

United States Patent

[11] 3,615,280

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Pat. No. 3,505,104
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[54] **ALUMINUM BRONZE ARTICLE HAVING A
 HARDENED SURFACE**
4 Claims, No Drawings
 [52] U.S. Cl. 29/199,
 29/197
 [51] Int. Cl. B32b 15/00
 [50] Field of Search..... 29/194,
 197, 197.5, 199

ABSTRACT: An aluminum bronze article having an improved wear resistance and surface hardness. The article comprises a base alloy aluminum bronze having an aluminum content in the range of 5 to 13 percent and an outer coherent surface having an aluminum content of 13 to 16 percent. The coherent aluminum-enriched surface is produced by diffusion and simultaneous alloying of aluminum into the microstructural phases present in the base alloy. The aluminum-enriched microstructure phases present at the outer surface of the article are hard and wear resistant.

ALUMINUM BRONZE ARTICLE HAVING A HARDENED SURFACE

This application is a division of application Ser. No. 589,802 filed Oct. 27, 1966 now U.S. Pat. No. 3,505, 104 Apr. 7, 1970.

This invention relates to a wear-resistant aluminum bronze article and to a method of making the same.

In many instances aluminum bronze alloys containing from 5 to 13 percent aluminum have the mechanical and physical properties for a specific application, yet lack the required wear resistance and surface hardness. To obtain increased wear resistance it is normally necessary to modify the alloy composition by increasing the aluminum content to a value in the range of 13 to 16 percent, yet the increased aluminum content results in a pronounced decrease in forming and machining properties. For example, by increasing the aluminum content of the aluminum bronze alloy, the tensile strength, hardness and wear resistance are increased, but with each phase change the alloy becomes increasingly more brittle and difficult to form and machine.

The present invention is directed to an aluminum bronze article having improved wear resistance and surface hardness. The article comprises a base alloy of aluminum bronze having microstructures consisting of all alpha phase, alpha plus beta-prime phases, or all beta-prime phase, depending on the aluminum content of the base alloy and a hard wear-resistant outer surface having a microstructure comprising of beta-prime phase, beta-prime plus gamma-two phases, or all gamma-two phase.

The base aluminum bronze alloy, having an aluminum content generally in the range of 5 to 13 percent can be readily formed and machined. After forming, the article is subjected to a surface-hardening treatment in which aluminum is diffused and simultaneously alloyed into the outer surface of the article to provide a hard, wear-resistant outer surface layer having an aluminum content in the range generally of 13 to 16 percent. More specifically, the surface hardening treatment consists of heating the aluminum bronze article to a temperature in the range of 1300° to 1700°F. in the presence of metallic aluminum and a halide compound in a closed chamber.

The article is retained in the chamber for a period of time sufficient for a chemical reaction to occur aluminum, the metallic aluminum, halide compounds and the base alloy aluminum bronze to permit aluminum to diffuse and simultaneously alloy at the surface of the aluminum bronze article to obtain the depth of penetration and surface microstructures desired.

The article is then cooled in the reaction chamber to room temperature and as cooling below 1,050° F. occurs, the beta phase of the aluminum bronze may transform to the eutectoid structure. Therefore the article is normally reheated to a temperature of about 1,100° F. for a period of about 1 to 3 hours and quickly cooled to room temperature.

The article of the invention has a relatively ductile base metal with a hard wear-resistant surface layer. The aluminum bronze base alloy can be formed to its final shape and then treated to diffuse and alloy the aluminum into the surface microstructure and produce the hard and wear-resistant surface. The aluminum bronze base alloy to be treated can be any conventional aluminum bronze alloy containing generally from 5 to 13 percent aluminum. The aluminum bronze can contain a wide variety of alloying elements such as iron, nickel, manganese, tin, zinc, silver, cobalt, chromium, vanadium and the like. Examples of aluminum bronze alloy compositions which can be treated in accordance with the invention are as follows in weight percent:

ALLOY COMPOSITION						
	1	2	3	4	5	6
Al.....	5-8	5-12	5-12	9-13	9-13	9-13
Fe.....	1.6-2.9	.25-8		2-7	2-7	2-7
Ni.....						2-7
Mn.....						2-7
Sn.....	.005-.69				1-5	1-5
Ag.....	.005-.69					
Si.....		1-5				
Cu.....	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.

Specific examples of aluminum bronze alloys falling within the above ranges are as follows in weight percent:

ALLOY COMPOSITION						
	1	2	3	4	5	6
Al.....	6.25	6.50	5.0	10.5	13.0	9.0
Fe.....	2.08	2.00		3.7	3.9	4.2
Ni.....						4.5
Mn.....					2.2	2.0
Sn.....	.16					
Ag.....	.15					
Fn.....						
Si.....			3.0			
Cu.....	91.36	91.50	92.0	85.8	80.9	80.3

The base alloy generally has an all alpha phase, alpha and beta-prime phases, or all beta-prime phase microstructure as alloys of this type can be readily formed and machined, while the wear resistant surface layer will generally contain from 13 to 16 percent aluminum and consist of an all beta-prime phase, beta-prime plus gamma-two phases or all gamma-two phase microstructure.

The aluminum concentration of the surface layer will decrease progressively from the outer extremity of the article inward. The depth of penetration of the aluminum which is diffused into the base alloy depends on the time of treatment. The depth of penetration can be up to 0.10 inches and generally the hardened surface layer will have a depth in the range of 0.010 to 0.025 inches in the finished article.

