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WROUGHT ALUMINUM BASE ALLOY AND METHOD OF PRODUCING IT

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My invention relates to improving aluminum base alloys containing magnesium, zinc, and copper.

Wrought aluminum base alloys containing magnesium and lesser amounts of zinc and copper possess many technically advantageous properties. In making some articles from the cold worked alloys, it is sometimes necessary to heat them to a temperature below the annealing temperature in order to secure the desired degree of workability. The alloys cannot, of course, be heated above the recrystallization temperature and still retain the benefits of the cold working. Since at times it becomes necessary to form articles from heavy sheet or plate that cannot be easily bent at room temperature, it becomes important to shape the material at an elevated temperature, and furthermore to employ sheet or plate which resists the permanent softening effect when heated up to the usual annealing temperature range. The forming of articles in this manner is known as hot forming. The softening effect caused by raising the temperature of the metal is to be distinguished from the softening produced by recrystallization, since the latter effect persists at room temperature after the metal has been heated, whereas in the former case the softening is dependent upon maintaining the metal at the elevated temperature.

The recrystallization temperature is not only a significant point in the making of articles by the hot forming process, but it also plays a part in making successful brazed joints from cold worked aluminum base alloys. The application of sufficient heat to metal parts being joined causes a heating of the metal with the result that recrystallization may occur in the cold worked metal.

The term "recrystallization," as understood in the art and as here employed, refers to the process by which new grains are formed from fragments of former grains in plastically deformed metal. As a result of recrystallization, the strains induced by the cold working are relieved. The temperature at which recrystallization begins varies with the degree of cold work and the rate of heating. The extent of recrystallization depends upon the temperature and the time at temperature. Whenever the conditions do not favor recrystallization, a substantial amount of the effect of cold working is retained by the metal.

An object of my invention is to provide a cold worked aluminum base alloy containing magnesium and lesser amounts of zinc and copper which has desirable workability along with a higher strength and is resistant to permanent softening when heated to the usual annealing temperature range for alloys of this type. Another object is to enlarge the temperature range

within which the properties of cold worked alloys can be retained to a substantial degree. A further object is to provide a means for raising the recrystallization temperature of cold worked aluminum base alloys containing magnesium, zinc and copper. Still another object is to provide a material which is free from Lüder lines when stretched.

My invention is predicated on the discovery that the addition of 0.01 to 1 per cent zirconium to an aluminum base alloy containing from 0.5 to 10 per cent magnesium, 0.25 to 8 per cent zinc, and 0.1 to 3 per cent copper will raise the recrystallization temperature of the alloy in the cold worked condition to a surprising extent. It is my preferred practice, however, to use from 0.1 to 0.5 per cent zirconium. I have found, for example, that the recrystallization temperature in many cases may be raised from 200 to 300° F. above that of the same alloy minus the zirconium where the two alloys have been subjected to the same work hardening and thermal treatments. This effect is, of course, modified by the degree to which the alloy has been work hardened and the duration of the thermal treatment, the greatest effect being obtained where there has not been much work hardening and there is a short exposure to an elevated temperature. In some cases recrystallization may be incomplete when the alloys containing zirconium are heated at 800 or 900° F. for short periods of time. The elevation of the recrystallization temperature in this manner permits the use of a higher temperature for hot forming operations without the loss of the benefits of cold working. Because of the increase in the recrystallization temperature, it becomes possible to heat the cold worked alloy up to the temperature range which was formerly employed to anneal the metal, namely, 600 to 700° F., and it is thus possible to gain the advantage of the added workability which is associated with the use of a higher temperature.

The aluminum base alloys with which this invention is concerned should at all times contain a greater amount of magnesium than zinc or copper in order to retain the characteristics of aluminum-magnesium alloys. Cold worked alloys containing from 1 to 6 per cent magnesium, 0.25 to 3 per cent zinc, and 0.10 to 1.5 per cent copper are especially benefited by the addition of zirconium thereto.

Another advantage derived from the addition of zirconium to the foregoing type of aluminum base alloys is that the appearance of Lüder lines is prevented in drawn and formed articles. Lüder lines are sets of wavy lines which sometimes appear on the surface of stretched metal but which have no effect upon the properties thereof. Because of the irregular appearance of the surface, articles exhibiting these Lüder lines

are usually objectionable in commercial production since the lines can only be removed by a considerable amount of polishing.

