United States Patent [19]

Sperry et al.

[11] **3,925,067**

[45] **Dec. 9, 1975**

[54] **HIGH STRENGTH ALUMINUM BASE CASTING ALLOYS POSSESSING IMPROVED MACHINABILITY**

[75] Inventors: **Philip R. Sperry**, North Haven; **Derek E. Tyler**, Cheshire; **Leon Butzky**, North Haven, all of Conn.

[73] Assignee: **Swiss Aluminium Limited**, Chippis, Switzerland

[22] Filed: **Nov. 4, 1974**

[21] Appl. No.: **520,412**

[52] **U.S. Cl.** **75/142**; 75/141; 148/2; 148/3; 148/32.5; 148/159

[51] **Int. Cl.**[2] **C22C 21/16**

[58] **Field of Search** 75/142, 141; 148/32, 32.5, 148/3, 2, 159

[56] **References Cited**

UNITED STATES PATENTS

3,475,166 10/1969 Raffin 75/142

Primary Examiner—R. Dean

Attorney, Agent, or Firm—David A. Jackson; Robert H. Bachman

[57] **ABSTRACT**

An aluminum base casting alloy possessing improved machinability comprising from about 3.5 to about 6.0% copper, from about 0.5 to 3.0% silver, up to about 1% manganese, from about 0.15 to about 0.90% magnesium, up to about 0.20% silicon, up to about 0.20% iron, from about 0.4 to about 0.7% bismuth, from about 0.4 to about 0.7% lead and the remainder aluminum.

8 Claims, No Drawings

HIGH STRENGTH ALUMINUM BASE CASTING ALLOYS POSSESSING IMPROVED MACHINABILITY

BACKGROUND OF THE INVENTION

Aluminum alloy castings having good physical properties especially high strength and wear resistance, have long been needed for a variety of reasons. Generally, aluminum casting alloys currently available have provided strength levels well below those obtainable with machined plates and billets, machine forging and wrought assemblies.

U.S. Pat. No. 3,475,166 teaches a high strength aluminum casting alloy having good physical properties. This patent teaches an alloy having good elevated temperature properties which would be desirable for designing pistons or stressed engine parts with reduced weight. However, this material does not have adequate resistance to galling and its lack of hard, brittle intermetallic phases coupled with a resistance to fracture results in machinability which is less than that of most casting alloys.

Accordingly, it is a principal object of the present invention to provide a new and improved aluminum base casting alloy having high strength and wear resistance coupled with improved machinability.

It is a further object of the present invention to provide an aluminum alloy as aforesaid which possesses good resistance to galling and seizing do to improved lubricity.

It is a particular object of the present invention to provide an aluminum casting alloy as aforesaid which is useful in the design of the pistons or other highly stressed engine parts which operate at elevated temperatures.

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

SUMMARY OF THE INVENTION

In accordance with the present invention, it has been found that the foregoing objects and advantages may be readily obtained. The aluminum base casting alloy of the present invention comprises from about 3.5 to about 6.0% copper, from about 0.5 to 3.0% silver, up to about 1% manganese, from about 0.15 to about 0.90% magnesium, up to about 0.20% silicon, up to about 0.20% iron, from about 0.4 to about 0.7% bismut, from about 0.4 to about 0.7% lead and the remainder aluminum. Naturally, numerous optional additives and conventional impurities may be readily utilized as will be seen from the ensuing specification.

The alloys of the present invention possess good elevated temperature properties and resistance to galling combined with improved machinability. The addition of bismuth and lead in the amounts utilized herein, in conjunction with an increase in the amount of magnesium added, has been found to provide the improved machinability surprisingly without detracting from the strength of the matrix.

In addition to the foregoing, other significant advantages may be obtained in accordance with the alloy of the present invention. For example, Brinell hardness is maintained at a surprisingly comparable level, indicating that the alloy possesses excellent wear resistance.

In addition, the present invention also comprises a method of processing the aluminum base casting alloy set forth above. The method comprises casting the alloy mixture into ingot form, remelting the resulting ingot and casting to form the final product. The foregoing procedure may be utilized in conjunction with conventional processing for alloys of this type. Thus, the alloy may be cast in the temperature range of 1250° to 1500°F, and may be aged in the temperature range of 300° to 500°F for from 1 to 24 hours. Further, a solution heat treatment is preferably provided after casting and before aging at a temperature of 850° to 975°F for from 1 to 40 hours, followed by quenching.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As indicated hereinabove, the aluminum base casting alloy of the present invention contains amounts of bismuth and lead each ranging from about 0.4 to about 0.7% by weight of the composition. The addition of the two metals in the above amounts to the basic matrix alloy enables them to be dissolved in the molten alloy and to separate out as droplets during solidification, subsequent to the formation of primary aluminum dendrites. Lead and bismuth have been found to react favorably in the alloy of this invention because they have a high surface tension in contact with aluminum which permits them to retain a globular shape, rather than forming films around grain boundries.

In addition to the additions of bismuth and lead as noted above, it has been found to be advantageous to add an additional quantity of magnesium to the alloy to retain the strength of the matrix. It was found that some of the magnesium already present in the alloy tended to associate with the lead-bismuth particles which subsequently formed, with the result that magnesium was lost as a hardening element to the alloy matrix. It has been found in accordance with the present invention, that additional magnesium may be added to the matrix alloy in an amount corresponding to 0.2 times the total amount of lead and bismuth additions. Thus, the addition of up to about 0.3% magnesium to the magnesium already present in the alloy serves to maintain a yield strength which is comparable to the unmodified alloy.

The alloy of the present invention contains magnesium in an amount from 0.15 to about 0.90%, and preferably from 0.2 to 0.85%. In addition to the improvement in yield strength, it has been found that the magnesium addition is necessary in combination with the copper in order to obtain appreciable response to heat treatment.

Silver may be added in the amount of from 0.5 to about 3.0%, and preferably from about 0.5 to about 0.6%. Silver provides a significant extra strengthening and hardening effect.

The copper addition is in the amount of 3.5 to about 6%, and preferably from about 4.0 to about 5.3%. The copper addition has been found to provide a strengthening effect. Copper is the principal precipitation hardening agent forming the supersaturated solid solution during solution heat treatment, from which submicroscopic particles form during artificial aging treatment. The manner and effectiveness of the precipitation process is favorably affected by magnesium and silver additions.

Naturally, numerous additives and impurities may be present in the resultant alloy. Thus, manganese and chromium may be present in amounts up to 1.0% and 0.35%, respectively, generally in an amount of about 0.2 to about 0.8% manganese and about 0.20 to about 0.35% chromium. Either of these additives are particu-

larly desirable if iron is present, since they change the form of the iron from coarse, needle shaped particles to rounded or equiaxed particles and lessen brittleness. Iron may be present in an amount ranging up to about 0.20% and preferably up to about 0.15%. Titanium may also be included in an amount ranging from about 0.15 to about 0.7% and preferably from about 0.20 to about 0.30% for cast grain refining, and zinc may be included in an amount up to about 0.5%. Nickel may also be added in amounts ranging up to 2.5% to add to elevated temperature stability. Naturally, if desired, any of the foregoing elements may be present in an amount as low as 0.001%. In addition to the foregoing, others may be present in an amount up to 0.05% each, total 0.25%.

Unless otherwise stated, all percentages specified herein are in weight percent.

The alloys of the present invention are particularly useful in the manufacture of pistons for internal combustion engines. In addition to their desirable elevated temperature properties and resistance to galling, the alloys of the present invention are characterized by a surprisingly improved machinability. This property is particularly noteworthy as it is achieved without a sacrifice in either the strength or ductility which characterizes the casting alloys of this system. Thus, the resistance of the alloys of the present invention to galling, seizing and fracture is maintained and serves to suit the alloys for the above noted automotive uses.

In accordance with the present invention, a method for the preparation of the above described casting alloys is disclosed which comprises casting the matrix alloy with bismuth and lead to form an ingot which is then remelted and cast to form the final casting. The foregoing sequence has been found to be advantageous in practice, as the lead and bismuth additions, when subsequently added to the molten alloy are difficult to dissolve, and tend to drop to the bottom of the furnace. As a result, the mixture requires a significant amount of agitation which results in the entrainment of much dross which affects the quality of the casting. The casting step of the present invention substantially eliminates this difficulty, and sound castings with good dispersion of leadbismuth particles are obtained.

The remaining parameters of the method of this invention are in accordance with conventional practice. Thus, the alloys of the present invention are cast in the temperature range of 1250° to 1500°F. The castings, which include the bismuth and lead additions, are mainly intended to be cast into approximate shape and machined or ground to final dimensions. However, other forming operations, such as forging and the like are contemplated and may be employed.

Following casting or forging, the alloys are heat treated. Heat treatment preferably comprises solution heat treatment, followed by a quenching step and an aging treatment. Thus, for example, the alloy is preferably solution heat treated at from 850° to 1000°F for from 1 to 40 hours, and preferably from 900° to 980°F for from 12 to 20 hours, followed by quenching into cold or boiling water. This procedure should be followed by an artificial aging treatment which will develop the strength and stability that the particular service temperatures require. The nature of the aging treatment may vary with the particular temper which is desired, and, for example, the alloy may be aged for a period of from 1 to 24 hours at temperatures ranging from 300° to 500°F. The solution heat treatment is particularly preferred as it develops higher properties.

The alloys of the present invention and improvements thereof will be more readily apparent from a consideration of the following illustrative examples.

EXAMPLE I

Five castings were made of the permanent mold (Durville) type which measured 7 × 8 × ¾. inches. All but one of these chill cast plates contained additions of 0.5% lead and 0.5% bismuth, and the latter samples each contained varying amounts of magnesium. The control sample, referred to in Table I below as Alloy No. 1, represented the conventional matrix alloy prepared in accordance with U.S. Pat. No. 3,475,166, which was employed for purposes of comparison in the following experiments. Melting was done in an alumina coated clay graphite crucible, using an induction coil for heating. After melting, the melt was fluxed with chlorine gas at a rate of 1.3 liters per minute for about 8 minutes before pouring. The melt was poured at a temperature of about 1400°F into a permanent mold which was preheated to 600°F. The resultant alloys had the compositions set forth in Table I below, with the balance being essentially aluminum in each case.

TABLE I

ALLOY NO.	ALLOY COMPOSITIONS									
	Cu	Ag	Mn	Mg	Cr	Si	Fe	Ti	Pb	Bi
1	4.30	.58	.28	.37	0.33	.027	.050	.22	—	—
2	4.40	.58	.28	.32	0.32	.027	.060	.21	.5	.5
3	4.40	.58	.27	.44	0.31	.030	.055	.21	.5	.5
4	4.40	.58	.26	.50	0.30	.032	.038	.20	.5	.5
5	4.30	.57	.26	.58	0.29	.031	.040	.20	.5	.5

EXAMPLE II

The alloys prepared in Example I were all heat treated to T7 temper in the following manner. The alloys were first heat treated at 930°F for two hours and the temperature was then raised to 980°F and held at that level for 16 hours. The alloys were then water quenched in cold water. After quenching, the alloys were aged at room temperature for 24 hours, and were then further aged at a temperature of 370°F for five hours to achieve T7 temper. The alloys were then machined to standard round tensile specimens and were tested. Results of the tensile testing and Brinell hardness measurements are set forth in Table II, below.

TABLE II

ALLOY NO.		Tensile Properties			
		Yield Strength at 0.2% (ksi)	Ultimate Tensile Strength (ksi)	Elongation in 2 in. %	Brinell Hardness-Kg/mm²
1	(Control)	60.2	64.8	3.5	130
2	(0.5 Pb + 0.5 Bi)	48.9	57.2	4.0	110
3	(0.5 Pb + 0.5 Bi + 0.1 Mg)	52.4	57.5	4.0	111
4	(0.5 Pb + 0.5 Bi + 0.2 Mg)	58.2	61.7	2.3	116

TABLE II-continued

ALLOY NO.	Tensile Properties: Yield Strength at 0.2% (ksi)	Ultimate Tensile Strength (ksi)	Elongation in 2 in. %	Brinell Hardness-Kg/mm²
(0.5 Pb + 0.5 Bi + 0.3 Mg)	60.1	62.1	1.0	129

From the tensile data shown above, it can be seen that compensating additions of up to 0.3% magnesium to the nominal 0.3% already present in the control alloy serve to maintain a comparable yield strength and hardness of the material.

