

UNITED STATES PATENT OFFICE

2,240,940

ALUMINUM ALLOY

Joseph A. Nock, Jr., Tarentum, Pa., assignor to
Aluminum Company of America, Pittsburgh,
Pa., a corporation of Pennsylvania

No Drawing. Application September 28, 1940,
Serial No. 358,925

3 Claims. (Cl. 75-141)

This invention relates to aluminum base alloys, and it is particularly concerned with wrought alloys that receive a solution heat treatment and are artificially aged. This application is a continuation-in-part of my copending application Serial No. 309,392, filed December 15, 1939.

It has been known that aluminum base alloys containing more than 15 per cent of zinc, especially those that also contain copper, magnesium and/or silicon, possess relatively high strength in the wrought form. These alloys, however, suffer from several disadvantages, as compared to alloys containing copper and magnesium as the chief added alloying elements but no zinc, namely, an increased weight where a large amount of zinc is used, increased difficulty in hot working, a lower resistance to corrosion, and under certain conditions a susceptibility to a form of corrosion known as "stress cracking." The early alloy compositions containing 15 per cent or more of zinc were later modified by the addition of such elements as copper, magnesium, and silicon, and some reduction in the amount of zinc. While the reduction in the amount of zinc and the addition of other alloying elements reduced the above named disadvantages, they were not entirely eliminated.

Some of the most satisfactory high strength aluminum base alloys containing less than 15 per cent zinc together with additions of magnesium, copper, and manganese, are those disclosed in U. S. Patent 1,924,729 to L. J. Weber. Although these alloys possess high strength and are resistant to stress cracking, they have been found to be susceptible to acceleration of corrosion under stress. This property has only become recognized with a refinement of testing procedure and equipment. Because of the importance of this property in materials used in structures which are designed to utilize the maximum loading characteristics of the structural material, an intensive search has been made in the field of high strength aluminum base alloys to find compositions that are relatively free from susceptibility to acceleration of corrosion under stress.

The principal object of my invention is to provide an improved wrought aluminum base alloy containing zinc as the principal added alloying component, which possesses both high strength and a high degree of resistance to corrosion under stress. A further object is to provide an age hardened alloy of this type having stable mechanical properties over a long period

of time. Another object is to provide an aluminum base alloy of this type which can be readily hot worked. Still another object is to provide a wrought solution heat treated and artificially aged aluminum base alloy containing zinc which exhibits substantially no acceleration of corrosion under stress.

My invention is predicated upon the discovery that aluminum base alloys composed of aluminum, 4 to 6 per cent zinc, 0.75 to 2.5 per cent magnesium, 0.1 to 2 per cent copper, 0.1 to 1 per cent manganese, and a small amount of one or more of the grain refining elements titanium, boron, zirconium, molybdenum, tungsten, cobalt, chromium, and vanadium, avoid to a large extent the above named disadvantages usually associated with aluminum base alloys containing substantial amounts of zinc. By the expression "grain refining elements," I mean that these elements refine the grain structure of the alloys in either the cast or wrought condition or both. At least one of the group of grain refining elements should be employed in the following amounts: 0.02 to 0.25 per cent titanium, 0.005 to 0.1 per cent boron, 0.01 to 0.15 per cent zirconium, 0.02 to 0.25 per cent molybdenum, 0.02 to 0.2 per cent tungsten, 0.02 to 0.2 per cent cobalt, 0.05 to 0.5 per cent chromium, and 0.02 to 0.2 per cent vanadium. Alloys falling within the foregoing range possess exceptionally high stable mechanical properties and resistance to corrosion when thermally treated in the conventional manner to improve their strength and hardness. I have also discovered that when these alloys are artificially aged after solution heat treatment they are remarkably resistant to the acceleration of corrosion under the influence of stress. Although many lower strength aluminum base alloys possess a satisfactory resistance to ordinary corrosion, it has been observed that it is difficult to obtain a high degree of resistance to acceleration of corrosion under stress in alloys having very high strength. By the expression "acceleration of corrosion under stress," I mean that upon exposure to the same corroding medium there is substantially no increase in the susceptibility to loss of strength in an alloy article under external stress as compared to the susceptibility to loss in strength in the same article under no external stress.

In addition to the foregoing improved resistance to acceleration of corrosion under stress, I have found that the alloy composition described above can be given a solution heat treatment over a wider temperature range than is possible

in a duralumin type of alloy. This property is of value in commercial heat treating operations, since variations in heating conditions can easily occur, and it is therefore desirable to use an alloy which is not too sensitive to such variations. In the case of my improved alloy, the solution heat treatment may be given within a range of 820 to 1000° F. The period of time required to secure the desired solution of soluble constituents will, of course, vary somewhat with the temperature and with the mass of material being heated, but this is a matter that can be easily determined under the particular conditions existing in commercial operation.

