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HEAT TREATMENT OF STRONG ALUMINUM ALLOYS

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This invention relates to improvements in the heat-treatment of alloys in which increased strength is obtained by so-called precipitation treatment called "aging", preceded by a solution treatment called "quenching". This invention produces greater improvement in strength of these alloys and removes, partly at least, from the strong aluminum alloys the drawback that heretofore has limited their usefulness; namely, inter-crystalline corrosion.

Although this invention is applicable to all alloys susceptible to such heat-treatment, its greatest application is in the field of light-aluminum alloys. Such alloys are commonly known to the trade as duralumin and consist of about 3 to 4% copper ½% manganese, ½% magnesium, some silicon and iron, and about 95% aluminum. Other aluminum alloys known as Hyb-Lum contain metals of the chromium group instead of manganese and nickel partly, at least, substituting the copper. Still another type of these alloys are "Lautal" and "25S", containing mainly copper and silicon as additions to aluminum.

It is common practice to quench these alloys in water of ordinary temperature from a temperature of above 950° F. The alloys of the duralumin type are then aged spontaneously at ordinary room temperature, and those of the Hyb-Lum type or "Lautal" type at elevated temperature. It is evident the combined presence of copper and magnesium is necessary for spontaneous aging and that the minimum aging temperature is dependent upon the amount of copper present with the magnesium in the alloy so that the spontaneous aging is very slight with alloys containing ½% copper and ½ to 1% magnesium and reaches its maximum effect at about 3 to 4% copper and ½ to 1% magnesium.

All these elloys are practically free from inter-crystalline corrosion before aging but not after aging. The commonly accepted theory of this phenomenon is that the copper aluminide and magnesium silicide have a widely different electric potential from that of the aluminum matrix and that the inter-crystalline corrosion is caused by electrolytic action. It is known that the alloys of the duralumin type age faster at elevated temperatures but that such accelerated aging causes a much intensified inter-crystalline corrosion.

I have discovered that the nature of the precipitation and the physical condition of the precipitate is dependent upon the length of time of aging or the rapidity of this precipitation, just as in water solutions of salts slow cooling and fast cooling cause entirely different precipitates of crystals.

I have also discovered that rapid aging causes such violent precipitation that the structure of the alloy is changed or destroyed and that it thereby becomes more susceptible to inter-crystalline corrosion. My research has now shown that slow aging, that is, aging under a slowly rising temperature, causes entirely novel and unforeseen results, which are of great benefit.

To operate my process, I first determine at which temperature aging begins. I then quench to a temperature approximately equal to that at which I have found that aging begins or at least where it is sufficiently slow for my purposes. I then increase the temperature slowly and either gradually or in steps until I reach a temperature at which no further aging takes place. I find that such prolonged aging at increasing temperature is very beneficial. To give a concrete example, take ordinary duralumin consisting of about 3½% copper plus ½% manganese, plus ½% magnesium and about 95% aluminum with some iron and silicon. By ordinary practice of quenching and aging it attains a strength of 38,000 pounds yield point and 58,000 pounds ultimate, with 18% elongation. If the quenching is done in ice water and/or the aging is accelerated by heating, the result is the same as far as strength goes, but the accelerated aging causes worse inter-crystalline corrosion.

For my purposes quenching is done in cold water (but not necessarily in ice water) preferably to below 60° F. The metal is then kept at that temperature until no further rapid increase in hardness is observed, say 24 hours at from 60° to 70° F. The temperature may then be raised to 80°–100° F. for another 24 hours, after which a rise to 180°–220° F. is permissible, also for 24 hours. Finally 24 hours at about 300° F. finishes the aging and the metal has a strength of 50,000 pounds yield point, 65,000 pounds ultimate, and 18% elongation. This metal has very little inter-crystalline corrosion, and the intermittent dipping test in salt water containing peroxide or hydrogen shows practically no change in strength and no impaired bending quality, whereas a sample of ordinarily quenched and aged metal loses as much as 50% of its strength, and becomes brittle. By still slower aging a maximum of 60,000 pounds yield and 70,000 pounds ultimate has been produced. As in ordinary practice, rolling or other stress hardening operations may be used before, under, and/or after the aging to raise the yield point and ultimate strength, with sacrifice of part of the elongation.

Another example is Hyb-Lum containing about ½% copper plus 1% nickel plus ¼% chromium plus ¼% molybdenum plus ¾% magnesium and about 96½% aluminum with about ¾% silicon and iron. This alloy has heretofore been considered to derive its superior resistance to inter-crystalline corrosion from its low copper contents. According to the present invention, this superiority depends upon more suitable aging conditions. This alloy is quenched as usual from about 960° F. in water of ordinary temperature, say about 70° F. At that temperature aging is very slow. According to previous practice, this alloy was subjected to 310° F., at which temperature it ages nearly completely in 16 to 20 hours. It has then a yield point of 42,000 pounds, ultimate strength 55,000 pounds and elongation about 10%. Subjecting it to retarded aging as herein described at 70° F. for about 12 hours, then at 150° F. for 12 hours and finally at 310° F. for 12 hours, the result is a strength of 48,000 pounds yield point, 60,000 pounds ultimate and 12% elongation. The inter-crystalline corrosion is now still more reduced and the intermittent dipping test in salt water containing peroxide of hydrogen for two weeks will only result in a slight surface corrosion. The good bending quality of this alloy is not impaired by the test, neither is there any change in the elongation.

It will be seen from these figures that duralumin is benefited to a greater extent than Hyb-Lum by this treatment. Similar alloys are benefited to the extent to which previously accepted standardized practice has been out of line with retarded aging. In this way heavy castings and thick sheets have had a better chance to age slowly than thin sections. The improvement under retarded aging is gradual, and no sharply defined critical points are to be observed.

It is evident that this process can be practiced with many variations. It is in this way not necessary to quench duralumin in cold water but if warm water is used it must as quickly as possible be cooled by other means such as a cool air current, because accelerated aging begins at or above 400° F. and as aging is completed at that temperature in about 30 minutes it should be evident that it is of great importance to bring the temperature down as quickly as possible.

The practical difficulties with this heat-treatment are as indicated above greatly reduced if the copper contents of the metal is lowered. This can be done by the use of nickel and the metals of the chromium group and even zinc is a good substitute for some of the copper. Partial or total reduction of the percentage of the magnesium can also be resorted to in which case the silicon contents must be raised, or other elements such as titanium added to take the place of silicon.

I claim as my invention:

1. The process of aging aluminum alloys susceptible to heat-treatment by quenching and aging, which comprises regulating the temperature of aging by beginning the aging at a low aging temperature and thereafter progressively increasing the temperature until the maximum temperature at which the alloy is to be aged is reached.

2. In the process of aging aluminum alloys which comprises beginning the aging at a temperature of about 60° F. or below, and thereafter progressively increasing the temperature to about 300° F., whereby the process of aging is retarded and the alloy will possess greater strength and less susceptibility to intercrystalline corrosion.

3. The process of producing strong aluminum alloys practically free from inter-crystalline corrosion, which comprises regulating the temperature of aging by beginning the aging at a low aging temperature, and thereafter progressively increasing the temperature to about 300° F.

4. The process of aging aluminum alloys susceptible to heat-treatment by quenching and aging, which comprises regulating the temperature of aging by beginning the aging at a low aging temperature and thereafter progressively increasing the temperature until the maximum aging temperature is reached, and completing the aging at such maximum temperature.

5. The process of aging aluminum alloys which comprises beginning the aging at a temperature of about 60° F., and thereafter progressively increasing the temperature until a temperature of about 300° F. is reached, and completing the aging at such temperature.

6. The process of producing strong aluminum alloys practically free from inter-crystalline corrosion, which comprises regulating

the temperature of aging by beginning the aging at a low aging temperature, and thereafter progressively increasing the temperature to about 300° F., and completing the aging at such temperature.

7. A strong light alloy containing over 95% of aluminum and substantially free from inter-crystalline corrosion, said alloy being aged in accordance with the method set forth in claim 1.

8. A strong light alloy containing over 95% of aluminum and substantially free from inter-crystalline corrosion, said alloy being aged in accordance with the method set forth in claim 2.

9. A strong light alloy containing over 95% of aluminum and substantially free from inter-crystalline corrosion, said alloy being aged in accordance with the method set forth in claim 3.

In testimony whereof I affix my signature.

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