The aluminum is diffused and simultaneously alloyed into the outer layer of the aluminum bronze base alloy by a conventional diffusion process commonly referred to as the calorizing process. According to this process, the base alloy article is placed in a closed chamber which contains metallic aluminum, an ammonium halide or a hydrogen halide and an inert material such as aluminum oxide, kaolin, or the like. The materials are heated, generally to a temperature in the range of 1300° to 1,700° F. and preferably 1,500° to 1,650° F. and held at this temperature for a period of about 4 to 8 hours, depending on the hardness and the depth of surface hardening desired. At this temperature, the aluminum is diffused and simultaneously alloyed into the surface of the aluminum bronze base alloy to provide a surface layer of microstructures having an increased aluminum content, generally in the range of 13 to 16 percent.

The aluminum bronze base alloy having an aluminum content in the range of 6 to 13 percent, will generally have a hardness in the range of 55 Rockwell B to 30 Rockwell C, while the hardened outer surface layer will generally have a hardness in the range of 85 Rockwell B to 60 Rockwell C.

Following the heating period, the article is cooled in the chamber to room temperature. During this slow cooling cycle, the beta phase in the aluminum bronze base alloy and in the newly formed surface structure may be transformed to eutectoid which will cause brittleness in the aluminum bronze article. To eliminate the eutectoid structure, the article is reheated to a temperature generally in the range of 1,100° to 1,250° F. and maintained at this temperature for a period of 1 to 3 hours. Following this heat treatment, the article is rapidly cooled to a temperature under 600° F. at a rate faster than 80° F. per minute. This cooling rate can be conveniently obtained by fan cooling or water quenching.

The article produced by the invention can be used in any application where surface hardness or wear resistance is a requirement. For example, the article can be used as a die material requiring a substantial amount of machining. The article can also be used for shafts or bearing members which are prone to galling, or for gear parts such as gear teeth on gear trains or wrench jaws on safety tools.

The following examples illustrate specific applications of the invention

Example No. 1

An aluminum bronze test specimen 1½" O.D. x ¾" I.D. x ¾" thick and consisting of 6.7 percent aluminum, 2.3 percent iron, 0.2 percent tin and the balance copper, was sub-

jected to the surface hardening treatment in a chamber containing metallic aluminum, aluminum oxide and ammonium iodide. The specimen was heated to a temperature of 1,600° F. and maintained at this temperature for a period of 8 hours. After cooling to room temperature the hardness of the base alloy was 65 Rockwell B, while the hardness of the outer surface layer was 85 Rockwell B. The specimen was then reheated to a temperature of 1,250° F. maintained at this temperature for a period of 2 hours and subsequently water quenched. The hardness of the base alloy after heat treatment was 58 Rockwell B and the hardness of the outer surface layer was 98 Rockwell B.

Example No. 2

A 1½" O.D. ×%" I.D. ×%" thick aluminum bronze test specimen having a composition consisting of 10.3 percent aluminum, 3.5 percent iron and the balance copper was subjected to a surface hardening treatment similar to that described with respect to example No. 1.

After the surface treatment, the article has a hardness of 36 Rockwell C one-sixteenth inch from the outer surface, a hardness of 32 Rockwell C one-eighth inch from the surface and a hardness of 25 Rockwell C one-fourth inch from the surface.

This base alloy had a microstructure consisting of a matrix of beta-prime phase containing particles of intermetallic compound, while the diffused outer surface layer had a metallographic structure consisting of beta-prime phase, gamma-two phase and intermetallic compound particles.

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. A wear-resistant aluminum bronze article comprising an aluminum bronze base alloy containing from 5 to 13 percent by weight of aluminum, and a relatively hard wear-resistant aluminum bronze outer layer coherent with the base alloy, said outer layer having an aluminum content in the range of 13 to 16 percent, and having the aluminum content of said outer layer progressively increasing from the base alloy to the outer extremity of said outer layer, said outer layer having a different microstructure than the base alloy and having substantially increased hardness and wear resistance as compared to said base alloy.

2. A wear-resistant aluminum bronze article, comprising an aluminum bronze base alloy containing from 5 to 13 percent by weight of aluminum and a relatively hard wear resistant aluminum bronze outer surface layer coherent with the base alloy, said outer layer having a greater aluminum content than said base alloy and the aluminum content of said outer layer progressively increasing from said base alloy to the outer extremity of said outer layer, said base alloy having a microstructure selected from the group consisting of all alpha phase, alpha plus beta-prime phase, and said outer layer having a progressively changing microstructure in a direction from the base alloy to the outer surface of the outer layer, said microstructure changing progressively from all beta-prime phase to beta-prime plus gamma-two phases to all gamma-two phase to thereby provide a hard wear resistant outer layer.

3. The article of claim 1, in which the outer layer has a thickness in the range of 0.010 to 0.025 inches in the finished article.

4. The article of claim 1, in which the base alloy has a hardness of 55 Rockwell B to 30 Rockwell C, and said outer layer has a hardness of 85 Rockwell B to 60 Rockwell C.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,615,280 Dated October 26, 1971.

Inventor(s) QUENTIN F. INGERSON

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 42, After "occur" insert ---between---

Signed and sealed this 9th day of May 1972.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents