

UNITED STATES PATENT OFFICE

2,157,150

RELIEF OF STRESS CRACKING IN
ALUMINUM-MAGNESIUM ALLOYS

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20 Claims. (Cl. 148—21.1)

This invention relates to aluminum base alloys containing substantial amounts of magnesium. More specifically the object of the invention is the elimination or substantial reduction of stress cracking in cast aluminum base alloys contain-

ing from 6 per cent to 14 per cent of magnesium. Aluminum base alloys containing magnesium in amounts with the range hereinabove specified form recent and important additions to the commercial aluminum alloy field. Such alloys may also contain amounts of other metals designed to modify or improve certain properties of the aluminum-magnesium alloys; such other metals are, for instance, manganese, chromium, anti-

mony, calcium, copper or zinc. My invention is applicable to cast aluminum-magnesium alloys containing these and other added elements. The invention comprises a special thermal treatment which reduces or eliminates a stress cracking tendency inherent in cast aluminum-magnesium alloys in the range hereinabove indicated which are subjected to intermittent or continuous stresses. This tendency is apparent in cast aluminum-magnesium alloys in the presence or absence of other elements.

The phenomenon known as stress cracking occurs when the alloys are in a stressed condition, the stress being either internal or external in source. The more severe the corrosive conditions the more apparent the tendency towards stress cracking. While under conditions of high stress and/or severe corrosion my method may not entirely eliminate susceptibility to stress cracking, it does substantially increase the serviceable life of the alloy and may under some conditions make it practically permanent. The entire phenomenon of stress corrosion and stress cracking is not as yet fully understood. Such understanding of the underlying causes is not necessary for a comprehension of the remedy whereby the stress-cracking tendency is substantially eliminated or markedly reduced.

From my investigations and from examination of castings treated in accordance with the precepts of my invention, I am of the opinion that the stress cracking is influenced by structural conditions within the alloy. Castings of aluminum-magnesium alloys containing from 6 to 14 per cent magnesium and heated and aged in manner known to the art prior to my discovery, are susceptible to stress cracking. While from a standpoint of physical properties it is very desirable that the alloys be thermally treated, such treatment is therefore not entirely advantageous. It now appears to me that the struc-

ture more resistant to stress cracking is characterized by a type of homogeneous precipitation of dissolved constituent from supersaturated solid solution, whereas the type of structure heretofore encountered after the treatments known to the art was characterized by a structure which I term a preferential precipitation wherein the precipitation had a tendency to make itself evident at the grain boundaries.

The thermal treatment whereby this end is accomplished comprises a number of steps, some of which may be varied somewhat in their practical application although their nature and purpose is similar. In brief the cast article of aluminum-magnesium alloy containing substantial amounts of magnesium is first heated to a temperature at which a substantial portion of the magnesium constituent is in solid solution, but below the temperature of the most fusible eutectic in the alloy. The article is held at this temperature for a period between, say about 10 hours and 40 hours so that a substantial solution effect is obtained. The article is then cooled to a point between this original temperature and room temperature; at which point it is preferably held for a limited time. The article is thereafter cooled to room temperature. This last cooling step may be effected in any suitable manner although I prefer a water quench as I have found that it generally results in better properties in the alloy.

In determining the proper time of holding at the solution temperature I have made determinations of varying extent, up to about 200 hours, but in the usual cases, with sand castings of ordinary section, a period of between about 10 and 40 hours is entirely satisfactory. An hour or longer is often sufficient for chilled castings. If the soluble constituent is either unusually fine or unusually coarse, the time may be shortened or lengthened respectively so as to attain substantial equilibrium at the solution temperature. This temperature, for aluminum-magnesium alloys containing from about 6 to 14 per cent of magnesium, may be in the neighborhood of from about 775° F. to 825° F.

After the solution treatment my preferred method, for castings of substantial size, comprises furnace cooling the casting to a temperature in the neighborhood of about between 700° F. and 750° F., oil quenching the casting to a temperature of between about 200° F. and 250° F., holding for a short time, say between about 5 minutes and one hour, and then cooling to room temperature.

Another method which I have found effective comprises giving the casting a solution treatment as heretofore noted, subjecting it to a controlled cooling by immersion in heated air at a temperature of about between 200° F. and 350° F., holding it for a short time, and then cooling it to room temperature.

It is apparent then that the essential features of the invention comprise the following steps; first, a solution or high temperature treatment; second, a controlled or interrupted cooling from the solution temperature to a lower temperature but higher than room temperature (two such intermediate steps have been used with excellent effect); third, a cooling to room temperature. In the two methods previously cited it would appear that the oil quench to an intermediate point acts in a manner equivalent to the furnace cooling and air quench, both methods giving the type of structure peculiarly suited to resist stress corrosion and stress cracking. Each method illustrates the general principle of a controlled intermediate cooling step.

In addition to its very favorable effect on stress cracking, my invention materially improves the other properties of the alloys and is applicable to cast aluminum alloys containing from about 6 per cent to about 14 per cent of magnesium. Alloys within this range, but containing from about 9 per cent to 11 per cent magnesium, constitute a class wherein my invention is especially helpful in the prevention of stress cracking and the amelioration of other mechanical properties. This beneficial effect persists even in the presence of various other alloying constituents as far as I have been able to determine.

After being subjected to the above outlined thermal treatment the alloy may be allowed to age spontaneously at room temperature or it may be given an aging treatment somewhat higher than room temperature.

The term aluminum-magnesium alloy as used in the appended claims signifies an alloy containing more than 50 per cent aluminum with magnesium in the amounts indicated in the claims, and my designation "aluminum-magnesium alloy" includes lesser amounts of other alloying constituents, the presence of which does not vary the salutary effect of the invention.

I claim:

1. A method of preventing stress cracking in cast aluminum-magnesium alloys containing from about 6 per cent to about 14 per cent of magnesium, the method comprising heating the alloy at a temperature and for a time sufficient to cause the majority of the soluble elements to go into solid solution, thereafter subjecting the said alloys to a controlled cooling to an intermediate temperature above about 200° F., so as to initiate an homogeneous incipient precipitation of the dissolved elements, maintaining the intermediate temperature for a brief period, and finally cooling the alloys to room temperature.

2. A method of preventing stress cracking in cast aluminum-magnesium alloys containing from about 6 per cent to about 14 per cent of magnesium, the method comprising heating the alloy from 1 to 40 hours at a temperature sufficient to cause a substantial portion of the soluble elements to go into solid solution, thereafter subjecting the said alloys to a controlled cooling to an intermediate temperature above about 200° F., maintaining the intermediate temperature for a brief period sufficient to initiate an homogeneous incipient precipitation of the dissolved ele-

ments, and finally cooling the alloys to room temperature.

3. A method of preventing stress cracking in cast aluminum-magnesium alloys containing from about 6 per cent to about 14 per cent of magnesium, the method comprising heating the alloy for from 1 to 40 hours at between about 775° F. and 825° F., thereafter subjecting the said alloys to a controlled cooling to an intermediate temperature above about 200° F., maintaining the intermediate temperature for a brief period sufficient to initiate an homogeneous incipient precipitation of the dissolved elements, and finally cooling the alloys to room temperature.

4. A method of preventing stress cracking in cast aluminum-magnesium alloys containing from about 6 per cent to about 14 per cent of magnesium, the method comprising heating the alloys for from 1 to 40 hours at between about 775° F. and 825° F., thereafter subjecting the alloys to a controlled cooling to a point between about 200° F. and 350° F., maintaining the alloys within this range for at least 15 minutes and finally cooling the alloys to room temperature.

5. A method of preventing stress cracking in cast aluminum-magnesium alloys containing from about 6 per cent to about 14 per cent of magnesium, the method comprising heating the alloys from 1 to 40 hours at between about 775° F. and 825° F., furnace cooling the casting to a temperature between about 700° F. and 750° F., air cooling the casting to a temperature of between about 200° F. and 350° F., maintaining this temperature for a period sufficient to initiate an homogeneous incipient precipitation of the dissolved elements, and finally cooling the alloys to room temperature.

6. A method of preventing stress cracking in cast aluminum-magnesium alloys containing from about 6 per cent to about 14 per cent of magnesium, the method comprising heating the alloys from about 1 to 40 hours at between about 775° F. and 825° F., subjecting the alloys to a controlled cooling by immersing in oil at a temperature of between about 200° F. and 250° F., holding the alloys within this temperature range for between about 5 minutes and one hour, and finally cooling the alloys to room temperature.

7. A cast aluminum-magnesium alloy substantially resistant to corrosion under stress containing from about 6 per cent to about 14 per cent of magnesium, characterized by a metallic structure wherein the magnesium constituent is minutely and substantially homogeneously dispersed, the structure being induced by a thermal treatment comprising a solution treatment at a temperature above about 775° F. but below the temperature of fusion of the lowest melting eutectic in the alloy, a controlled cooling to a lower temperature but above about 200° F., a pause of from about 5 minutes to 1 hour at said lower temperature, and finally a cooling to room temperature.

8. A method of preventing stress cracking in cast aluminum-magnesium alloys containing from about 6 per cent to about 14 per cent of magnesium, the method comprising heating the alloys for from 1 to 40 hours at between about 775° F. and 825° F., thereafter subjecting the alloys to a controlled cooling to a point between about 200° F. and 350° F., maintaining the alloys within this range for from 15 minutes to one hour, and finally quenching the alloys in water.

9. A method of preventing stress cracking in cast aluminum-magnesium alloys containing

from about 6 per cent to about 14 per cent magnesium, the method comprising heating the alloys from about 1 to 40 hours at between about 775° F. and 825° F., subjecting the alloys to a controlled cooling by immersing in oil at a temperature of between about 200° F. and 250° F., holding the alloys within this temperature range for between about 5 minutes and one hour, and cooling the alloys to room temperature in water.

10. A method of preventing stress cracking in cast aluminum-magnesium alloys containing from about 9 per cent to about 11 per cent of magnesium, the method comprising heating the alloy at a temperature and for a time sufficient to cause the majority of the soluble elements to go into solid solution, thereafter subjecting the said alloys to a controlled cooling to an intermediate temperature about 200° F. above, so as to initiate an homogeneous incipient precipitation of the dissolved elements, maintaining the intermediate temperature for a brief period, and finally cooling the alloys to room temperature.

11. A method of preventing stress cracking in cast aluminum-magnesium alloys containing from about 9 per cent to about 11 per cent of magnesium, the method comprising heating the alloy from 1 to 40 hours at a temperature sufficient to cause a substantial portion of the soluble elements to go into solid solution, thereafter subjecting the said alloys to a controlled cooling to an intermediate temperature above about 200° F., maintaining the intermediate temperature for a brief period sufficient to initiate an homogeneous incipient precipitation of the dissolved elements, and finally cooling the alloys to room temperature.

12. A method of preventing stress cracking in cast aluminum-magnesium alloys containing from about 9 per cent to about 11 per cent of magnesium, the method comprising heating the alloy for from 1 to 40 hours at between about 775° F. and 825° F., thereafter subjecting the said alloys to a controlled cooling to an intermediate temperature above about 200° F., maintaining the intermediate temperature for a brief period sufficient to initiate an homogeneous incipient precipitation of the dissolved elements, and finally cooling the alloys to room temperature.

13. A method of preventing stress cracking in cast aluminum-magnesium alloys containing from about 9 per cent to about 11 per cent of magnesium, the method comprising heating the alloys for from 1 to 40 hours at between about 775° F. and 825° F., thereafter subjecting the alloys to a controlled cooling to a point between about 200° F. and 350° F., maintaining the alloys within this range for from 15 minutes to one hour, and finally cooling the alloys to room temperature.

14. A method of preventing stress cracking in cast aluminum-magnesium alloys containing from about 9 per cent to about 11 per cent magnesium, the method comprising heating the alloys from 1 to 40 hours at between about 775° F. and 825° F., furnace cooling the casting to a temperature between about 700° F. and 750° F., air cooling the casting to a temperature of between about 200° F. and 350° F., maintaining this temperature for a period sufficient to initiate an homogeneous incipient precipitation of the dissolved elements, and finally cooling the alloys to room temperature.

15. A method of preventing stress cracking in

cast aluminum-magnesium alloys containing from about 9 per cent to about 11 per cent magnesium, the method comprising heating the alloys from about 1 to 40 hours at between about 775° F. and 825° F., subjecting the alloys to a controlled cooling by immersing in oil at a temperature of between about 200° F. and 250° F., holding the alloys within this temperature range for between about 5 minutes and one hour, and finally cooling the alloys to room temperature.

16. A cast aluminum-magnesium alloy containing from about 9 per cent to about 11 per cent of magnesium, characterized by a metallic structure wherein the magnesium constituent is minutely and substantially homogeneously dispersed, the structure being induced by a thermal treatment comprising a solution treatment at a temperature above about 775° F. but below the temperature of fusion of the lowest melting eutectic in the alloy, a controlled cooling to a lower temperature but above about 200° F., a pause of from about 5 minutes to 1 hour at said lower temperature, and finally a cooling to room temperature.

17. A method of preventing stress cracking in cast aluminum-magnesium alloys containing from about 9 per cent to about 11 per cent magnesium, the method comprising heating the alloys for from 1 to 40 hours at between about 775° F. and 825° F., thereafter subjecting the alloys to a controlled cooling to a point between about 200° F. and 350° F., maintaining the alloys within this range for from 15 minutes to one hour, and finally quenching the alloys in water.

18. A method of preventing stress cracking in cast aluminum-magnesium alloys containing from about 9 per cent to about 11 per cent magnesium, the method comprising heating the alloys from about 1 to 40 hours at between about 775° F. and 825° F., subjecting the alloys to a controlled cooling by immersing in oil at a temperature of between about 200° F. and 250° F., holding the alloys within this temperature range for between about 5 minutes and one hour, and cooling the alloys to room temperature in water.

19. A method of treating aluminum-magnesium alloys containing from about 6 to about 14 per cent of magnesium comprising heating the alloys at a temperature and for a time sufficient to place at least a part of the magnesium in solid solution in the aluminum, said amount of magnesium in solution being in excess of the amount soluble at lower temperatures, and thereafter subjecting the alloys to a further thermal treatment at lower temperatures but in excess of 200° F. to initiate relatively homogeneous intra-granular precipitation of a part of the dissolved magnesium.

20. A process for improving the resistance to corrosion under stress of aluminum-magnesium alloys containing from 6 to about 14 per cent of magnesium comprising heating the alloy at a temperature above the temperature of solid solubility but below 450° C. and for a time sufficient to place at least a substantial portion of the magnesium in solid solution in the aluminum, and thereafter subjecting the alloy to a further thermal treatment at lower temperatures but in excess of 100° C. to produce a homogeneous precipitation throughout the grains of the dissolved magnesium in excess of the solid solubility at said lower temperature.

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4

CERTIFICATE OF CORRECTION.

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May 9, 1939.

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It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, first column, line 18, claim 10, for "about 200° F. above," read above about 200° F.; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 20th day of June, A. D. 1939.

Henry Van Arsdale

(Seal)

Acting Commissioner of Patents.