Another advantage possessed by my alloy is that it may be quenched from the solution heat treating temperature in a variety of quenching media without great effect upon the ultimate mechanical properties of the alloy. In other words, my alloy is not as sensitive to variations in a quenching procedure, especially if the copper content does not exceed about 1 per cent, as are many of the aluminum base alloys. In a number of cases an air blast quench can be used whereas this cannot be employed in quenching duralumin type of alloys if maximum strength and resistance to corrosion is desired.

As mentioned hereinabove, my improved alloy must be artificially aged in order to attain high stable mechanical properties and maximum resistance to corrosion under stress. Although my alloy will spontaneously age at room temperature after being quenched from the solution heat treating temperature, and exhibit a continuous increase in strength over a long period of time, I have found that the resistance to acceleration of corrosion under stress decreases with prolonged aging at room temperature which is, of course, highly undesirable. If, however, the alloy is artificially aged instead of aging at room temperature, the desired resistance to corrosion is obtained. The artificial aging treatment should consist of reheating the quenched alloy to a temperature between 225 and 340° F. and holding it at that temperature for a period of 4 to 50 hours. In general, I have found that aging at a temperature of 275° F. for 8 to 12 hours produces a very satisfactory combination of properties.

In the manufacture of articles from sheet, it is often necessary to cold form the sheet. In the case of the solution heat treated and aged duralumin type alloys, the age hardening occurs at room temperature and progresses so rapidly after the alloy has been quenched that it is difficult to cold form the alloy. In contrast to such a condition, my alloys age harden but slowly after having been quenched from the solution heat treating temperature with the result that they may be readily cold formed over a much longer period after quenching. After the cold forming operation the alloys are artificially aged in the manner described above. I have also found that even the artificially aged material can be readily cold formed as compared to other age hardened aluminum base alloys of the duralumin type.

In the manufacture of my alloys, aluminum is used which contains the usual impurities of iron and silicon. In general, I prefer to use metal containing less than about 0.4 per cent total of iron and silicon. However, it is possible to allow as much as 0.75 per cent silicon and 0.5 per cent iron. Where the alloys are cast by a continuous process, the silicon should not exceed 0.2 per cent.

Through use of the foregoing thermal treatments, I have been able to consistently obtain in

these alloys tensile strengths of 70,000 pounds per square inch or higher, yield strengths of 60,000 pounds per square inch, and elongations of about 12 per cent. Furthermore, I have found that these alloys possess a very high endurance limit as compared to other age hardened aluminum base alloys. Aluminum base alloys having such mechanical properties find ready application in structures which must possess a maximum strength with a minimum amount of material. Although these high mechanical properties can be developed in the alloy, it may nevertheless be fabricated by any of the well known working processes, such as rolling, forging or extruding.

Several examples may be cited to illustrate the properties obtainable in my improved alloys. The alloys tested had the following chemical compositions:

TABLE I
Chemical composition, per cent

| Alloy | Zinc | Magnesium | Copper | Manganese | Silicon | Iron | Titanium |
|--------|------|-----------|--------|-----------|---------|------|----------|
| A..... | 6.02 | 1.4 | 1.55 | 0.38 | 0.40 | 0.25 | 0.14 |
| B..... | 4.00 | 1.32 | 1.47 | 0.38 | 0.43 | 0.32 | 0.08 |
| C..... | 5.52 | 2.15 | 1.52 | 0.49 | 0.11 | 0.24 | 0.14 |
| D..... | 5.55 | 2.21 | 0.55 | 0.41 | 0.09 | 0.16 | 0.06 |
| E..... | 5.67 | 1.95 | 0.51 | 0.52 | 0.09 | 0.15 | 0.09 |
| F..... | 5.29 | 2.05 | 1.46 | 0.41 | 0.18 | 0.32 | 0.09 |
| G..... | 5.24 | 2.10 | 0.74 | 0.42 | 0.15 | 0.29 | 0.09 |

All of the alloys were rolled to sheet 0.064 inch in thickness in the usual manner and thermally treated as follows: Sheets from alloys C, D, E, F, and G were heated in an air furnace at 920° F. for 20 minutes, quenched in cold water and aged at 275° F. for 12 hours. Sheets from alloy A were heated at 970° F. for 20 minutes, quenched in cold water and aged 12 hours at 320° F., while sheet from alloy B was heated at 970° F. for 20 minutes, quenched in cold water and aged for 18 hours at 320° F. Following these treatments, tensile test specimens were taken from the sheets of the several alloys for the several tests. The average mechanical properties of these alloys were as follows:

TABLE II
Mechanical properties

| Alloy | Tensile strength | Yield strength | Elongation |
|--------|------------------|----------------|------------|
| | Lbs./sq. in. | Lbs./sq. in. | Percent |
| A..... | 70,110 | 62,300 | 13.3 |
| B..... | 63,560 | 49,800 | 15.5 |
| C..... | 74,120 | 65,550 | 12.0 |
| D..... | 71,960 | 65,800 | 13.0 |
| E..... | 71,400 | 65,000 | 11.8 |
| F..... | 73,500 | 62,900 | 12.0 |
| G..... | 72,200 | 64,250 | 11.8 |

Additional tensile test specimens were subjected to an alternate immersion test for 48 hours consisting of elevating from and lowering the specimens into an aqueous solution of 5 per cent sodium chloride and 0.3 per cent hydrogen peroxide. One group of specimens from each alloy were exposed to the test in an unstressed condition, while the other group were stressed as simple beams in an amount equal to 75 per cent of the yield strength. At the conclusion of the 48 hour period, the specimens were removed and their mechanical properties determined. A comparison was made between the properties of the corroded specimens and the original properties of the several alloys. The change brought about by corrosion is expressed

in the table below in terms of the per cent lost with respect to the original tensile strength and elongation values.

