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## ALUMINUM BASE ALLOY

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This invention relates to an aluminum base alloy which possesses a unique combination of the properties of strength, resistance to stress corrosion and good machinability.

Aluminum base alloys containing copper as the principal added alloying component and small amounts of lead and bismuth have been successfully used for the manufacture of articles which are shaped by machining operations. Such articles are commonly referred to in the trade as screw machine products. Although these products have adequate strength in the solution heat treated condition, with or without subsequent precipitation treatment, their resistance to corrosion, especially stress corrosion is not as good as demanded for certain applications. For example, when employed as fasteners with structural members of other types of aluminum base alloys, serious corrosion can occur under severe conditions.

It is an object of this invention to provide a readily machinable aluminum base alloy which in the solution heat treated condition, with or without subsequent precipitation hardening possesses a relatively high strength and a high resistance to corrosion, especially stress corrosion. Another object is to provide a readily machinable aluminum base alloy that has low tool wear characteristics. A further object is to provide a readily machinable aluminum base alloy which can be hot worked and quenched thereby obviating the need for subsequent solution heat treatment. Still another object is to provide a readily machinable alloy that can be cold worked before or after the precipitation hardening treatment without adverse effect upon the resistance to stress corrosion. These and other objects and advantages will be apparent from the following description and embodiments of the invention.

My invention is predicated on the discovery that an aluminum base alloy consisting essentially of aluminum, 1 to 2.5% by weight of the intermetallic compound  $Mg_2Si$ , 0.4 to 0.75% of bismuth and 0.4 to 0.75% of lead exhibits in the solution heat treated and precipitation hardened condition a comparatively high strength, a high resistance to stress corrosion and excellent machinability. Moreover, screw machine products made of this alloy can be employed in association with structural members of other aluminum base alloys with little or no corrosion, especially stress corrosion. Extensive machining tests on the alloy have demonstrated that tool wear is minimized because of the absence of any significant amount of uncombined silicon. The alloy is easily hot and cold worked and is particularly adapted to the manufacture of extruded products. Furthermore, the strength and machinability of the alloy can be increased by cold working it either before or after the precipitation hardening treatment.

The alloying elements magnesium and silicon should be present in the proportions necessary to form from 1 to 2.5% by weight of the intermetallic compound  $Mg_2Si$  with allowance for a slight excess of either element. To state the proportions more precisely, the silicon content should be between 45 and 65% of the magnesium content. If larger or smaller amounts of silicon are present the machining characteristics are impaired. To obtain the best results, the  $Mg_2Si$  content should fall within the range of 1.4 to 1.7%.

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Both lead and bismuth must be present to develop the desired machinability, and within the proportions of 0.4 to 0.75% each. If smaller amounts are used, the machinability is noticeably diminished while larger quantities impair the strength and resistance to corrosion. In any preferred practice the two elements should be employed in substantially equal amounts.

To improve the strength without adversely affecting the resistance to corrosion it may be advisable to add 0.1 to 0.5% copper. Larger amounts are detrimental to the resistance to corrosion.

To further supplement the strength without diminishing the resistance to corrosion it is sometimes helpful to include at least one element of the group composed of 0.1 to 0.5% manganese and 0.02 to 0.3% chromium. These proportions should be observed in order to minimize adverse quenching effects on the microstructure.

If grain refinement is a problem in the production of particular alloys, it may be advisable to incorporate from 0.01 to 0.25% of titanium.

The usual impurities may be present in the alloy such as iron. This element can be tolerated in amounts up to 0.5%. The quantity of other metallic impurities normally present in aluminum is too small to have any significant effect upon the properties of the alloy.

To achieve the desired high level of strength the alloys should be subjected to a thermal treatment involving heating to a temperature between 920 and 1075° F. for a sufficient length of time to effect substantially complete solution of the soluble alloy components. The length of time will vary with the particular alloy and the thickness of the body being treated. Thus, in treating a wrought product, it may be sufficient to soak at the desired temperature for 1/4 to 2 hours whereas in treating an ingot before working the soaking period may extend up to 24 hours. Following the solution treatment the alloy body should be rapidly cooled to much lower temperature. In the case of wrought products which are heated to the solution heat treating temperature quenching can be done in a water bath or spray or an equivalent liquid coolant. In the case of hot working an ingot, as in an extrusion operation, the worked product can be chilled immediately from the working temperature upon completion of the working operation. In the case of an extrusion this can be done as the shape emerges from the die. Quenching in this manner has been found to be beneficial to the machining characteristics of the alloy as well as reducing the costs of manufacture.

Although the products may be employed in the as-quenched or chilled condition, it is usually advisable to subject them to a precipitation hardening treatment consisting of heating to 275 to 450° F. for a period of from 1 to 24 hours and thereby obtain a high strength. However, to achieve the maximum strength, the alloy should be cold worked either before or after the precipitation treatment.

As indicated above, the alloy can be readily worked by any of the well-known metal processes, rolling, extrusion, forging, drawing, and the like, in both the hot and cold conditions. The rolling and extrusion processes are generally the most economical ones to provide stock for the manufacture of screw machine products.

In addition to the metal working operations incident to producing the desired size and shape of stock, it can be cold worked either before or after the precipitation hardening treatment as mentioned above. Such cold work should not effect reductions in cross section of more than about 30% since the alloy becomes too hard and surface defects are apt to appear if greater reductions are employed. Cold working in combination with the precipitation hardening treatment serves to increase the strength

and improve the machinability of the product. This is achieved without any substantial effect upon the resistance to corrosion.

The unique combination of properties found in my alloy is illustrated by the following examples in comparison with some alloys which do not possess such a combination of properties. The compositions of the alloys are given in Table I below, aluminum and impurities constituting the balance in each case.

TABLE I  
Percent Composition of Alloys

| Alloy  | Mg   | Si   | Cu   | Cr    | Mn    | Bi    | Pb    | Ti   |
|--------|------|------|------|-------|-------|-------|-------|------|
| A----- | 0.95 | 0.60 | 0.25 | 0.06  | ----- | 0.55  | 0.55  | 0.06 |
| B----- | 0.95 | 0.60 | 0.25 | 0.25  | ----- | ----- | ----- | 0.06 |
| C----- | 0.95 | 0.60 | 0.25 | 0.25  | ----- | 0.55  | 0.55  | 0.06 |
| D----- | 0.8  | 1.3  | 0.25 | ----- | 0.7   | 0.4   | 0.4   | 0.06 |

Alloy A, which is representative of my invention, was cast, the ingot preheated within the solution heat treating temperature range and extruded into the form of rod 1.25 in. in diameter, the rod being water quenched as it emerged from the die. The other alloys were cast, the ingots preheated for working purposes and then forged to 1.125 in. rod. One portion of the alloy A rod was cold drawn with a reduction in cross section of 20% and not subjected to any further treatment, this portion being identified below in Table II as A-1. Another portion of the cold drawn rod was given a precipitation hardening treatment of 18 hours at 320° F. and is identified in the following table as A-2. A third portion of the extruded and quenched rod was given the foregoing precipitation hardening treatment and then cold drawn with a 20% reduction in cross section. This portion is designated A-3 in the table below. All of the forged rod samples were given a solution heat treatment at 970 to 1050° F., quenched in cold water and heated 18 hours at 320° F. One portion of the C alloy which is also representative of my invention, was cold drawn with a 20% reduction in cross section after the precipitation hardening treatment, this portion being referred to below as C-2, the portion without the cold drawing being designated C-1.

The tensile properties and machining characteristics of the various rod samples were determined. The machinability was evaluated by a simple turning test on a lathe with box-type tools having different cutting angles used with various depths of cut, rate of feed and turning speeds. The size and length of chips were given a rating on the following numerical basis. Very short tight curls were rated as 1, long lengths with curls up to 3/8" in diameter were rated as 2, long lengths with curls up to 1" in diameter were rated as 3, continuous curls up to 2" in diameter were rated as 4, and larger chips were rated as 5.

The tensile properties, elongation and chip size of several alloys and in various conditions are given in Table II below.

TABLE II  
Tensile Properties and Machining Results

| Alloy    | Tensile Strength, p.s.i. | Yield Strength, p.s.i. | Percent Elongation | Chip Size Rating |
|----------|--------------------------|------------------------|--------------------|------------------|
| A-1----- | 54,000                   | 52,000                 | 10                 | 1.4              |
| A-2----- | 58,000                   | 56,000                 | 14                 | 1.4              |
| A-3----- | 62,000                   | 61,000                 | 10                 | 1.3              |
| B-----   | 46,000                   | 42,000                 | 18                 | 4                |
| C-1----- | 47,000                   | 40,000                 | 20                 | 1.8              |
| C-2----- | 53,000                   | 51,000                 | 9                  | 1.4              |
| D-----   | 57,000                   | 49,000                 | 15                 | 1.3              |

From the standpoint of tensile properties it is evident from the foregoing results that samples B and C-1 which received identical treatment had substantially the same

strength and elongation values, however, the machinability of sample B without the lead and bismuth was considerably inferior to that of sample C-1. The benefit of cold working after the precipitation treatment in respect to tensile properties and machinability is to be seen in sample C-2. The A samples reflect the advantages of different combinations of cold work and precipitation hardening treatments and still retain an excellent machinability.

