United States Patent Office

3,219,491

Patented Nov. 23, 1965

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3,219,491
THERMAL TREATMENT OF ALUMINUM BASE ALLOY PRODUCT

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No Drawing. Filed July 13, 1962, Ser. No. 209,763
8 Claims. (Cl. 148—11.5)

This invention relates to the thermal treatment of aluminum-manganese type alloys in the course of making various products by a mechanical working of the metal. Alloys of this type are not subjected to solution heat treatment and subsequent precipitation hardening in commercial operations to increase their strength and hardness, but are simply work hardened to gain strength in addition to that provided by the presence of manganese. For this reason, they are frequently referred to as being non-heat treatable alloys. In the course of making semi-finished as well as finished products of these alloys, it is a common practice to relieve the strains generated by the working operation by an annealing treatment. Where the annealing is employed between metal working steps it is called intermediate annealing and where the finished product is softened the treatment is referred to as being a final anneal.

Annealing or softening of work hardened aluminum-manganese alloys is usually accomplished by heating the alloys to a temperature between about 650 and 800° F. and cooling to room temperature. Usually a short holding or soaking period of but 1 to 2 hours at the predetermined temperature is allowed to insure relief of work hardening strains and the recrystallization that accompanies such relief.

While the grain size of the annealed products is satisfactory for many purposes, it often becomes critical where the product has received a final anneal and is then subjected to a small reduction in cross section or is subjected to a local deformation as in a forming or shaping operation. If the annealed product exhibits large or coarse grains the subsequent general or localized working may produce what is known as the orange peel defect. This defect is characterized by a surface having a non-uniform rippled appearance and is visible to the naked eye. Although grain growth may be controlled to some extent by the addition of very small amounts of certain high melting point elements, such additions not only add to the cost of the alloy but introduce problems in the melting, casting and working operations and do not insure a fine grain size in the finished product. We have found that a fine uniform grain size can be produced without the addition of any high melting point grain refining elements by employing a novel two step thermal treatment.

It is an object of our invention to provide a method of thermally treating aluminum-manganese type alloys in the course of making wrought products therefrom which will yield a uniform fine grain size when the products are annealed, especially at the stage of a final anneal. A particular object is to provide a thermal treatment which will substaantially decrease or prevent the occurrence of the orange peel defect.

Our invention is predicted upon the discovery that by dissolving at least a portion of the manganese in the solid aluminum in an aluminum-manganese type of alloy that has been worked and subsequently causing precipitation of a substantial part of the dissolved manganese in the form of a manganese-containing alloy constituent of the proper size and distribution, the occurrence of large or coarse grains is inhibited in the annealed product. Manganese is difficultly soluble and hence solution must be effected at a relatively high temperature and over a period of time. The amount of manganese which can be dissolved in solid aluminum is limited. Under equilibrium conditions in a binary alloy, 1.8% is about the maximum amount which can be taken into solution at a temperature of 1215 to1220° F. For the purpose of our treatment it is not necessary that such a maximum be attained but rather that a substantial portion of the manganese which be dissolved should be placed in solution. It will be appreciated that the mass of alloy being heated, the maximum temperature attained, the amount of manganese which is present and possibly other elements will affect the quantity of manganese which will be dissolved.

The alloys which are benefited by our treatment contain from 0.5 to 2.0% manganese and the usual impurities of up to 0.75% iron, 0.4% silicon, up to 0.1% zinc and up to a total of 0.15% of others of a minor character. To increase the strength of the alloy it may be desirable to add from 0.1 to 2.0% magnesium but where this is done, the silicon content must be limited to less than 0.2%. Copper occurs as an impurity in the alloy, usually less than 0.1%, but to control action of the alloy under corrosive conditions it may be desirable to increase the copper content to 0.35%. The presence of magnesium and copper do not disturb the response of the manganese to the thermal treatment.

