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COPPER BASE ALLOYS CONTAINING COBALT, BERYLLIUM, AND ZIRCONIUM

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This is a continuation-in-part of our copending, now abandoned, application Serial No. 104,234, filed April 20, 1961.

The present invention relates to novel copper base alloys comprising beryllium.

In the development of generators parts, such as rotor wedges, it is desirable to fabricate such parts out of alloys having high mechanical strength and high electrical conductivity. Also, the alloys should be characterized by a relatively good ductility at temperatures up to about 538° C., since such temperatures are possible during severe faulting of a generator, which conditions combined with stresses produced during generator operation could be detrimental to alloy members having low strength and ductility in this temperature range.

The strength of such members may be increased by cold working and then age hardening. However, if the alloy is allowed to recrystallize during aging, the cold worked structure and the associated increased strength will be largely lost. Therefore, it is desirable to age the alloy below the recrystallization temperature which is facilitated by raising the recrystallization temperature.

An object of the present invention is to provide a copper base alloy characterized by high mechanical strength and high electrical conductivity and adequate ductility to withstand stresses at elevated temperatures whereby members of the alloy are free from the possibility of sudden brittle failure.

Another object of the invention is to provide a copper base alloy comprising predetermined proportions of beryllium, cobalt, zirconium, and the balance copper and small amounts of incidental impurities.

Still another object of the invention is to provide a cold worked, age hardened member comprising predetermined proportions of beryllium, cobalt, zirconium, and the balance copper and small amounts of incidental impurities and with lead not exceeding 0.005%.

Other objects of the invention will, in part, be obvious and will, in part, appear hereinafter.

In accordance with the present invention, there is provided a copper base alloy comprising from 0.4% to 0.7% by weight of beryllium, from 2% to 3% by weight of cobalt, from .12% to 0.4% by weight of zirconium and the balance copper with small amounts of incidental impurities. It is desirable that the percent of cobalt to beryllium ratio be maintained at approximately 5:1 for optimum electrical conductivity. It is particularly desirable that the lead content of the alloy not exceed 0.005%.

Members of the alloy can be cast to shape or wrought by hot and cold working. The member can be solution annealed by heating up to temperatures of about 750° C. and above and appropriately quenched. The members can be aged at temperatures of from 300 to 600° C. to develop a desirable strength and hardness. The alloy is characterized by high mechanical strength, high electrical conductivity and relatively good ductility at both room and elevated temperatures.

A feature of the present invention is to cold work members of the alloys and then age harden the members in order to impart improved strength properties.

In the alloys of the present invention, the problem of recrystallization during age hardening is avoided by the specified additions of zirconium to the copper base alloy comprising strengthening elements cobalt and beryllium, one of the purposes of the zirconium being for inhibiting the onset of recrystallization. The zirconium addition substantially raises the recrystallization temperature of the alloy, so that the alloy may be aged after cold working without any loss of strength previously gained by the cold working and with substantial further increase in strength achieved by the age hardening process. With the normally accepted impurity levels for copper base alloys this alloy is still brittle at elevated temperatures. It also has been discovered that this alloy can be made relatively ductile at elevated temperatures by keeping lead as an impurity to a level at or below 0.005% by weight. Therefore, in the manner described above, the higher strength of a cold worked material can be realized without lowering ductility or electrical conductivity.

A particularly good alloy of the invention comprises nominally 0.5% by weight of beryllium, 2.5% by weight of cobalt, 0.25% by weight of zirconium, and the balance copper and small amounts of incidental impurities with lead in particular not exeeding 0.005%.

It should be understood that nickel may be substituted in whole or in part for cobalt, and hafnium may be substituted for all or a part of the zirconium. Furthermore, while zirconium and/or hafnium need not be present in the alloy in appreciable amounts, it is highly desirable to have either of these present since they raise the recrystallization temperature of the copper beryllium alloy.

The following example is illustrative of the teachings of the invention.

Three 17 pound heats of beryllium-cobalt copper alloys were melted in a pure graphite crucible under a partial pressure of argon gas. The alloys were then cast into iron molds. The first alloy heat comprised 2.5% cobalt, 0.29% zirconium, 0.54% beryllium, lead below 0.005% and the balance copper. The second alloy heat comprised 2.5% cobalt, 0.54% beryllium, 0.01% lead and the balance copper. The third alloy heat comprised 2.5% cobalt, 0.54% beryllium, lead below 0.005%, and the balance copper. The resulting ingots were then hot forged to 1 inch diameter rods, solution anealed at 927° C. for one hour, and water quenched. The effect of prior cold work on the age hardening process was then investigated by first cutting test bars from the forged ingots and then cold reducing cross sections of the test bars up to 42%. The test bars were then aged to maximum hardness at 450° C. A portion of each heat was also aged without prior cold deformation and tested.

A portion of one of the test ingots containing zirconium and no detectable lead was extruded and cold worked to a 32% reduction in area resulting in the shape of a rotor wedge. The wedge was age hardened at 450° C. in a nonoxidizing atmosphere for 4 hours.