Although aluminum-magnesium-zinc-copper alloys such as described hereinabove are useful in and of themselves, it has been found to be advantageous at times to include certain other metals known as hardening elements to enhance some desired properties. The metals which constitute this group of hardening elements and the amount of each metal to be used are as follows: manganese, 0.05 to 1.5 per cent; titanium, 0.01 to 0.5 per cent; chromium, 0.05 to 1.5 per cent; vanadium, 0.05 to 1 per cent; cobalt, 0.1 to 1 per cent; and nickel, 0.1 to 2 per cent. The total amount of these elements should not in any case exceed 4 per cent, and preferably less than 2 per cent. The addition of these elements does not destroy the effect of the zirconium and in some cases they may even accentuate the beneficial effect of zirconium in raising the temperature of recrystallization.

The beneficial effect of adding zirconium to aluminum-magnesium-zinc-copper alloys may be better appreciated through reference to the following examples. Three alloys were tested which had the following nominal compositions by weight:

- (A) 1.2 per cent magnesium, 0.5 per cent zinc, 0.15 per cent copper, 0.1 per cent titanium.
- (B) 1.2 per cent magnesium, 0.5 per cent zinc, 0.15 per cent copper, 0.1 per cent titanium, 0.12 per cent zirconium.
- (C) 1.2 per cent magnesium, 0.5 per cent zinc, 0.15 per cent copper, 0.1 per cent titanium, 0.22 per cent zirconium.

The balance of the alloys in each case was a commercial grade of aluminum containing about 0.25 per cent of the usual impurities. Ingots of these alloys were hot rolled to slabs 0.25 inch in thickness in the usual manner and annealed, then cold rolled to sheet having a thickness of 0.064 inch, which represented a reduction of 75 per cent from the thickness of the previously annealed material. The cold rolled sheets were heated at 650° F. for 2 hours and cooled to room temperature to observe the softening effect of a common annealing practice. Samples from these sheets were tested to determine their strength and elongation. The average values for these properties were as follows:

Alloy	Tensile strength	Yield strength	Elongation
	Lbs. per sq. in.	Lbs. per sq. in.	Per cent
A.....	21,000	8,000	26
B.....	24,000	12,000	22
C.....	26,000	18,000	22

From these results it can be seen that the zirconium has caused the alloys B and C to resist softening. An X-ray examination of this material showed that recrystallization was complete in alloy A which did not contain zirconium but this element had interfered with recrystallization in the other alloys.

Sheet samples of the above alloys were drawn into small trays to determine whether any Lüder lines would appear. It was found that these lines appeared in the case of alloy A but not in trays made from alloys B and C.

The term "aluminum base alloy" as herein employed refers to those alloys which contain at least 75 per cent aluminum.

I claim:

1. A wrought aluminum base alloy containing from 0.5 to 10 per cent magnesium, 0.25 to 8 per cent zinc, 0.1 to 3 per cent copper, and 0.01 to 1 per cent zirconium, said alloy being characterized by having a higher recrystallization temperature than the same alloy devoid of zirconium where both alloys have received the same amount of work hardening and the same thermal treatment.

2. A wrought aluminum base alloy containing from 0.5 to 10 per cent magnesium, 0.25 to 8 per cent zinc, 0.1 to 3 per cent copper, 0.01 to 1 per cent zirconium, and from 0.01 to 4 per cent of at least one of the hardening elements of the group consisting of manganese 0.05 to 1.5 per cent, titanium 0.01 to 0.5 per cent, chromium 0.05 to 1.5 per cent, vanadium 0.05 to 1 per cent, 0.1 to 1 per cent cobalt, and nickel 0.1 to 2 per cent, the balance being aluminum.

3. A wrought aluminum base alloy containing from 0.5 to 10 per cent magnesium, 0.25 to 8 per cent zinc, 0.1 to 3 per cent copper, and 0.01 to 1 per cent zirconium, the balance being aluminum.

4. A wrought aluminum base alloy containing from 1 to 6 per cent magnesium, 1 to 3 per cent zinc, 0.25 to 1.5 per cent copper, 0.1 to 0.5 per cent zirconium, the balance being aluminum.

5. The method of producing a cold worked aluminum base alloy containing between about 0.5 and 10 per cent magnesium, 0.25 and 8 per cent zinc, and 0.1 and 3 per cent copper and exhibiting improved recrystallization characteristics, comprising the steps, incorporating from about 0.01 to 1 per cent zirconium in the molten alloy at an appropriate stage in its production, casting a body of said alloy, cold working said alloy body, and thereafter heating the wrought body to a temperature below that at which complete recrystallization occurs but above the temperature at which a similar cold worked alloy devoid of zirconium will completely recrystallize.

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