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[54] **PROCESSING COPPER BASE ALLOYS**

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[58] **Field of Search** .... 148/11.5 R

[56] **References Cited**

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[57] **ABSTRACT**

Processing copper alloys to obtain an improved combination of yield strength and elongation. The process is characterized by cold rolling with interpass heat treatments to a total reduction of at least 70%, followed by a final heat treatment under specified conditions.

6 Claims, No Drawings

PROCESSING COPPER BASE ALLOYS

BACKGROUND OF THE INVENTION

The process of the present invention is concerned with treating copper base alloys in order to obtain an improved combination of yield strength characteristics and elongation.

Since most engineering components, springs in particular, must operate in the elastic regime, information regarding the onset of plastic flow in metal systems has long been one of the most important engineering design criteria. The mechanical property of great interest in this region is the elastic limit. However, there are practical difficulties in determining the elastic limit with information from the engineering tensile test. Since the elastic limit can be as much as 10–15 ksi greater than the proportional limit, which is the stress at which the stress-strain curve becomes nonlinear in the elastic regime, determination of the elastic limit would require that each tensile specimen be alternatively loaded and unloaded to increasingly higher loads until that load is reached which produces a permanent set in the specimen.

However, the 0.01% offset yield strength approximates and is frequently used in place of the elastic limit in spring design. Thus, for engineering applications in which little or no plastic flow can be tolerated an enhanced 0.01% offset yield strength would lead to improved materials utilization and performance.

Accordingly, it is a principal object of the present invention to provide a process for obtaining improved yield strength characteristics in copper base alloys, particularly high 0.01% offset yield strength.

It is a further object of the present invention to provide a process as aforesaid which obtains an improved combination of 0.01% offset yield strength and percent elongation.

A further object of the present invention is to provide a process as aforesaid which is suitable for manufacturing parts while allowing retention of the desired high yield strength properties.

A further object of the present invention is to provide a process as aforesaid which is simple, inexpensive, easily practiced commercially and versatile.

Further objects and advantages of the present invention will appear hereinbelow.

SUMMARY OF THE INVENTION

In accordance with the process of the present invention it has been found that the foregoing objects and advantages may be readily obtained. The process of the present invention comprises:

A. providing a copper or copper base alloy material in plate form having a thickness of from 0.300 inch to 1,800 inch;

B. cold rolling said material in at least three cold rolling cycles to a total reduction of at least 70% and preferably at least 85%, with an intermediate heat treatment between each cold rolling cycle of from 100° to 350°C for from 1 to 4 hours, provided that the rolling reduction in each cold rolling cycle is at least 25%; and

C. subjecting said material to a final heat treatment after the last cold rolling cycle, said final heat treatment being at a temperature of from 100° to 350°C for from 30 minutes to 8 hours.

The starting plate material may use a variety of materials, such as hot rolled plate, fully recrystallized plate or continuously cast plate.

The material produced in accordance with the process of the present invention may be utilized to manufacture parts. When the part is manufactured, the yield strength properties fall off due to the cold work which is given to the part as a result of the forming operation. Therefore, a further thermal treatment may be performed on the formed part at a temperature of from 100° to 350°C for from 30 minutes to 8 hours in order to restore the desirable high 0.01% offset yield strength.

The process of the present invention readily obtains high 0.01% offset yield strength in copper base alloys in combination with good elongation. Furthermore, it can be seen that the process is simple and easy to perform and inexpensive in a commercial operation.

Further advantages of the instant process will appear hereinbelow.