In making wrought products it is, of course, necessary to cast the alloy in a form suitable for working such as an ingot, slab or bar. Before working the cast body, it should be heated to a temperature between 1050 and 1150° F. and held within that temperature range for 4 to 72 hours. This treatment aids in developing a more uniform structure in the cast body and minimizes any effects of segregation and is referred to herein as a preheat treatment. The heated body is slowly cooled to the hot working temperature range and hot worked, or it can be further cooled to room temperature and then be reheated to the working temperature. To secure the best results the cooling from the preheating to the hot working temperature range should be at a slow rate, less than 50° F. per hour. The cooling in any case should not be drastic such as a quenching. Although it is a general practice to hot work a cast body to obtain a relatively large reduction in thickness, in some cases it may be possible to cold work the thermally treated ingot, slab or bar. In any case the cast structure is broken down by the working thereby producing a wrought structure. Any hot working is generally performed within a temperature range of 650 to 900° F. and the worked product cooled to room temperature as a matter of convenience in handling.

The product of the foregoing heating and working operations is next reheated to a temperature between 850 and 1050° F. and held within that temperature range for a period of 1 to 30 hours. Generally, a longer time at temperature is desirable where the soaking temperature is in the lower portion of the temperature range than where a higher temperature treatment is employed. In any case the heating must continue for a sufficient length of time to permit the solution of at least a portion of the manganese within its limits of solubility under the particular conditions involved.

If desired, the heated body of the alloy may then be allowed to cool to a temperature between 600 and 800° F. and further hot worked or it may be permitted to cool to room temperature and reheated to that temperature range and worked. Alternatively, the thermally treated wrought product can be cold worked to effect the desired reduction in thickness.

The thermally treated wrought product which may or may not have been further worked is subjected to a second thermal treatment which consists of heating it to a temperature between 600 and 800° F. and holding it within this temperature range for a period of 2 to 30 hours. This treatment serves to induce what appears to be a precipitation of a manganese-containing constituent in very finely divided form uniformly distributed throughout the product. The precipitation occurs within the grains as well as at grain boundaries, there being no area of preferential precipitation. It will be appreciated that the solution heat treating and precipitating steps will serve not only for the purposes described but they will also relieve any work hardening strains introduced by the preceding working operation and therefore obviate the need for a conventional intermediate annealing step.

The product of the precipitation treatment is subsequently work hardened as by working at room temperature. The extent of the reduction in cross section and attendant work hardening is a matter of choice providing the reduction exceeds about 10%. Smaller reductions tend to promote the growth of coarse grains when the product is later annealed.

The two step operation of solution treatment and precipitation may be repeated if desired. Thus, a partially fabricated hot worked product may be given both treatments and the worked product made therefrom may be further treated at the same or a different temperature within the stated range and for the same or a different length of time. Similarly, this same two step operation might be used with partly fabricated cold worked products.

As stated above, the precipitation treatment may be applied to a hot worked product or one that has been cold worked following the solution treatment or it may be applied to the solution treated product without any intervening working operation, the location of the two treatments in the fabricating schedule being a matter of choice. In the case of rolling sheet, for example, it may be convenient to treat the hot rolled slab or plate before any cold rolling is done. In making wire, for example, the hot rolled bar or rod may be treated while in the making of forgings or hot pressings, the bloom or partially shaped end product can be treated. Generally speaking, the best results, i.e. the finest grain size, are obtained if the solution and precipitation treatments are employed just before the last working operation which involves a substantial reduction in thickness of the worked piece prior to the final anneal. Where sheet is being rolled this means that the sheet or plate is given the two step treatment immediately preceding the final cold rolling operation and final anneal. It is to be understood that while the foregoing represents a preferred practice the benefits of the two step treatment are also obtained where that treatment is followed by more than one working operation before the final anneal. A conventional intermediate anneal between such working steps has no significant effect upon the precipitated manganese-containing constituent.

The final step in the treatment of the wrought product is that of annealing to remove work-hardening strains and produce a softened metal. Normally this consists of simply heating the product to a temperature between 650 and 800° F. with or without a short period of holding within that temperature range and cooling to room temperature. The annealed product will have a grain size of more than about 2500 grains per cubic millimeter, and frequently grain sizes of 10,000 grains or more per cubic millimeter. This is in contrast to the coarse grains generally obtained heretofore by the usual working and annealing practices where the grain count is on the order of less than 1000 grains per cubic millimeter.