Tool wear tests were made on samples A-1, A-2, A-3, C-2 and D employing radioactive tracer techniques. The samples A-1 and C-2 showed the least wear and were comparable to the commercial alloy nominally consisting of aluminum, 5.5% copper, 0.5% bismuth and 0.5% lead. The tests on A-2 and A-3 showed greater wear while the D sample produced a tool wear 4 to 5.5 times that of A-1 and C-2. The presence of silicon in excess of that combined with magnesium is considered to account for the high wear of the cutting tool.

Stress corrosion tests were made on all of the samples listed in Table II above. The test specimens consisted of machined rings in the shape of a C having an outside diameter of approximately 0.75 in., a width of 0.75 in. and a wall thickness of 0.064 in., the axis of the specimens being parallel to the axis of the rod stock. A stress was applied thereto equivalent to 50 to 75% of the yield strength in a longitudinal direction. The stressed samples were exposed to alternate immersion in a 3.5% NaCl solution wherein the samples were cyclically raised from and lowered into the solution. All of the samples except D remained intact for a period of more than 9 months but the D sample failed within less than 30 days.

It is apparent from the stress corrosion test results that the presence of bismuth and lead does not cause early failure and that cold working the alloys after solution heat treatment had no adverse effect upon resistance to stress corrosion. This is important for it shows that a high strength and excellent machinability can be combined with a high resistance to stress corrosion.

Having thus described my invention and certain embodiments thereof, I claim:

1. An aluminum base alloy consisting essentially of aluminum, 0.63 to 2.02% magnesium and 0.37 to 1.04% silicon, said magnesium and silicon being present in the proportions necessary to form between 1 and 2.5% by weight of the intermetallic compound  $Mg_2Si$ , and from 0.4 to 0.75% each of bismuth and lead, said alloy being characterized in the wrought condition by a combination of high strength, a high resistance to stress corrosion and a machinability superior to that of the same alloy under the same conditions without said bismuth and lead.

2. An alloy according to claim 1 which also contains 0.1 to 0.5% copper.

3. An alloy according to claim 1 which also contains at least one element of the group 0.1 to 0.5% manganese and 0.02 to 0.3% chromium.

4. An alloy according to claim 1 which also contains 0.01 to 0.25% titanium.

5. An alloy according to claim 1 which contains from 1.4 to 1.7% of the intermetallic compound  $Mg_2Si$ .

6. A wrought aluminum base alloy in the solution heat treated and precipitation hardened condition consisting essentially of aluminum, 0.63 to 2.02% magnesium and 0.37 to 1.04% silicon, said magnesium and silicon being present in the proportions necessary to form between 1 and 2.5% of the intermetallic compound  $Mg_2Si$ , and from 0.4 to 0.75% each of the bismuth and lead, said alloy having an internal structure resulting from a solution heat treatment at 920 to 1075° F. and precipitation hardening at 275 to 450° F. and characterized by a combination of high strength, a high resistance to stress corrosion and a machinability superior to that of the same alloy under the same conditions without said bismuth and

lead.

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7. An alloy according to claim 6 which also contains 0.1 to 0.5% copper.

8. An alloy according to claim 6 which has been cold worked less than 30% between the solution heat treatment and precipitation hardening treatment.

9. An alloy according to claim 6 which has been cold worked less than 30% after the precipitation hardening treatment.

10. An alloy according to claim 7 which also contains at least one element of the group 0.1 to 0.5% manganese and 0.02 to 0.3% chromium.

11. An alloy according to claim 7 which also contains 0.01 to 0.25% titanium.

12. An alloy according to claim 7 which contains from 1.4 to 1.7% of the intermetallic compound  $Mg_2Si$ .

13. A hot worked, quenched and cold worked aluminum base alloy product, said alloy consisting essentially of aluminum, 0.63 to 2.02% magnesium and 0.37 to 1.04% silicon, said magnesium and silicon being present in the proportions necessary to form between 1 and 2.5%

of the intermetallic compound  $Mg_2Si$ , 0.1 to 0.5% copper, and from 0.4 to 0.75% each of lead and bismuth, said product having an internal structure resulting from solution heat treating a body of the alloy prior to hot working it, said treatment consisting of heating the body to a temperature between 920 and 1075° F., hot working the body, quenching the hot worked product from the hot working temperature and thereafter cold working said product less than 30%, said product being characterized by a combination of high strength, a high resistance to stress corrosion and a machinability superior to that of the same alloy under the same conditions without said lead and bismuth.

14. A product according to claim 13 which also contains at least one element of the group 0.1 to 0.5% manganese and 0.02 to 0.3% chromium.

#### References Cited in the file of this patent

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**Dedication**

3,031,299.—*Charles B. Criner*, Murrysville, Pa. ALUMINUM BASE ALLOY.  
Patent dated Apr. 24, 1962. Dedication filed May 26, 1972, by  
the assignee, *Aluminum Company of America*.

Hereby dedicates to the Public the remaining term of said patent.

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