

[54] **HIGH DAMPING
COPPER-MANGANESE-ALUMINUM ALLOY**

[75] Inventors: **Joseph F. Nachman; Alvin N. Hammer**, both of San Diego, Calif.

[73] Assignee: **International Copper Research Association Inc.**, New York, N.Y.

[22] Filed: **Nov. 17, 1972**

[21] Appl. No.: **307,363**

Related U.S. Application Data

[62] Division of Ser. No. 187,811, Oct. 8, 1971, abandoned.

[52] U.S. Cl. **148/160, 75/161, 75/162, 148/32.5**

[51] Int. Cl. **C22c 9/00, C22f 1/08**

[58] Field of Search **75/161, 162; 148/13.2, 148/32, 32.5, 160**

References Cited

UNITED STATES PATENTS

2,165,316 7/1939 Thomas 75/161

3,079,252 2/1963 Webb et al. 75/161

OTHER PUBLICATIONS

Fiz Metal Metalloved, 27 No. 1, 1969 pgs 135-140.

Proceedings, AIMME, 1928, pages 483, 498-500.

Transactions, AIMME, Vol. 171, 1947 pgs. 70-104.

Z. Metallkunde Bd. 57 (1966) H 12, pages 889-901.

Primary Examiner—C. Lovell

Attorney, Agent, or Firm—Pennie & Edmonds

[57]

ABSTRACT

An alloy exhibiting high mechanical damping properties consists essentially of 32 to 42 percent by weight manganese, 2 to 4 percent by weight aluminum, and the balance copper. Damping properties are notably enhanced by annealing the cold worked alloy at 1200°F. to 1400°F., quenching, and aging at 400°F. to 900°F. for 1½ to 24 hours.

4 Claims, No Drawings

HIGH DAMPING**COPPER-MANGANESE-ALUMINUM ALLOY**

This is a division, of application Ser. No. 187,811, filed Oct. 8, 1971 now abandoned.

NATURE AND SCOPE OF THE INVENTION

This invention relates to copper-base alloys having high mechanical damping properties and to a method for heat treating such alloys to enhance their mechanical damping properties.

The alloys of the invention consist essentially of 32 to 42 percent by weight manganese, 2 to 4 percent by weight aluminum, and the balance copper. Preferably the manganese content is substantially 40% by weight and the aluminum is in the range from 2 to 3 percent by weight. Impurities normally present in commercially pure copper-manganese alloys (made from commercial forms of electrolytic copper and electrolytic manganese) may be present.

The mechanical damping properties of alloys is notably enhanced by subjecting the alloy in the hot or cold worked condition to a heat treatment which comprises annealing the alloy at a temperature in the range from 1200°F. to 1400°F., then quenching the alloy to room temperature (preferably in water), and then aging the alloy by reheating to a temperature in the range from 400°F. to 900°F. for a period of time from 1½ to 24 hours, followed by cooling to room temperature (advantageously by simple air cooling). Preferably the aging is effected by reheating the alloy after quenching first to a temperature in the range from 400°F. to 550°F. for a time from 12 to 20 hours, and then further reheating the alloy at a temperature in the range from 800°F. to 900°F. for a period of time from 1½ to 4 hours. A particularly satisfactory heat treatment comprises annealing the alloy at approximately 1275°F. (preferably for about one-half hour) and quenching in water, followed by aging first by reheating at a temperature of approximately 400°F. for about 16 and then at approximately 840°F. for about 1½ to 3 hours, and thereafter cooling in air to room temperature.

The invention includes within its scope alloys of the composition stated above in the heat treated condition resulting from applying to such alloys the heat treatment method of the invention. These heat treated alloys have notably enhanced mechanical damping properties.

BACKGROUND OF THE INVENTION

Copper-manganese alloys containing aluminum have long been known. Interest in such alloys extends at least as far back as the discovery in 1898 of the so-called Heusler alloys (composed generally of about 10 to 30 percent by weight manganese, about 5 to 15 percent by weight aluminum, and the balance copper). Unfortunately the Heusler alloys are quite brittle; and although some of them can undergo a limited amount of work, they are not acceptably workable for most commercial purposes. In contrast, the alloys of this invention can be quite readily worked; and moreover their damping properties especially in the heat treated condition are substantially better than are found in the Heusler alloys.

A nickel-bearing copper-manganese-aluminum alloy having high damping capacity is described in U.S. Pat. No. 3,230,078. This alloy is composed of 25 to 50 percent copper, 2.5 to 6 percent aluminum, 0.5 to 3.5 per-

cent nickel, and the balance manganese except for minor amounts of impurities (especially carbon and silicon). The manganese content of these alloys is at least 47 percent and may be as high as 60 percent. On account of their high manganese to copper ratio, the castability of these alloys is unsatisfactory. Also, they are not cold-workable to a significant extent; and when hot-worked their damping properties are impaired. Hence, their utility is limited, for all practical purposes, to articles which can be fabricated simply by casting and machining, such as marine propellers.