Table III

[First heat: 2.5% Co, 0.29% Zr, 0.54% Be, Pb less than 0.005%, bal. Cu]

Cold Reduction Prior to Aging (percent)	Testing Temperature (° C.)	Room Temperature Hardness (Rockwell "B")	Yield Strength at 0.2% Offset (p.s.i.)	Ultimate Tensile Strength (p.s.i.)	Elongation (percent)	Reduction of Area (percent)	Impact Strength Charpy V-notch (foot-pounds)
0	27	103	94,500	120,700	20.7	40.7	18.5
0	427	103	79,300	82,900	3.4	6.1	13.5
20	27	106	120,200	135,100	16.1	38.6	7.0
20	427	106	97,900	99,100			6.0
30	27	104	115,050	126,850	15.9	31.1	10.0
30	427	104	90,100	92,100	4.5	10.9	7.5
32	27	104	115,900	128,250	13.9	30.4	8.0
32	427	104	91,500	97,700	6.1	8.7	7.0
42	27	104	112,700	125,850	18.0	29.9	8.5
42	427	104	88,000	93,400	3.3	7.4	8.0

The results of testing the copper beryllium alloy containing lead, second heat, is indicated in Table I. While the alloy appears to have a relatively high mechanical strength as indicated by the yield strength, it should be noted that the percent elongation in this alloy decreases very rapidly as the temperature increases, with the alloy becoming completely embrittled at some temperature between room temperature and 316° C.

Table I

[Second heat: 2.5% Co, 0.54% Be, 0.01 Pb, bal. Cu]

Cold Reduction Prior to Aging (percent)	Testing Temperature (° C.)	Yield Strength at 0.2% Offset (p.s.i.)	Tensile Strength (p.s.i.)	Elongation (percent)
0	R.T.	96,600	109,300	18.0
0	316	79,900	82,300	0.7
0	427		71,600	0.2
0	538		42,200	0.2
30	R.T.	106,850	119,800	17.8
30	316	88,750	91,950	2.3
30	427		75,550	0.9
30	538	50,800	51,100	1.6

Table II indicates the results obtained from testing the third heat, the copper beryllium alloy without lead or zirconium. The data shows that the mechanical strength of the alloy is slightly lower than the strength of the alloy containing lead. But it should be particularly noted that this alloy is not completely embrittled at elevated temperatures like the alloy which contains lead.

Table II

[Third heat: 2.5% Co, 0.54% Be, lead below 0.005%, bal. Cu]

Cold Reduction Prior to Aging (percent)	Testing Temperature (° C.)	Yield Strength at 0.2% Offset (p.s.i.)	Ultimate Tensile Strength (p.s.i.)	Elongation (percent)
0	316	59,550	67,550	9.3
0	427	59,050	62,200	4.5
30	R.T.	107,450	121,200	18.8
30	316	77,000	79,450	14.5
30	427	65,700	66,950	9.1

The test results of the copper beryllium alloy of the first heat, with zirconium and without lead are given in Table III. These results show that the elevated temperature ductility of this alloy is substantially the same as the alloy of Table II. Clearly then this establishes the absence of lead as the determining factor. The mechanical strength of the improved alloy is substantially greater at elevated temperatures than the alloys of Tables I and II. The test bar cut from the shape of a rotor wedge was tested at 427° C. and the results indicated a yield strength of 91,500 p.s.i., a tensile strength of 97,700 p.s.i., and a percent elongation of 6.1.

Accordingly, the alloys of the present invention have properties of yield strength and ductility far superior to any known copper base alloys containing beryllium, cobalt and zirconium.

It is intended that the foregoing be construed as illustrative and not in limitation of the invention.

We claim as our invention:

1. A cold worked, age hardened copper base alloy member consisting essentially of from 0.4% to 0.7% by weight of beryllium, from 2% to 3% by weight of cobalt, from 0.12% to 0.4% by weight of zirconium and the balance copper and small amounts of incidental impurities with lead not exceeding 0.005%, the member being cold worked at least 10% and age hardened to a temperature of from 300° C. to 600° C. for a period of the order of 0.25 or more hours to impart relatively high mechanical strength to the member without a substantial decrease in ductility.

2. A cold worked, age hardened rotor wedge suitable for use in electrical generating apparatus, the wedge consisting essentially of from 0.4% to 0.7% by weight of beryllium, from 2% to 3% by weight of cobalt, from 0.12% to 0.4% by weight of zirconium and the balance copper and small amounts of incidental impurities with lead not exceeding 0.005%, the wedge having been cold worked at least 10% and age hardened to a temperature of from 300° C. to 600° C. for a period of the order of 0.25 or more hours to impart high mechanical strength to the wedge without a significant decrease in ductility.

3. A copper base alloy consisting essentially of from 0.4% to 0.7% by weight of beryllium, from 2% to 3% by weight of cobalt, from 0.12% to 0.4% by weight of zirconium and the balance copper and small amounts of incidental impurities.

4. A copper base alloy consisting essentially of from 0.4% to 0.7% by weight of beryllium, from 2% to 3% by weight of cobalt, from 0.12% to 0.4% by weight of zirconium and the balance copper and small amounts of incidental impurities with lead not exceeding 0.005%.

5. A copper base alloy consisting essentially of about 0.5% by weight of beryllium, 2.5% by weight of cobalt, 0.25% by weight of zirconium and the balance copper and small amounts of incidental impurities with lead not exceeding 0.005%.

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