TABLE III
Corrosion losses

| Alloy | Unstressed | | Stressed | |
|-------|------------------|------------|------------------|------------|
| | Tensile strength | Elongation | Tensile strength | Elongation |
| A | -6 | -25 | -7 | -29 |
| B | -3 | -16 | -3 | -18 |
| C | -5 | -50 | -6 | -54 |
| D | -1 | -25 | -1 | -25 |
| E | -2 | -7 | -1 | -7 |
| F | -3 | -38 | -4 | -38 |
| G | -8 | -75 | -10 | -83 |

It will be observed that there is little difference in loss of tensile strength between the stressed and unstressed specimens. This indicates that the applied stress had substantially no effect upon the resistance to corrosion, and hence it may be said that there has been no acceleration of corrosion by stress.

The effect of the copper content of the alloy upon the resistance to corrosion and acceleration of corrosion under stress when a less drastic quenching medium than cold water is used, is shown in the following tests. For this purpose, sheets from alloys C, D, E, and G were used. The sheets from alloys C, D, and E were heated in an air furnace at 920° F. for 20 minutes and quenched in a high velocity air blast, the air being at room temperature, and aged for 12 hours at 275° F. The G alloy material was likewise heated in an air furnace at 920° F. for 20 minutes, one portion being quenched in boiling water, and another portion quenched in a commercial quenching oil at room temperature. Material from both portions were aged for 12 hours at 275° F. The mechanical properties of these alloys in this condition were as follows:

TABLE IV
Mechanical properties

| Alloy | Quench | Tensile strength | Yield strength | Elongation |
|-------|---------------|------------------|----------------|------------|
| | | Lbs./sq. in. | Lbs./sq. in. | Percent |
| C | Air blast | 73,010 | 62,100 | 12.8 |
| D | do. | 70,000 | 62,850 | 12.3 |
| E | do. | 71,110 | 64,200 | 12.8 |
| G | Boiling water | 69,090 | 61,150 | 10.3 |
| G | Oil | 71,500 | 63,950 | 12.0 |

Tensile test specimens from the material described above were subjected to the 48 hour alternate immersion test referred to hereinabove, one portion of the test specimen being exposed in the unstressed condition and the other portion being stressed 75 per cent of the yield strength. The per cent change in properties caused by corrosion are given in the table below.

TABLE V
Corrosion losses

| Alloy | Quench | Unstressed | | Stressed | |
|-------|---------------|------------------|------------|------------------|------------|
| | | Tensile strength | Elongation | Tensile strength | Elongation |
| C | Air blast | -14 | -67 | -24 | -88 |
| D | do. | -5 | -76 | -4 | -76 |
| E | do. | -5 | -57 | -6 | -65 |
| G | Boiling water | -5 | -63 | -5 | -48 |
| G | Oil | -7 | -67 | -6 | -64 |

It will be observed that alloy C which contained more than 1 per cent copper suffered proportionately greater losses than the other alloys containing less than 1 per cent copper. It is also evident that stressing the latter alloys containing less than 1 per cent copper had substantially no effect upon the resistance to corrosion.

Having thus described my invention, I claim:

1. A wrought, heat treated, and artificially aged aluminum base alloy composed of from 4 to 6 per cent zinc, 0.75 to 2.5 per cent magnesium, 0.1 to 2 per cent copper, 0.1 to 1 per cent manganese, and at least one of the group of grain refining elements consisting of 0.02 to 0.25 per cent titanium, 0.005 to 0.1 per cent boron, 0.01 to 0.15 per cent zirconium, 0.02 to 0.25 per cent molybdenum, 0.02 to 0.2 per cent tungsten, 0.02 to 0.2 per cent cobalt, 0.05 to 0.5 per cent chromium, and 0.02 to 0.2 per cent vanadium, the balance being aluminum.

2. A wrought, heat treated, and artificially aged aluminum base alloy composed of from 4 to 6 per cent zinc, 0.75 to 2.5 per cent magnesium, 0.1 to 2 per cent copper, 0.1 to 1 per cent manganese, 0.05 to 0.5 per cent chromium, and 0.02 to 0.25 per cent titanium, the balance being aluminum.

3. A wrought, heat treated, and artificially aged aluminum base alloy composed of from 4 to 6 per cent zinc, 0.75 to 2.5 per cent magnesium, 0.1 to 2 per cent copper, 0.1 to 1 per cent manganese, and 0.02 to 0.25 per cent titanium, the balance being aluminum.

JOSEPH A. NOCK, JR.