Binary manganese-copper alloy containing 65 percent manganese and 35 percent copper has been found to have very high damping properties but this alloy is not satisfactorily castable and its corrosion resistance is poor. Hence it cannot readily be fabricated into mechanical structures in which its damping properties can be exploited, nor can it be used satisfactorily in any mechanical structure subject to a corrosive environment.

DETAILED DESCRIPTION OF THE INVENTION

Alloys according to the invention are made by conventional methods. For example, electrolytic grade copper may be melted in an induction furnace, and then electrolytic manganese and commercial aluminum pig are plunged beneath the surface of the molten copper to inhibit oxidation and to minimize volatilization. The melt may be cast into ingot form, solidified, and worked hot or cold, or both, to the desired final bar, strip, wire or tube form. If desired the alloy, after casting into suitable shape, may be forged to final form. The alloy may also be used directly, if desired, in the as-cast condition.

The alloy of the invention, as noted above, is essentially a ternary alloy of copper, manganese and aluminum. Significant additions of fourth elements should be avoided. For example, the addition of even a few percent of bismuth, antimony or tin greatly impairs the workability of the alloy. Additions of such higher melting metals as iron or nickel likewise is to be avoided. In general the only metals present other than the three specified are the small amounts of impurities normally presented in commercial high-grade copper-manganese alloys.

Heat-treatment of the alloy generally is preferred to develop maximum damping characteristics. The annealing and reheating (aging) treatments as described above may be carried out in conventional heat treatment equipment, in air or in a controlled atmosphere furnace or by immersion in a fused salt bath. Heat treatment may be applied to coils of strip or wire prior to manufacture of finished articles, or the fabricated or partially fabricated articles may be made first and then subjected to the desired heat treatment. As-cast, forged, drawn, or cold-worked articles may be heat treated before or after any final machining operation.

Following are specific examples of the alloy and the heat treatment method of the invention.

EXAMPLE 1

An alloy composed of substantially 40.0 percent by weight manganese, 3.5 percent by weight aluminum, and 56.5 percent by weight copper was prepared by melting together under an argon atmosphere in alumina crucibles in an induction furnace appropriate quantities of aluminum pig, electrolytic copper cathodes, and electrolytic manganese chips. The melt was

poured into stainless steel ingot molds coated with an alundum cement mold wash and allowed to solidify and cool substantially to room temperature. The resulting ingots were homogeneous, sound, and of good surface quality.

An ingot thus produced was surfaced by light grinding, soaked at 1300°F. for one hour, and hot rolled at 0.020 inch per pass to 50 percent reduction. The resulting hot rolled bar, about 0.125 inch thick, was then cold rolled to 0.030 inch. Hot and cold working according to this schedule proceeded without difficulty. The alloy showed no tendency to be hot short, and was cold rolled without significant edge or surface cracking.

The cold rolled alloy strip was then heat treated as follows: It was annealed in air at 1275°F. for one-half hour; then quenched in water; then aged at 400°F. for 16 hours in air; then air-cooled to room temperature; then further aged at 840°F. for 1½ hrs; and then cooled in air to room temperature.

The damping characteristics of the heat treated alloy were measured and compared at various stresses to the damping of 410 stainless steel. This material was chosen as a reference because it is widely used in compressor blades and it exhibits reasonably good damping properties. Damping was measured by clamping a specimen of the rolled strip, 0.5 inch wide by 9.0 inches long, in a machinist's vise with 5.0 inches of the specimen projecting as a cantilever beam from the vise jaws. A 120-ohm foiltype strain gage of 0.125 inch gage length was attached to the projecting beam 0.25 inch from the grip of the vise jaws. The beam was then deflected to slightly higher than desired stress as indicated by the strain gage and released. The strain signal was monitored on a strip chart recorder in the form of an exponentially decaying sine wave. The specimen damping d_s was determined by the relationship,

$$d_s = 1/m \ln(e_n/e_m)$$

where e_n is the strain amplitude for the n th vibration cycle after the beam has been released from the deflected position; and e_m is the amplitude after an additional m cycles. The positions of n and m cycles were chosen such that the strain amplitude at the point $n + m/2$ represents the stress at which measurement of damping was desired, e.g., 1000, 2000, or 10,000 psi. The damping characteristic of the alloy relative to that of 410 stainless steel, R , is then determined as a simple ratio of d_s to the corresponding damping, d_{ss} , of the stainless steel,

$$R = d_s/d_{ss}$$

For the alloy of this example, R was found to have the remarkably high values of 10.8 at a stress of 1000 psi, 13.2 at 2000 psi, and 7.37 at 10000 psi.

