic alloy rod material. Such rod material may be made up in round, square or other cross-sectional shapes and in a variety of suitable sizes. Such rod material consisting of my new alloy is of especial utility in the manufacture of screw machine parts and is also of utility for fabrication of articles by hot forging. The alloy may be made in rod form by extruding and drawing a cast billet in the usual way or, by casting, hot rolling and drawing.

The new alloy is also desirable in the production of sand castings of high strength and is especially desirable when the casting has to be machined.

The new alloy is highly desirable for such articles as nuts, bolts, small gears, bushings, cable unions, valve seats and stems, clamps, nozzles, fittings, etc., etc. The alloy is highly corrosion-resistant and is very hard.

In the preparation of the alloy, conventional methods of alloying the metals together may be employed. If desired the zirconium may be added to the molten basic alloy as a copper-zirconium or as a silicon-zirconium alloy, both of which are available commercially.

The new alloy of this invention is preferably prepared without any element being present other than aluminum, silicon, zirconium and copper. When, however, it is said that the alloy consists substantially of copper, in addition to the aluminum, silicon and zirconium, it is to be understood that other metal or metals may be present in small amount, e. g., as impurities, but that such other metal or metals do not counteract the benefits of improved tensile strength and improved machinability in such a way as to nullify the benefits that are afforded according to this invention by the incorporation of zirconium in an aluminum, silicon bronze. However, such impurities or addition of other metals should be kept at a minimum since, for instance, appreciable quantities of iron, nickel or cobalt materially reduce the plasticity of the alloy when hot. Moreover, while it is common practice to add lead to copper base alloys to improve machinability, the addition of lead to the alloy of this invention in sufficient quantity to effect machinability materially reduces its notched bar impact test value.

In other words, the addition of lead renders the alloy notch-sensitive.

Somewhat more generally the employment of zirconium in alloys containing at least about 85% by weight of copper and containing aluminum and silicon is regarded as within the scope of this invention. Preferably the aluminum and silicon taken together constitute at least about 5% by weight of the alloy.

While this invention has been described in connection with certain specific examples, it is to be understood that this has been done for illustrative purposes only and that the scope of this invention is governed by the language of the following claims.

I claim:

1. A metallic alloy containing about 3% to about 8% by weight of aluminum; about 0.6% to about 4.4% by weight of silicon, and about 0.05% to about 1.0% by weight of zirconium, the balance being substantially copper.

2. A metallic alloy containing aluminum, silicon, and zirconium, the balance being substantially copper, the amount by weight of aluminum being substantially 3% to substantially 8%, the amount by weight of silicon varying directly from between substantially 3% to substantially 4.4% for an aluminum content of substantially 3% to between substantially 0.6% and substantially 2.5% for an aluminum content of substantially 8%, and the amount by weight of zirconium being about .01% to about 1.0%.

3. A metallic alloy containing aluminum, silicon, and zirconium, the balance being substantially copper, the amount by weight of aluminum being substantially 3% to substantially 8%, the amount by weight of silicon varying directly from between substantially 3.1% and substantially 4.1% for an aluminum content of substantially 3% to between substantially 1.9% and substantially 2.9% for an aluminum content of substantially 8%, and the amount by weight of zirconium being substantially 0.1% to substantially 0.4%.

4. A metallic alloy containing aluminum, silicon and zirconium, the balance being substantially copper, the amount by weight of zirconium being about 0.05% to about 1.0%, and the

amounts of aluminum and silicon being any amounts indicated by coordinate points found substantially on or within a quadrilateral determined by the coordinate points *a*, *b*, *c* and *d* for coordinate rectilinear axes, one of which is per cent. aluminum and the other of which is per cent. silicon, the points *a*, *b*, *c* and *d* being as follows:

- (a) 3% aluminum; 3% silicon
- (b) 3% aluminum; 4.4% silicon
- (c) 8% aluminum; 2.5% silicon
- (d) 8% aluminum; 0.6% silicon

5. A metallic alloy containing aluminum, silicon, and zirconium, the balance being substantially copper, the amount by weight of zirconium being about .2% to about .4%, and the amounts of aluminum and silicon being any amounts within substantially $\frac{1}{2}$ % silicon of any coordinate points on a line determined by the coordinate points *x* and *y* for coordinate rectilinear axes, one of which is per cent. aluminum and the other of which is per cent. silicon, the coordinates for points *x* and *y* being as follows:

- (x) 3% aluminum; 3.6% silicon
- (y) 8% aluminum; 1.4% silicon

6. An alloy having the following composition by weight:

	Per cent
Aluminum -----	6.5 to 7.0
Silicon -----	1.5 to 2.2
Zirconium -----	0.2 to .4
Copper -----	Balance

7. A readily machinable bronze alloy rod of high tensile strength which is made of an alloy containing about 3% to about 8% by weight of aluminum, about 0.6% to about 4.4% by weight of silicon, and about 0.05% to about 1.0% by weight of zirconium, the balance being substantially copper.

8. A metallic alloy containing aluminum, silicon, zirconium and copper, the amount by weight of copper being at least about 85%, the amount by weight of zirconium being at least about .01%, and the amount by weight of aluminum and silicon taken together being at least about 5%.

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