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METHOD OF FORMING ARTICLES FROM HEAT-TREATABLE ALUMINUM-BASE ALLOYS

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The invention relates to the forming of sheet metal articles from aluminum base alloys whose physical properties are susceptible of improvement through the application of a solution heat treatment, and particularly it has to do with a method of die-pressing sheet made from those alloys which renders them capable of such improvement without any subsequent solution heat treatment.

The aluminum base alloys to which the invention is particularly applicable are those which contain, in addition to aluminum, a constituent or constituents capable of entering into solid solution with aluminum, and whose solubility in solid aluminum decreases with falling temperature. These alloys chiefly contain copper, magnesium, manganese, silicon, and zinc, in varying combinations and proportions. Specific examples of them are as follows: (A) copper 3 to 5 per cent, magnesium 0.5 per cent, maganese 0.6 per cent; (B) copper 4 to 5.5 per cent, manganese and silicon about 0.75 per cent each; (C) magnesium about 0.5 per cent, silicon about 1.0 per cent; the balance in each case being aluminum except for the customary impurities.

It is well known that certain physical properties of these alloys can be improved very appreciably by subjecting them to a heat treatment at a characteristic elevated temperature, for the purpose of dissolving as far as possible the excess solid-solution forming constituents, and cooling them quickly from that temperature. The tensile strength and hardness of these alloys when heated in this manner are improved as compared to the material just after hot working or annealing, and the ductility is usually improved; while the latter property is markedly improved with respect to cold worked material. Tensile strength and hardness may be further materially improved by subsequently aging the heat treated alloy at room temperature or at temperatures below about 200° C. The ductility is little affected by this aging treatment when carried out at room temperature, or in the first stages of aging at higher temperatures, but is usually reduced by aging at elevated temperatures long enough to obtain maximum hardness. This improvement is believed to be due to precipitation of the excess constituent in the form of very minute particles.

These alloys are used to a large extent in the form of fabricated shapes, made by die-pressing of sheet. Some of these forms are made by annealing the sheet or other material and then cold forming it in a die. It is, however, desirable and necessary in many cases that the metal be hot formed, and it is to these hot forming processes that my invention relates.

Heretofore in the fabrication of heat treated shapes of aluminum base alloy the practice has always been to reheat the alloy, after the forming operation, at the characteristic solution heat treatment temperature, and then to quench and age it in order to develop the desired increase in certain of its physical properties. This heat treatment subsequent to forming is undesirable, both because by it the formed articles may often become warped or otherwise deformed, and because of the time and expense incident thereto. Nevertheless, prior to my invention this subsequent solution heat treatment of die-pressed articles was considered absolutely necessary in order to obtain the increased physical properties.

An object of this invention is to provide a method of die-pressing this type of heat treatable aluminum base alloys which renders them directly capable of the improvement in physical properties without applying the subsequent solution heat treatment heretofore considered necessary to develop the full properties of the alloy.

Another object of the invention is to provide a method of die-pressing these heat treatable aluminum base alloys which eliminates the solution heat treatment previously necessary after the forming operation, and which eliminates also the warping usually incurred in that heat treating step.

The invention is predicated upon my discovery that a very substantial increase in certain of the physical properties of aluminum base alloys of the type described may be obtained by heating sheet made from such an alloy to the temperature necessary to cause

increased solution of the excess of the soluble constituent, or constituents, and, while the alloy sheet is thus heated, forming it into an article by pressing in a die or dies in a manner such that the article is formed and concurrently cooled rapidly enough to retain substantially all of the dissolved constituent in solution, and then, without again heating it to the elevated solution heat treatment temperature, aging the article at room or at a suitable elevated temperature.

In the practice of the invention alloy sheet of the type described is heated to or slightly below the characteristic solution heat treatment temperature, that is to a temperature at which material solution of the excess solid-solution forming constituent will occur. The temperature to which the alloy is heated will depend upon the particular alloy used, and, in the case of alloys A, B and C, it varies from about 480° to 530° C. The sheet is heated for a period of time sufficient to permit substantially maximum solution of the soluble constituent at the temperature used; and with relatively thin sheet prolonged soaking at the heat treating temperature will not be necessary.

As thus heated, the sheet is formed by subjecting it to a die-pressing operation. The pressing operation is conducted so as to prevent any material precipitation of the excess dissolved constituents. In accordance with the invention this precipitation is prevented by the use of relatively cool dies which cool the heated alloy at the same time that it is formed in them. This result is secured by maintaining the dies at a temperature considerably below the heat treating temperature; and to this end the temperature of the dies is kept below 200° C., and preferably below 100° C. The extent of cooling obtained in this manner during the forming operation will in part depend upon the relation of the mass of metal being shaped and the mass and temperature of the dies, but it will be understood that the shaped article is preferably held within the dies until it has cooled sufficiently. This cooling within the die has the added advantage that the article is confined during cooling, and therefore undergoes substantially no warpage. After being thus cooled the article is removed from the die, and, if necessary or desired, it may be further cooled in air or in water.

The articles formed and concurrently cooled in dies may then be aged to increase their tensile strength, ductility and hardness. In the case of alloy A, aging takes place at room temperature, while alloys B and C may be aged at elevated temperature below about 150° C.