EXAMPLE 2

Several alloy specimens of the same composition as that of Example 1 were similarly prepared, fabricated and heat treated except that the final aging at 840° was for different lengths of time. The values for R measured for these specimens are shown in the following table:

Time of Aging at 840°F.	at 1000 psi	R at 2000 psi	at 10000 psi
2 hours	9.89	9.64	9.32

-Continued

Time of Aging at 840°F.	at 1000 psi	R at 2000 psi	at 10000 psi
3 hours	9.62	7.52	10.0
3½ hours	6.76	6.52	9.58

EXAMPLE 3

An alloy composed of 37.5 percent by weight manganese, 3.5 percent by weight aluminum, and 59.0 percent by weight copper was melted and cast into ingots as described in Example 1. An ingot thus produced was hot rolled, after surfacing by light grinding and soaking at 1300°F. for one hour, to 0.030 inch strip. The hot rolled strip was heat treated as described in Example 1, except that the second aging treatment at 840°F. continued for four hours, after which the values for R were determined to be 7.31 at 1000 psi, 7.48 at 2000 psi, and 7.80 at 10000 psi.

EXAMPLE 4

An alloy of 35 percent by weight manganese, 3.5 percent by weight aluminum, and 61.5 percent by weight copper was melted and cast into ingots, and the ingots surfaced by light grinding, as described in Example 1. The ingot was then hot rolled to 0.030 inch strip as described in Example 2. The strip was heat treated as described in Example 1 except that the second aging treatment at 840°F continued for four hours. Values for R for the heat treated strip were found to be 5.02 at 1000 psi, 7.76 at 2000 psi and 4.32 at 10000 psi.

EXAMPLE 5

An alloy composed at 32.5 percent by weight manganese, 3.5 percent by weight aluminum, and 64.0 percent by weight copper was melted, cast into ingots, and surface-ground as described in Example 1. The ingots then were annealed at 1200°F. for twelve hours, water quenched, and cold rolled 35 percent reduction in area. The alloy was then re-annealed at 1200°F. for one hour, water quenched, and again cold rolled 35 percent reduction in area; and this sequence of re-annealing, quenching and cold rolling continued until the strip was reduced to 0.030 inch thick. The cold rolled strip was heat treated as described in Example 1, except that the second aging at 840°F. continued for three hours. Values for R for the heat treated alloy were found to be 5.22 at 1000 psi, 4.66 at 2000 psi, and 4.55 at 10000 psi.

The substantial improvement of the new alloys in comparison with the most workable of the Heusler alloys (20 percent by weight manganese, 10 percent by weight aluminum, and 70 percent by weight copper) was demonstrated by melting and casting this alloy in the manner described in Example 1, and hot working to strip form. The working schedule involved soaking for one hour at 1500°F., rolling at 0.020 inch per pass for 50 percent reduction, grinding out cracks and conditioning the surface by grinding, and then heating to 1450°F. and rolling at 0.012 inch per pass to 0.030 inch strip. Values for R of the strip as rolled were 0.93 at 2000 psi and 0.59 at 10000 psi (i.e. inferior in damping properties to 410 stainless steel). Annealing at 1250°F. for one-half hour followed by water quenching increased the values of R only to 1.62 at 2000 psi and 1.05 at 10000 psi. Aging the annealed and quenched

5

strip at 400°F. for 16 hours led to no improvement -- the R values were then 1.40 at 2000 psi and 0.72 at 10000 psi. Annealing the alloy at 1300°F. followed by oil quenching, then aging at 840°F. for two hours, and cooling in air changed the R values only slightly to 1.62 at 2000 psi and 0.69 at 10000 psi., and increased the brittleness of the alloy. Aging at 840°F. for four hours followed by cooling in air made the alloy extremely brittle -- too brittle in fact to measure its damping by the procedure described.

We claim:

1. A hot and cold workable alloy exhibiting high mechanical damping properties and consisting essentially of 32 to 42 percent by weight manganese 2 to 4 percent by weight aluminum and the balance copper, said alloy being in the heat-treated condition resulting from annealing at a temperature in the range from 1200°F. to 1400°F., quenching to room temperature, aging at a temperature in the range from 400°F. to 550°F. for a period of time from 12 to 20 hours, then further aging at a temperature in the range from 800 to 900°F. for a period of time from 1½ hours to 4 hours, and cooling to room temperature.

2. An alloy according to claim 1 in the heat-treated condition resulting from annealing at a temperature of

6

approximately 1275°F followed by quenching in water, then aging at about 400°F. for about 16 hours, then further aging it at about 840°F. for about 1½ to 3 hours, and cooling in air to room temperature.

3. The method of increasing the mechanical damping properties of an alloy consisting essentially of 32 to 42 percent by weight manganese, 2 to 4 percent by weight aluminum, and the balance copper which comprises annealing the alloy at a temperature in the range from 1200°F to 1400°F., then quenching the alloy to room temperature, then reheating the alloy to a temperature in the range from 400°F. to 550°F. for a period of time from 12 to 20 hours, then further aging at a temperature in the range from 800 to 900°F. for a period of time from 1½ hours to 4 hours, and then cooling to room temperature.

4. The method according to claim 3 which comprises annealing the alloy at a temperature of approximately 1275°F. and quenching it in water, reheating it at a temperature of approximately 400°F. for about 16 hours, then further reheating it at approximately 840°F. for about 1½ to 3 hours, and cooling it in air to room temperature.

* * * * *

30

35

40

45

50

55

60

65