EXAMPLE III

Samples of Alloys No. 1 and 5, representing the basic matrix alloy and the alloy containing lead and bismuth together with 0.3% additional magnesium, respectively, were subjected to drilling tests to compare machinability. The test consisted of a measurement of the time required to drill a standard size hole to a standard depth in each of the samples. The results of this test are set forth in Table III, below.

TABLE III

DRILL MACHINING TESTS ALLOY NO.	Drilling Time (seconds)
1	26.1
5	22.3

The results of the drilling tests clearly show that the alloy of this invention possesses substantially improved machinability over the matrix alloy representative of the prior art.

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. An aluminum base casting alloy possessing improved machinability consisting essentially of from about 3.5 to about 6.0% copper, from about 0.5 to 3.0% silver, up to about 1% manganese, from about 0.15 to about 0.90% magnesium, up to about 0.20% silicon, up to about 0.20% iron, from about 0.4 to about 0.7% bismuth, from about 0.4 to about 0.7% lead and the remainder aluminum.

2. The alloy of claim **1** which further comprises from about 0.15 to about 0.7% titanium for grain refinement, and up to about 0.35% chromium for improved ductility.

3. The alloy of claim **1** wherein said copper is from 4.0 to 5.3%, said silver is from 0.5 to 1% and said magnesium is from about 0.20 to 85%.

4. The alloy of claim **3** wherein said lead and said bismuth are each present in amounts of about 0.4 to 0.6%.

5. An aluminum base casting alloy possessing improved machinability which consists essentially of from about 3.5 to about 6.0% copper, from about 0.05 to 3.0% silver, from about 0.2 to about 0.8% manganese, from about 0.15 to about 0.90% magnesium as a strengthening agent, from about 0.15 to about 0.7% titanium as a grain refiner, up to about 0.20% silicon, up to about 0.20% iron, from about 0.4 to about 0.7% bismuth, from about 0.4 to about 0.7% lead and the remainder aluminum.

6. The alloy of claim **5** comprising from about 4.2 to 4.5% copper, from about 0.5 to 0.6% silver, from about 0.2 to 0.3% manganese, from about 0.20 to about 0.85% magnesium, from about 0.20 to about 0.35% chromium, from about 0.020 to about 0.035% silicon, from about 0.030 to about 0.070% iron, from about 0.20 to about 0.30% titanium, from about 0.4 to about 0.6% lead, from about 0.4 to about 0.6% bismuth and the remainder aluminum.

7. A method of preparing an aluminum base alloy casting possessing improved strength and machinability which comprises:

A. casting ingot form an aluminum base alloy consisting essentially of from about 3.5 to about 6.0% copper, from about 0.5 to 3.0% silver, up to about 1% manganese, from about 0.15 to about 0.90% magnesium, up to about 0.20% silicon, up to 0.20% iron, from about 0.4 to about 0.7% bismuth, from about 0.4 to about 0.7% lead, remainder aluminum;

B. remelting the ingot prepared in step A, and finally casting the resultant melt; and

C. heat treating the final casting of step B to improve the tensile properties thereof.

8. The method of claim **7** wherein the heat treatment of step C comprises a solution heat treatment, quench and an aging treatment.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,925,067

DATED : December 9, 1975

INVENTOR(S) : Philip R. Sperry, Derek E. Tyler and Leon Butsky

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 48, delete "bismut" and insert --bismuth--

Column 2, line 61, after "by" insert --the--

Column 3, line 43, delete "leadbismuth" and insert --lead-bismuth--

Column 4, line 17, delete "7 X 8 X 3/4. inches and insert --7" X 8" X 3/4"--

Column 4, line 36, between lines 36 and 37, after "ALLOY COMPOSITIONS" insert and center --Composition in Weight Percent--

Column 6, line 39, after "casting" insert --into--

Signed and Sealed this

twenty-ninth Day of June 1976

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks