REDUCING THE SUSCEPTIBILITY OF ALLOYS, PARTICULARLY ALUMINIUM ALLOYS, TO STRESS CORROSION CRACKING

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Filed: Mar. 13, 1973
Appl. No.: 340,757

ABSTRACT

A method is described of thermally treating the 7,000 series aluminum alloys that have been subjected to a solution heat treatment at a high temperature and then to an ageing treatment at a lower temperature, thereby hardening the alloy but likewise producing therein a susceptibility to stress-corrosion cracking. The novel method comprises the steps of (1) subjecting the alloy to a retrogression heat treatment for a short period of time at a temperature above the age-hardening temperature of the alloy but below the solution heat treatment temperature, and (2) subsequently subjecting the alloy to a re-ageing heat treatment for a substantially longer period of time at the age-hardening temperature of the alloy. This method substantially reduces the susceptibility of the alloy to stress-corrosion cracking while retaining its original strength.

2 Claims, No Drawings
REDUCING THE SUSCEPTIBILITY OF ALLOYS, PARTICULARLY ALUMINIUM ALLOYS, TO STRESS CORROSION CRACKING

BACKGROUND OF THE INVENTION

The present invention relates to a method for reducing the susceptibility of certain alloys to stress-corrosion cracking. The invention is particularly useful with respect to aluminium alloys of the 7000 series aluminium alloys containing zinc, magnesium and copper, especially aluminium alloy 7075 and is therefore described in connection with such alloys, but it will be appreciated that it could be used also for improving the stress-corrosion resistance of other alloys, such as magnesium, stainless steel and titanium alloys.

High strength aluminium alloys, for example of the 2000 and 7000 series, are subjected to a solution heat treatment at a high temperature followed by an ageing treatment at a considerably lower temperature in order to obtain their high strength. However, such treatment normally produces a susceptibility to stress-corrosion cracking, that is the rupture of metal that occurs under the combined influence of a corrosive environment and applied or residual tensile stress. For this reason, the 7000 series alloys such as 7075 are sometimes subjected to a modified ageing procedure, called over-ageing, likewise at only moderately elevated temperature to reduce this susceptibility to stress-corrosion cracking, but this further heat treatment also has the effect of reducing the strength of the alloy.

For example, taking the case of a high strength aluminium alloy 7075, the solution heat treatment is usually effected at about 480°C, and the ageing heat treatment, commonly called T6 temper, is usually effected at about 121°C for about 24 hours. Instead of the T6 temper, in which case the alloy still has a high susceptibility to stress-corrosion cracking, there is commonly used another heat treatment, called the T73 temper, which is a two-stage over-ageing treatment, the details of which are described in U.S. Pat. No. 3,198,676. While this over-ageing treatment (T73 temper) does reduce the susceptibility of the alloy to stress-corrosion cracking, it also reduces its strength about 15%.

BRIEF SUMMARY OF THE INVENTION

The present invention provides a method for reducing the susceptibility of the 7000 series aluminium alloys to stress-corrosion cracking while still retaining substantially the original strength of the alloy.

According to the present invention, the alloy that has been subjected to a solution heat treatment at a high temperature and then to an ageing treatment (e.g., the T6 temper) at a lower temperature, is subsequently subjected to (1) a retrogression heat treatment for a short period of time at a temperature above the age-hardening temperature of the alloy but below the solution heat treatment, and (2) to a re-ageing heat treatment for a substantially longer period of time at the age-hardening temperature of the alloy.

The age-hardening temperature of the above step (2) is preferably the same as that of the normal ageing (e.g., T6) treatment but may be another suitable age-hardening temperature applicable to the particular alloy being treated.

The present invention can therefore broadly be characterized by the combined steps of (1) retrogression and (2) re-ageing, rather than the heretofore used age-hardening alone (T6 temper) or over-ageing (T73 temper), for reducing susceptibility to stress-corrosion cracking. The heat treatment of the present invention may therefore be termed as "RR temper" (retrogression and re-ageing).

The following explanation may be helpful in understanding the present invention. The susceptibility to stress-corrosion cracking is believed to be due to networks of dislocations which are produced during the solution heat treatment of precipitation hardening alloys. For example, it has been found that such dislocations in the 7075 T6 alloy are formed during the quenching from the solution heat treatment temperature. These dislocations are substantially removed by the previously mentioned over-ageing treatment (T73 temper), but at the same time the strength of the alloy is reduced.