The benefits derived from using the solution and precipitation treatments are illustrated in the following examples of rolled sheet. The alloy employed had a nominal composition of aluminum, 1.1% manganese, 0.25% silicon, 0.65% iron and 0.15% copper. The alloy was cast in the form of an ingot by the common direct chill continuous casting process. The ingot was given a preheat treatment consisting of heating at 1100° F. for 16 hours, cooling to 900° F. and hot rolling to sheet about 0.17" in thickness. The hot rolled sheet was annealed, cold rolled to 0.125" thick sheet, cut into sections which were given the solution and precipitation treatments shown in Table I before being cold rolled to sheet 0.045" in thickness. The sheet was given a slow final batch anneal at 650° F. and examined for grain size and count made in accordance with the procedure described in the publication of the American Society of Testing Materials Standards, volume 3, E112 –58T (1958), pages 506 to 520 to give the number of grains per cubic millimeter. The treatments and grain counts are given in Table I below.

TABLE I

Effect of thermal treatment on grain size

Solution Heat Treatment		Precipitation Treatment		Grains/mm.³
Temp., ° F.	Time, Hours	Temp., ° F.	Time, Hours	
1,000	4	700	16	5,655
950	4	700	16	8,736
900	4	700	16	4,576

The grain size was observed to be uniform and much finer than that obtained in sheet of the same alloy which had been produced according to conventional hot rolling, annealing and cold rolling practices. Such conventionally produced sheet had a typical grain count of less than 1000 per cubic millimeter.

Sheet products made in accordance with our process have been successfully fabricated into cooking utensils and other items involving a drawing operation. These products have been free from the orange peel defect whereas those made from sheet fabricated according to conventional practice frequently showed that defect.

Having thus described our invention and certain embodiments thereof, we claim:

1. The method of producing a uniform fine grain size in annealed wrought products of an alloy consisting essentially of aluminum and 0.5 to 2.0% manganese, said method comprising casting a body of said alloy, preheating said cast body between 1050 and 1150° F. for a period of 4 to 72 hours to minimize any effect of segregation, cooling at a controlled rate to the hot working temperature range, working said preheated body sufficiently to break down the cast structure, heating said worked body to a temperature between 850 and 1050° F. and holding within that temperature range for a period of 1 to 30 hours to cause solution of at least a portion of the manganese, cooling the worked solution treated product, thereafter subjecting the said product to a precipitation treatment consisting of holding the product within the temperature range of 600 to 800° F. for a period of 2 to 30 hours, cooling the precipitation treated product to room temperature, cold working said product with a reduction of at least 10% and finally annealing the cold worked product at 650 to 800° F.

2. The method of claim **1** wherein the preheated cast body is hot worked within the temperature range of 650 to 900° F.

3. The method according to claim **1** wherein the precipitation treatment immediately follows the solution treatment.

4. The method according to claim **1** wherein the solution treated product is worked before receiving the precipitation treatment.

5. The method of claim 1 wherein the aluminum-manganese alloy also contains from 0.1 to 2% magnesium and the silicon impurity content is less than 0.2%.

6. The method of claim 1 wherein the aluminum-manganese alloy also contains up to 0.35% copper.

7. The method according to claim 1 wherein the pretreated cast body is cooled to the hot working temperature at a rate of less than 50° F. per hour.

8. The method of producing a uniform fine grain size in annealed wrought products of an alloy consisting essentially of aluminum and 0.5 to 2.0% manganese, said method comprising casting a body of said alloy, preheating said cast body at 1050 to 1150° F. for a period of 4 to 72 hours, slowly cooling to the hot working temperature range, hot working said preheated cast body at 650 to 900° F., heating the hot worked product to a temperature between 850 and 1050° F. and holding within that temperature range for a period of 1 to 30 hours, cooling the product, subjecting the solution treated product to a precipitation treatment consisting of holding within a temperature range of 600 to 800° F. for a period of 2 to 30 hours, cooling the precipitation treated product to room temperature, cold working it with a reduction of at least 10%, and finally annealing the cold worked product at 650 to 800° F.

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