DETAILED DESCRIPTION

The process of the present invention, as indicated hereinabove, may be readily utilized with any copper or copper base alloy material. Thus, commercial purity or pure copper may be readily employed. A particularly suitable series of copper alloys for use in the process of the present invention are the phosphor bronzes, which are copper base alloys containing from 1 to 10% tin, such as CDA copper alloy No. 505, 510, 521 and 524. In addition, the iron containing copper alloys containing from 1 to 5% iron may be readily utilized, such as CDA copper alloy **194** and **195.** In addition the nickel-silvers are desirably suitable for use in the process of the present invention. These alloys are copper base alloys containing from about 10 to 20% nickel and from about 5 to 40% zinc, such as CDA copper alloy No. 762, 752, and 745. A further series of copper alloys which may be desirably utilized include the aluminum-bronzes and brasses containing from 2 to 13% aluminum, such as CDA copper alloy 638 and 688. Naturally, many other copper alloys may be desirably utilized in the process of the present invention. Generally, any copper base alloy may be conveniently utilized, such as: The CDA 2XX series, brasses containing from about 5 to 40% zinc; copper alloys containing beryllium; the CDA 4XX series, tin brasses containing tin and zinc; silicon-bronzes; manganese-zinc containing copper alloys as CDA alloys 669 and 672; and cupro-nickels containing from about 5 to 35% nickel as CDA alloys 706 and 715.

The starting material should be a copper or copper base alloy material in plate form having a thickness of from 0.300 inch to 1.800 inches. The plate material may be obtained by any desired method. For example, one may start from a copper base alloy ingot which is hot or cold rolled to plate thickness. The cold rolled plate may then be annealed to the fully recrystallized condition. Alternatively, one may provide a continuously cast copper base alloy plate as starting material.

The process of the present invention cold rolls the plate material in at least three cold rolling cycles to a total reduction of at least 70%, with an intermediate heat treatment of from 100 to 350°C for from 1 to 4 hours between each cold rolling cycle. The rolling reduction in each cold rolling cycle should be at least 25% and the total reduction in all cold rolling cycles is preferably greater than 85%. Thus, one may have the following sequence: cold reduction; heat treatment; cold reduction; heat treatment; and cold reduction. Alternatively, one may desirably utilize four cold rolling cycles with three intermediate heat treatment steps.

Following the final cold reduction step, the material may be subjected to a final low temperature heat treatment at final gage. This heat treatment step should be for from 30 minutes to 8 hours at a temperature of from 100 to 350°C.

In the heat treatment steps generally longer times are used with lower temperatures.

It is a particular advantage of the process of the present invention that parts may be readily formed from the thermally treated strip. We have found that formed parts may lose a portion of the desirably high yield properties due to the cold work which they have been subjected to. In order to restore the high yield properties, the formed parts may be given a further low thermal temperature treatment of from 30 minutes to 8 hours at temperatures between 800°C and 350°C.

In the heat treatment steps generally longer times are used with lower temperatures.

In addition to imparting improved 0.01% offset yield strength, the process of the present invention also obtains numerous advantages. The material of the present invention retains the finely structured cold worked matrix. In addition, the process of the present invention maintains and strengthens the deformation texture, resulting in improved texture strengthening of the sheet and formed part. Still further, the process of the present invention allows sufficient recovery of ductibility at a marginal strength loss in order to enhance cold rollability for the additional cold rolling steps and for subsequent forming of the final material.

The process of the present invention and advantages obtained thereby may be readily understood from a consideration of the following illustrative examples.

EXAMPLES

A copper base alloy ingot was provided having the following composition: tin, 4.4%; phosphorus, 0.07%; balance essentially copper. The ingot was initially hot rolled and milled to 0.450 inch gage and was processed to 0.010 inch gage utilizing the processing schedules A and B set forth below.

Process schedule A involved cold rolling the material 97.8% directly to 0.010 inch gage. This was done for comparative purposes and does not represent the process of the present invention.

Process schedule B involved a total reduction of 97.8% to 0.010 inch gage and utilized four cold rolling cycles with three in process heat treatment steps as follows: cold roll 90.0% to 0.045 inch, heat treat for 2 hours at 250°C, cold roll 40.0% to 0.027 inch, heat treat for 2 hours at 250°C, cold roll 40.8% to 0.016 inch, heat treat for 2 hours at 250°C and finally cold roll 37.5% to the final gage of 0.010 inch. Thus, the total reduction and final gage are the same for process schedules A and B.

Tensile properties were determined for the longitudinal and transverse sheet orientations for the material obtained by the two foregoing processing schedules. The properties for process schedule A are listed in Table I, while those for process schedule B are presented in Table II. The properties of the as-cold rolled condition are identified in the tables by the designation CR. Properties were also determined on cold rolled material subjected to a final low temperature heat treatment for a period of 2 hours at temperatures 200°, 250°, 275° or 300°C. These heat treated properties are also presented in Tables I and II.

Comparisons of the tensile properties of the material obtained by process schedule A with those obtained by process schedule B show the improvement of the final heat treated 0.01% offset yield strength obtainable with the process schedule of the present invention. Furthermore, when compared at equivalent 0.01% offset yield strengths, the percent elongation values of material processed according to schedule B are superior to those of scedule A.

TABLE I

TENSILE PROPERTIES OF PHOSPHOR BRONZE PROCESSED ACCORDING TO SCHEDULE A

Material	Strengths in ksi 0.01% YS	0.1% YS	0.2% YS	UTS	Percent Elongation
Longitudinal					
CR 97.8%	77	113	121	130	<0.5
200°C-2 Hours	86	112	—	126	<0.5
250°C-2 Hours	75	99	100	109	3.4
275°C-2 Hours	74	96	101	103	6.7
300°C-2 Hours	64	85	89	92	15.8
Transverse					
CR 97.8%	—	—	—	—	—
200°C-2 Hours	96	132	141	151	1.5
250°C-2 Hours	88	118	—	130	4.8
275°C-2 Hours	—	—	—	—	—
300°C-2 Hours	72	98	—	104	13.8

TABLE II

TENSILE PROPERTIES OF PHOSPHOR BRONZE PROCESSED ACCORDING TO SCHEDULE B

Material	Strengths in ksi 0.01% YS	0.1% YS	0.2% YS	UTS	Percent Elongation
Longitudinal					
CR 97.8%	83	116	123	129	<0.5
200°C-2 Hours	86	115	—	125	2.5
250°C-2 Hours	85	102	—	109	5.9
175°C-2 Hours	76	99	103	106	7.9
300°C-2 Hours	64	85	88	90	17.2
Transverse					
CR 97.8%	90	126	137	150	<0.5
200°C-2 Hours	101	131	138	144	<0.5
250°C-2 Hours	96	122	128	131	3.5
275°C-2 Hours	96	119	122	124	3.6
300°C-2 Hours	75	97	101	103	13.2

This invention may be embodied in other forms or carried out in other ways without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered as in all respects illustrative and not restrictive, the scope of the invention being indicated by the appended claims, and all changes which come within the meaning and range of equivalency are intended to be embraced therein.

What is claimed is:

1. A method for improved yield strength characteristics in copper or copper base alloys which comprises:

A. providing a copper base alloy selected from the group consisting of the phosphor bronzes and copper alloys containing from 1–5% iron, in plate form having a thickness of from 0.300 to 1.800 inches;

B. cold rolling said material in at least three cold rolling cycles to a total reduction of at least 70% with an intermediate heat treatment of from 100° to 350°C for from 1 to 4 hours between each cold rolling cycle, provided that the rolling reduction in each cold rolling cycle is at least 25% and

C. subjecting said material to a final heat treatment after the last cold rolling cycle, said final heat treatment being at 100° to 350°C for from 30 minutes to 8 hours.

2. A method according to claim **1** wherein the total reduction in step (B) is at least 85%.

3. A method according to claim **2** wherein step (B) includes four cold rolling cycles with three intermediate heat treatment cycles.

4. A method according to claim **1** wherein the starting material in step (A) is provided by hot rolling an ingot to plate form having a thickness of from 0.300 to 1.800 inches.

5. A method according to claim **2** wherein said copper alloy contains iron in an amount of from 1 to 5%.

6. A method according to claim **1** wherein said starting material is a copper base alloy ingot which is cold rolled to plate thickness.

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