Effect of T6 heat treatment on tensile strength of EN AB-48000 alloy modified with strontium

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Received 18-04-2011; accepted in revised form 20-04-2011

Abstract

Among alloys of non-ferrous metals, aluminum alloys have found their broadest application in foundry industry. Silumins are widely used in automotive, aviation and shipbuilding industries; as having specific gravity nearly three times lower than specific gravity of cast iron. The silumins can be characterized by high mechanical properties. To upgrade mechanical properties of a castings made from silumins one makes use of heat treatment, what leads to change of their structure and advantageously affects on mechanical properties of the silumins.

In the paper are presented test results concerning effect of dispersion hardening on change of tensile strength of EN AB-48000 silumin modified with strontium. Investigated alloy was melted in electric resistance furnace. Temperature ranges of solution heat treatment and ageing heat treatment were selected on base of curves from ATD method, recorded for refined alloy and for modified alloy. The heat treatment resulted in change of $R_m$ tensile strength, while performed investigations have enabled determination of temperatures and durations of solution heat treatment and ageing heat treatment, which precondition obtainment of the best tensile strength $R_m$ of the investigated alloy.

Keywords: Modification, ATD, Heat Treatment, Tensile Strength

1. Introduction

Due to various loads of static and dynamic character, acting on a casting alloy during their operation, there is a need of comprehensive testing of the material with respect to its mechanical properties, aimed at determination of a „resistance” of this material to action under different loads.

Mechanical properties of metals and alloys such as: tensile strength $R_m$, elongation, impact strength and other properties, constitute the main parameters which determine application of a given alloy as material destined to casting machinery parts.

Contemporary production engineering strives at application of a materials being characteristic of the highest strength, because such strength enables reduction of consumption of materials, and the same reduction of weight of a machine or a structure.

Silumins are the most commonly widespread casting alloys produced on base of aluminum, i.e. alloys from Al-Si system. It is connected with a broad series of operational and technological advantages of this group of alloys [1-3].

Upgraded mechanical properties of silumins can be also obtained through introduction of alloying additions (Cu, Mg, Ni, Mn, and others) [4-8], through modification [1-3, 9-11] and through heat treatment [2-3, 12-13].

In the near-eutectic and hypo-eutectic silumins classified among silumins with needle-like structure, mechanical properties – especially elongation and impact strength – are very low due to presence of brittle phase of silicon in form of big, irregular plates with sharp contours [3]. Through modification of these silumins it is possible to obtain refinement of grains (dendrites) and crystals of the phases precipitated primarily during crystallization, and...
considerable reduction of interphase distance in grains of eutectic mixture. Production of such structure results in growth of mechanical properties of the alloy.

Eutectic silicon morphology, particle size and shape, plays an important role in determining of the mechanical properties of Al–Si alloy castings. The silicon particles, appearing as coarse, acicular needles under normal cooling conditions, act as crack initiators, lowering the mechanical properties. Strontium modification changes the silicon morphology from acicular to fibrous, resulting in a significant decrease in the size of the Si particles, and a corresponding increase in the particle count per unit area. Strontium modification has been observed to lower fragmentation, necking, spheroidization, and coarsening, while the α-Fe Chinese script particles are not affected [16].

Heat treatment is one of the major factors used to enhance the mechanical properties of heat-treatable Al–Si alloys, through an optimization of both solution and aging heat treatments given to these alloys. The solution treatment homogenizes the cast structure and minimizes segregation of alloying elements in the casting [15].

The segregation of solute elements resulting from dendritic solidification may have an adverse effect on mechanical properties. The time required for homogenization is determined by the solution temperature and by the dendrite arm spacing. Silicon particles undergo fragmentation, necking, spheroidization, and coarsening, β-Fe needles gradually undergo necking and fragmentation, while the α-Fe Chinese script particles are not affected [16].

Heat treatment process parameters such as aging temperature and aging time operate differently according to different conditions [17].

Due to fact that the most often growth of alloy’s strength after heat treatment is accompanied by a drop of elasticity, their optimal system should be selected depending on a given application of the alloy. Selection of optimal parameters of heat treatment process enables not only improvement of mechanical and technological properties of a material, but also have an effect on economic aspect of the process.

2. Methodology of the research

The first stage of investigations consisted in tests of crystallization course of the alloy produced from pig sows.

Investigated alloy was melted in electric resistance furnace and refined with RAFAL 1 preparation in quantity of 0.6% of mass of charge, in temperature of 710°C. After completion of the refinement (60 minutes) one removed oxides and slag from the metal-level and performed modification of the alloy with strontium, using AlSr10 master alloy in quantity of 0.4% of mass of the charge (0.04% Sr).

Process of solidification and melting of the alloy (ATD method) was recorded with use of fully automatic Crystaldimat analyzer.

Specimens to strength tests were poured in metal mould heated to temperature of 250°C and were prepared according to PN-88/H-88002 standard. Next, the specimens underwent operations of solution heat treatment and artificial ageing.

After accomplished heat treatment one performed static tensile test on ZD-20 tester.

Chemical composition of the investigated alloy is specified in the Table 1. Analysis of chemical composition was performed with use spectrometry method (emission spectrometer with glow-discharge excitation of GDS 850A type).

