The article deals with the basic knowledge of Zn-Al-Cu system and precipitant hardening of ZnAl4Cu3 alloys. This alloy is a widely used commercial material for fabricating various construction parts through pressure die-casting. The article thereinafter in the experimental section includes a description of precipitant hardening, which was used for the casting of an alloy of ZnAl4Cu3 and its impact on the structure and hardness properties of castings.

1. INTRODUCTION

In the automotive industry, besides aluminium alloys, there are also currently used zinc based alloys, which serve for the production of tiny parts (such as are widow wiper holders, lock parts and petrol system parts).

For this reason, Department of Engineering Technology, Faculty of Mechanical Engineering – Technical University of Liberec, has been involved in observing the foundry and mechanical properties of those alloys. This work pays attention to pursuing the influence of precipitation hardening on the ultimate tensile strength and hardness with a ZnAl4Cu3 alloy.

1.1 Characteristics of the Zn-Al-Cu system

The basis of all practically used zinc based alloys is the Zn-Al system. Its constitution diagram published by MURPHY [1] is given in Fig. 1. Both metals are in their solid state mutually partially soluble with eutectic crystallization.
The most used alloy derived from this system is ZnAl4Cu3, which is applied for the manufacture of various construction elements submitted to die cast. A ternary diagram of the Zn-Al-Cu system is mentioned in Fig. 2.

At a temperature of ternary eutectics of 375 °C, four phases - melt, η - phase (solid solution rich in Zn, hexagonal lattice), β – phase (solid solution rich in Al, cubic face - centered lattice), ε – phase (Cu-Zn) are in balance.

At lower temperatures, the phase rich in Al will disintegrate, the influence of copper on that disintegration is not known. The solubility of copper and aluminium in solid zinc decreases from the eutectic temperature, at a temperature of 274 °C, the solubility of Al is 0,9 % and that of Cu is 1,9 %. Below the eutectic temperature, phase η, phase ε, and phase α (phase rich in Al; cubic face- centered lattice) are in balance.

2. EXPERIMENT – THERMAL TREATMENT OF THE ZNAL4CU3 ALLOY

The aim of this work was observing the structure and mechanical properties of castings from the zinc alloy of the Zn-Al-Cu type after their precipitation hardening. The ZnAl4Cu3 alloy was applied for the experiment. The observed properties were examined on test rod-like castings, cast in a steel mould with vertical mould joint, pre-heated at an approx. temperature of 200 °C, see Fig. 3. Within the experiment, 25 test castings were cast; subsequently, those test castings were worked to the dimensions given in Fig. 3 so that they can correspond to the ČSN EN ISO 10002-1 standard. Hardness was measured on all rods; 5 rods were taken away for tests without thermal treatment (Group 1). The remaining 20 rods were thermally treated then.

Table 1 A survey of carried out experiments

<table>
<thead>
<tr>
<th>Group of specimens</th>
<th>Thermal treatment (TT)</th>
<th>Conditions of the experiment</th>
<th>Observing the structure</th>
<th>Observing the mechanical properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Without TT (initial condition)</td>
<td>Luminous microscopy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>TT + 1 day of ageing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>TT + 14 days of ageing</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>4.</td>
<td>TT + 21 days of ageing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>TT + 28 days of ageing</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The heating of specimens was carried out in a furnace, homogenization-heating temperature was 240°C and soaking time at this temperature was 30 minutes. Then test rods were cooled in water of a temperature 20°C immediately and left for spontaneous (natural) hardening (ageing). Those rods were separated into four other groups. Time intervals in which the influence of hardening was observed are presented in Table 1.

2.1 Evaluating the metallographic structure observation

Specimens for microscopic observation were prepared by a usual metallographic method. For accentuating the structure, chromium trioxide solution (200 g), sodium sulphate (7g), sodium fluoride (2g) and distilled
water (1000 ml) were used. The structure was observed with a Neophot 21 microscope. Examples of the observed structures are given in Figures 5 and 6.

In Fig. 5, there is presented a structure of test rod specimens in a condition after casting. The structure is formed from phase $\eta$ (rich in zinc – hexagonal lattice), phase $\alpha$ (rich in Al – face centered cubic lattice) and phase $\epsilon$ (CuZn$_4$). Phase $\eta$ is separated here in elongated crystals of dark colour in dimensions of 0,04 up to 0,16 mm in the longitudinal direction and 0,03 up to 0,07 mm in the lateral direction.
In Fig. 6, specimen structure in a condition of 21 days after thermal treatment is given. Again, the structure is formed from η phase and α phase. Black points occurring in the dendrites of η phase are of the precipitating ε phase. The size of the dendrites of η phase is 0.06 up to 0.12 mm in the longitudinal direction and 0.04 up to 0.16 mm in the lateral direction.

2.2 Measuring the hardness of specimens

Hardness was set by the Brinell method (ČSN 42 0371) on a WPM – 308 hardness tester, indentation ball diameter was 2.5 mm, weighting force 62.5 kp (612.92 N), and acting time 30 s. Hardness observation was carried out on test rods in a state after casting and in the given time intervals – 1 day, 14, 21, and 28 days after thermal treatment, see Table 1. Graphic processing of the results of hardness measuring is illustrated in Fig. 7.

![Graphic processing of the results of Brinell hardness measuring](image)

Fig. 7 Graphic processing of the results of Brinell hardness measuring

2.3 Tensile strength measuring

Observing the tensile strength of test rods from the ZnAl4Cu alloy in a state after casting and in the various grade of their precipitation hardening has been carried out on the TIRA 2300 apparatus. Graphically processed results of tensile strength measuring are mentioned in Fig. 8.

3. CONCLUSION

The work has confirmed that in ZnAl4Cu3 alloy castings, their mechanical properties can be enhanced with the aid of thermal processing – precipitation hardening. Precipitation hardening of the ZnAl4Cu3 alloy can be carried out under those conditions: heating up to a temperature of 240°C, temperature dwell (homogenization) and water cooling in a temperature of 20°C, and natural ageing. The alloy structure in a condition after casting is formed from the phase η (rich in zinc – hexagonal lattice), phase α (rich in Al – face centered cubic lattice) and phase ε (i.e. chemical compound CuZn₄). After thermal treatment, an oversaturated solid solution is generated which disintegrates itself after a certain time after cooling. After precipitation hardening, specimens showed structure, which consisted from the phase η and phase α. In η phase are small separations of the precipitating ε phase (ZnCu₄).
Fig. 8 Graphic elaboration of the tensile strength measurement results

The average value of the hardness of tested rods after casting achieved 108 HB; 1 day after hardening, a value of 137 HB was measured, which is an increase of 23.5%. Due to further natural ageing, an increase of this value by 9% (up to 146 HB) occurred. The most marked hardness increase expressed itself within 24 hours after thermal treatment; then, a slow increase followed.

The average value of tensile strength of testing rods after casting reached 255 MPa; 1 day after hardening, a value of 284 MPa was measured, i.e., an increase of 10.6%. Because of further natural ageing, an increase of this value by 4% (up to 296 MPa) occurred. The most remarkable increase of tensile strength became evident analogous to hardness within 24 hours after thermal treatment.

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