In the present invention, the retrogression treatment partially redissolves the precipitate responsible for the previous hardening of the material, resulting in a softening of the material. The retrogression treatment is also believed to disperse the networks of dislocations responsible for the susceptibility to stress corrosion. The subsequent re-ageing step re-hardens the material to recover its original maximum strength properties. The T73 temper, on the other hand, results in permanent and non-recoverable softening of the material due to a more advanced state of the age-hardening process, thereby producing a greater extent of precipitation and conversion of coherent to non-coherent precipitation.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Described below are a number of examples of which the novel heat treatment was effected on samples of 7075–T6 aluminium alloys. These are alloys of aluminium containing from 5.1–6.1 per cent zinc, 2.1–2.9% magnesium, 1.2–2.0% copper, and traces of other elements. Such an alloy had first been subjected to a solution heat treatment at a temperature of about 480°C, and a subsequent T6 ageing treatment of a temperature of about 121°C for about 24 hours. The samples were taken from material in the form of 3 inch thick rolled plate. All testing was carried out in the short transverse direction. Tensile-type samples were loaded in tension to a stress corresponding to 75% of their yield point (0.2% proof stress) and subjected to a boiling solution of 6% NaCl in water until rupture occurred.

In the case of 7075–T6 aluminium alloys, it was found that the retrogression treatment is preferably effected from 200°C to 260°C for a few seconds to a few minutes. More particularly, the preferred combinations of time and temperature are 90–120 seconds at 200°C; 15–60 seconds at 220°C; 15 seconds at 240°C; and 7 seconds at 260°C. The subsequent re-ageing treatment is not as critical with respect to temperature or time, but preferably should be effected at the temperature of 115–125°C for up to several days. In the preferred examples, the re-ageing was effected at 121°C for 16–48 hours.

The retrogression heat treatment in the examples described below was carried out in a silicone oil bath in view of the very short times involved. The samples were then air cooled or water quenched before being subjected to the re-ageing treatment.

The results obtained in a series of tests performed as described above are set-forth in Table 1 below with re-
spect to stress-corrosion resistance, and in Table 2 below with respect to strength.

<table>
<thead>
<tr>
<th>HEAT TREATMENT*</th>
<th>STRESS CORROSION LIFE, HOURS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samples</td>
<td>A</td>
</tr>
<tr>
<td>1. T6 alone</td>
<td>0.6</td>
</tr>
<tr>
<td>2. T6 + 120</td>
<td>26</td>
</tr>
<tr>
<td>3. T6 + 120</td>
<td>43.4</td>
</tr>
<tr>
<td>4. T6 + 120</td>
<td>16.0</td>
</tr>
<tr>
<td>5. T6 + 15</td>
<td>36.25</td>
</tr>
<tr>
<td>6. T6 + 60</td>
<td>42.8</td>
</tr>
<tr>
<td>7. T6 + 15</td>
<td>22.25</td>
</tr>
<tr>
<td>8. T6 + 15</td>
<td>31.1</td>
</tr>
<tr>
<td>9. T6 + 7</td>
<td>29.4</td>
</tr>
</tbody>
</table>

*Note: W.O. = water quenched; A.C. = air cooled

It will be seen from Table 1 that, whereas the samples in the T6 temper failed within an average time of about 41 minutes, samples treated in accordance with the novel “RR temper” lasted for periods of 11 to 74 hours, depending on the retrogression and re-ageing conditions employed. It will also be seen from Table 2 that the original strength of the alloy was substantially retained, as compared to the T73 temper, wherein the strength is reduced about 15%.

The depth of the material affected by the novel heat treatment can be controlled by the retrogression conditions employed, the section thickness, and the heating medium. For example, a liquid bath could have effect only on a limited depth of the material, whereas induction heating in the retrogression step could considerably increase the effective depth. The novel heat treatment is therefore particularly adaptable as a user's heat treatment to be applied to an article in the final or near-final machined condition.

What is claimed is:

1. A method of substantially reducing the susceptibility to stress-corrosion cracking of the 7,000 series aluminum alloys containing zinc, magnesium, and copper, while still retaining their original mechanical strength, which alloys have been subjected to a solution heat treatment at a high temperature and then to an aging treatment at a lower temperature thereby hardening the alloy but likewise producing therein a susceptibility to stress-corrosion cracking, comprising the steps of:
   a. subjecting the alloy to a retrogression heat treatment for a few seconds to a few minutes at a temperature of from 200°C to 260°C, which temperature is above the age-hardening temperature of the alloy but below the solution heat treatment temperature; and
   b. subsequently subjecting the alloy to a re-aging heat treatment at a temperature from 115°C to 125°C for a substantially longer period of time than in step (a) up to several days.
2. The method as defined in claim 1, wherein said alloy is aluminum alloy 7075.

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