Table 1. Chemical composition of the investigated alloy

<table>
<thead>
<tr>
<th>EN AB–48000</th>
<th>Si [%]</th>
<th>Cu [%]</th>
<th>Zn [%]</th>
<th>Fe [%]</th>
<th>Mg [%]</th>
<th>Ti [%]</th>
<th>Mn [%]</th>
<th>Ni [%]</th>
<th>Cr [%]</th>
<th>Al [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>from pig sow</td>
<td>11.5</td>
<td>0.25</td>
<td>0.02</td>
<td>0.25</td>
<td>1.2</td>
<td>0.03</td>
<td>0.25</td>
<td>1.15</td>
<td>0.07</td>
<td>rest</td>
</tr>
<tr>
<td>refined</td>
<td>11.0</td>
<td>1.15</td>
<td>0.02</td>
<td>0.30</td>
<td>1.15</td>
<td>0.03</td>
<td>0.30</td>
<td>1.20</td>
<td>0.09</td>
<td>rest</td>
</tr>
<tr>
<td>modified</td>
<td>11.0</td>
<td>1.15</td>
<td>0.15</td>
<td>0.50</td>
<td>1.10</td>
<td>0.05</td>
<td>0.35</td>
<td>1.35</td>
<td>0.09</td>
<td>rest</td>
</tr>
</tbody>
</table>

In the Figure 1 are presented curves of heating (melting) and crystallization of refined and modified alloy, recorded with use of ATD method.

On thermal curve are marked temperature ranges of solution and ageing heat treatments of the investigated alloy.

In the Table 2 are listed parameters of heat treatment operations within three-stage plan of the testing with four variables. In case of accepted plan of the testing, number of variables have amounted to 27.

Table 2. Parameters of heat treatments of the alloy

<table>
<thead>
<tr>
<th>Solution temperature $t_p$ [°C]</th>
<th>Solution time $t_p$ [h]</th>
<th>Ageing temperature $t_a$ [°C]</th>
<th>Ageing time $t_a$ [h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{p1}$ - 500</td>
<td>0.5</td>
<td>$t_{a1}$ - 180</td>
<td>2</td>
</tr>
<tr>
<td>$t_{p2}$ - 520</td>
<td>1.5</td>
<td>$t_{a2}$ - 235</td>
<td>5</td>
</tr>
<tr>
<td>$t_{p3}$ - 530</td>
<td>3</td>
<td>$t_{a3}$ - 310</td>
<td>8</td>
</tr>
</tbody>
</table>

Temperatures of solution and ageing heat treatments were selected on base of values of points from ATD melting curves (Fig. 1).
3. Description of obtained results

To the heat treatment was used refined and modified alloy. Tensile strength $R_m$ was determined for the alloy: refined, refined and modified, after solution heat treatment, and after successive solution and ageing heat treatments.

In the Fig. 2 are presented average values of tensile strength $R_m$ of EN AB-48000 alloy after the heat treatment, referenced to values obtained for the alloy without heat treatment.

Tensile strength obtained in case of refined alloy amounted to from 225 to 229 MPa. After modification the tensile strength $R_m$ (218–230 MPa) was not changed practically. After performed treatment of solution the tensile strength $R_m$ was included within interval of 210–252 MPa.

In the Figs. 3–4 are presented spatial diagrams of influence of temperatures and durations of solution and ageing treatments on change of tensile strength $R_m$ of the investigated alloy.

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Fig. 1. Curves from ATD method for refined and modified EN AB-48000 alloy

Fig. 2. Change of tensile strength $R_m$ of the investigated alloy for individual systems of the testing plan

Fig. 3. Effect of temperature and duration of solution heat treatment on tensile strength $R_m$ of EN AB-48000 alloy ($t_s=180^\circ C$, $\tau_s=5$ hours)
Fig. 4. Effect of temperature and duration of ageing on tensile strength $R_m$ of EN AB-48000 alloy ($t_s=520^\circ$C, $\tau_p=1.5$ hours)

Making comparison of obtained average values of parameters from the test for the alloy after heat treatment and the alloy without the heat treatment one ascertained a growth of tensile strength $R_m$ up to 186% (system no. 13, Fig. 2) comparing with the modified alloy which did not undergo the heat treatment. The highest value of the tensile strength $R_m=426$ MPa was obtained for: temperature of solution of 520°C, time of solution of 1.5 hour, ageing temperature of 180°C and ageing time of 5 hour. Whereas the lowest tensile strength $R_m=176$ MPa was obtained for the specimens solutioned during 1.5 hour in temperature of 500°C and after ageing during 2 hour in temperature of 310°C.

4. Conclusions

On base of obtained test results it should be ascertained that heat treatment of EN AB-48000 alloy results in growth of its tensile strength $R_m$.

The highest values of the tensile strength $R_m$ were obtained for the following parameters of heat treatment process:

- solution temperature - 520-530°C,
- solution time – 0.8 to 2.2 hour,
- ageing temperature – below 200°C,
- ageing time – 4 to 6 hour.

The lowest values of the tensile strength $R_m$ were obtained for the following parameters of the heat treatment:

- solution temperature – below 510°C,
- solution time – above 1 hour,
- ageing temperature above 280°C,
- ageing time – 3 to 8 hour.

Growth of the tensile strength $R_m$ of EN AB-48000 alloy through application of heat treatment is conditioned by selection of suitable parameters of solution and ageing treatments.

References