The following examples are illustrative of the invention. Sheet varying in thickness from 1/8 inch to 1/2 inch was prepared from an aluminum base alloy containing about 3.5 to 4 per cent of copper, 0.5 per cent of magnesium and 0.6 per cent of manganese. This sheet was formed into 90° angles and channels of various sizes by heating the sheet to about 500° C., and, while thus heated, die pressing it. After cooling sufficiently in the die, the formed articles were removed and cooled further in air or by immersion in water. The articles were then permitted to age for several days at room temperature, when they were tested. These angles and channels showed tensile strengths varying from 53,000 to 54,000 pounds per square inch, yield points of 28,000 to 30,000 pounds per square inch, and Brinell hardness numbers of 90 to 92. Samples of the same material die-pressed in the customary manner at lower temperatures and reheated to the heat treatment temperature in a bath of fused nitrates after forming, and subsequently quenched and aged, showed tensile strengths from 56,000 to 57,000 pounds per square inch, yield points of 30,000 to 33,000 pounds per square inch, and Brinell hardness numbers of 98 to 100.

In another test, side eaves, such as are used on railway cars, and composed of the same alloy as described in the preceding example were made by heating the material to a temperature of 480° to 510° C. and pressing in a suitable die. After cooling, the eaves were taken from the die, further cooled either in air or in water and aged at room temperature. When tested they gave a tensile strength of 58,000 pounds per square inch and a Brinell hardness number of 90.

In the foregoing examples the dies were made of such size that the heat transfer from the material to the die did not appreciably raise the temperature of the die, thus causing a sudden partial chilling of the material in the forming operation, sufficient to prevent any substantial deposition of the excess dissolved constituents and to prevent material growth of any particles which may have been precipitated. In general, the die temperature did not exceed 85° during the operation.

Thus by selecting preheating temperatures appropriate to the particular alloy, and by forming the thus heated alloy and cooling the article thus formed, it is unnecessary to reheat the article to secure the properties characteristic of the subsequent heat treatment hitherto employed, thereby saving the time and cost involved.

The invention has the added advantage that it substantially eliminates the tendency which was always present in prior practice, toward formation of large grains in regions subjected to critical strain. According to the present invention it is unnecessary to reheat the formed articles to the solution heat treatment temperature, and the aging temperatures are so much below the recrystallization temperature as to permit no appreciа-

ble grain growth. Throughout the specification, and in the appended claims, the expression "aluminum base alloy" refers to an alloy containing more than 50% of aluminum by weight.

According to the provisions of the patent statutes, I have explained the principle and mode of operation of my invention, and have given specific examples of how it may be practiced. However, I desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

I claim:

1. The method of forming an article capable of developing increased tensile strength and hardness from aluminum base alloy sheet containing a solid-solution forming constituent in excess of the amount soluble at normal temperature, comprising heating the alloy sheet to cause increased solution of the excess of the soluble constituent, and while thus heated die-pressing it and cooling the article in the die rapidly enough to retain the major portion of the dissolved constituent in solution.

2. The method of forming an article capable of developing increased tensile strength and hardness from aluminum base alloy sheet containing copper in excess of the amount soluble at normal temperatures, comprising heating the alloy sheet to cause increased solution of the excess copper, and while thus heated die-pressing it and cooling the article in the die rapidly enough to retain the major portion of the dissolved copper in solution.

3. The method of forming an article capable of developing increased tensile strength and hardness from aluminum base alloy sheet containing from about 3 to 5.5 per cent copper, comprising heating the alloy sheet to cause increased solution of the excess copper, and while thus heated die-pressing it and cooling the article in the die rapidly enough to retain the major portion of the dissolved copper in solution.

4. The method of forming an article capable of developing increased tensile strength and hardness from aluminum base alloy sheet containing a solid-solution forming constituent in excess of the amount soluble at normal temperature, comprising heating the alloy sheet to cause increased solution of the soluble constituent, and while thus heated die-pressing it in a cold die and simultaneously cooling the article in the die rapidly enough to retain the major portion of the dissolved constituent in solution.

5. The method of forming an article capable of developing increased tensile strength and hardness from aluminum base alloy sheet containing copper in excess of the amount soluble at normal temperatures, comprising heating the alloy sheet to cause increased solution of the excess copper, and while thus heated die-pressing it in a cold die and simultaneously cooling the article therein rapidly enough to retain the major portion of the dissolved copper in solution.

6. The method of forming an article capable of developing increased tensile strength and hardness from aluminum base alloy sheet containing from about 3 to about 5 per cent of copper, about 0.5 per cent magnesium and about 0.6 per cent manganese, comprising heating the alloy sheet to cause solution of the excess copper, and while thus heated die-pressing it and cooling the article in the die rapidly enough to retain the major portion of the dissolved copper in solution.

7. The method of forming an article capable of developing increased tensile strength and hardness from an aluminum base alloy containing a solid-solution forming constituent in excess of the amount soluble at normal temperature, comprising heating the alloy to cause increased solution of the soluble constituent, work-forming the alloy, and cooling the formed article rapidly enough to retain the major portion of the dissolved constituent in solution.

In testimony whereof, I sign my name.

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