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High-aluminium zinc alloy (ZnAl27Cu2) modified with titanium and boron

A. Zyska*, Z. Konopka, M. Łągiewka, M. Nadolski, A. Chojnacki

[a] Department of Foundry, Technical University of Częstochowa, ul. Armii Krajowej 19, 42-200 Częstochowa, Polska

*Corresponding author. E-mail address: zyska@mim.pcz.czest.pl

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Abstract

The paper presents the results of investigations concerning the influence of the titanium-boron modifier quantity on the structure and mechanical properties of ZnAl27Cu2 alloy. The modification has been performed with the use of AlTi5B1 master alloy, thus introducing into the molten alloy 0.015%Ti and 0.003%B; 0.025%Ti and 0.005%B; 0.035%Ti and 0.007%B and eventually 0.045%Ti and 0.009%B. Samples for examination have been cast in sand moulds. The optimum mechanical properties R_m=440MPa and A_5=8% have been achieved by introducing 0.035% Ti and 0.007% B into the alloy. It has been found that morphological changes of the primary crystals of α solid solution take place due to the modification. The dendrites with widely outspread arms take the shape of rounded, globular crystals. The size of α phase crystals decreases, but to the rather small degree, proportionally to the quantity of added modifier.

Keywords: Zn alloys, Modification, Structure, Mechanical properties

1. Introduction

The high-aluminium zinc alloys are competitive casting materials as referred to the tin bronzes. They exhibit higher strength, hardness, and castability, their anti-frictional properties are similar to those of bronzes and their density is lower [1-6]. They are significantly less expensive and have lower melting temperature, therefore costs of casting production are much lower than for bronze alloys. They can be used for castings working under a temperature up to 100-120°C in the non-corrosive environment [1-7]. Zn-Al alloys are alloyed with copper in the quantity from 1% to 4%. Copper effectively increases their mechanical properties, but simultaneously it causes dimensional instability of castings. This problem can be solved by proper thermal treatment [8-10]. Zn-Al-Cu alloys can be dispersion hardened thanks to the diversified, decreasing with the temperature drop, dissolution of aluminium and copper in zinc. Copper- and aluminium-rich phases are precipitated during the accelerated ageing (a rather complicated process) of the supersaturated α solid solution. This results in an increase of mechanical properties and in dimensional stabilization of castings. Structural and volume changes taking place during the supersaturation are comparable with those which would have been occurred at the temperature of 20°C after 5 years [11-14].

The primary structure of a casting has a significant influence on the effectiveness of the thermal treatment of Zn-Al-Cu alloys. This structure depends in turn from the refining and modification processes, solidification conditions, segregation of alloy additions, the quantity and the type of impurities, etc [15].

Titanium, zirconium, nickel, manganese, and chromium are more often used for refining the crystallites of zinc alloys. Experiments [16] performed for the modified ZnAl27Cu2 alloy have shown that the addition of:

- boron in the quantity of 0.002-0.005% results in an increase of alloy elongation at almost the same tensile strength;
- titanium in the quantity of 0.02-0.0019% and boron from 0.003 to 0.007% causes an increase in elongation at the slight increase in tensile strength;
- zirconium up to 0.038% does not influence mechanical properties of the alloy, but implies the refining of crystallites;

- titanium and boron with the simultaneous increase in magnesium content up to 0.018% results in an increase of both elongation and tensile strength;
- lanthanum in the quantity of 0.05% positively influences elongation, but has no distinct effect on tensile strength;
- cerium in the quantity of about 0.05% influences the alloy in a similar way as the lanthanum addition.

Modification increases also the impact resistance of the alloy, but impairs its creep strength.

The purpose of the present work has been to assess the modifying influence of titanium-boron master alloy on the structure of ZnAl27Cu2 alloy and to examine the influence of modifier quantity on the mechanical properties of castings.

2. Material and the methodics of examinations

The examined material has been the standardized ZnAl27Cu2 alloy (PN-EN 1774:2001). The AlTi5B1 aluminium-titanium-boron master alloy in the form of 10 mm diameter rods has been used for modification. The alloys have been melted and modified in the induction furnace of medium frequency in steel crucible coated with the protective layer of graphite, boric acid, and borax. After melting, the alloys have been overheated up to the temperature of 580°C, alloyed with the modifying master alloy, and held at this temperature for 10 minutes. Then the liquid alloy has been cooled down to the temperature of 540°C and cast into sand moulds. Rod specimens with 16 mm diameter have been cast. Five melting cycles have been performed, one for achieving the non-modified alloy, the next four with adding titanium-boron modifier in quantities adequate to introduce 0.015%Ti and 0.003%B; 0.025%Ti and 0.005%B; 0.035%Ti and 0.007%B; 0.045%Ti and 0.009%B, respectively in subsequent cycles.

The examination of mechanical properties have been held for standardized specimens of length to diameter ratio of 5:1 according to the PN-EN 10002-1:2 Standard, by means of the ZWICK-1488 servo-hydraulic testing machine. Microstructural observations have been done by means of the Nikon Epiphot optical microscope for the metallographic specimens taken out of the tabs of the examined tensile test specimens.

3. Examination results

Figures 1 and 2 represent the influence of the Ti-B modifier on the mechanical properties of ZnAl27Cu2 alloy, whereas figure 3a-3d shows structural changes caused by modifying treatment. They allow for the statement that the titanium-boron master alloy affects the structure of ZnAl27Cu2 alloy in the modifying way and causes an increase in its mechanical properties. Taking a closer look at the individual properties one can notice that:

- an addition of modifier in the quantity up to 0.025%Ti and 0.005%B causes a drop in the yield strength. For greater modifier additions (0.035% Ti and 0.007% B) the $R_{0.2}$ value distinctly increases and reaches the largest value of 365 MPa. Exceeding this modifier quantity results in the $R_{0.2}$ decrease;
- the tensile strength increases with the increasing quantity of introduced modifier up to the 0.035% Ti and 0.007% B content, and then the drop in R_m occurs. The R_m value reaches 442 MPa due to the addition of titanium-boron master alloy in the quantity introducing 0.035% Ti and 0.007% B, and this value is about 20% higher than that of the non-modified alloy;
- the alloy elongation achieves the maximum value (above 8%) after adding the titanium-boron master alloy in the quantity of 0.025% Ti and 0.005% B. This value exceeds by several times the respective A_5 value for the non-modified alloy, which exhibits the elongation of the order of 1.2%. The modifier addition exceeding 0.025% Ti and 0.005% B results in a slight decrease of A_5 to the level of 6%.

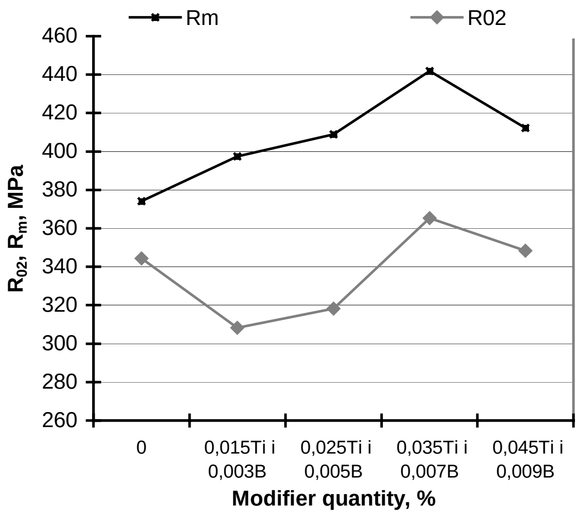


Fig. 1. The influence of Ti-B modifier quantity on strength properties of ZnAl27Cu2 alloy

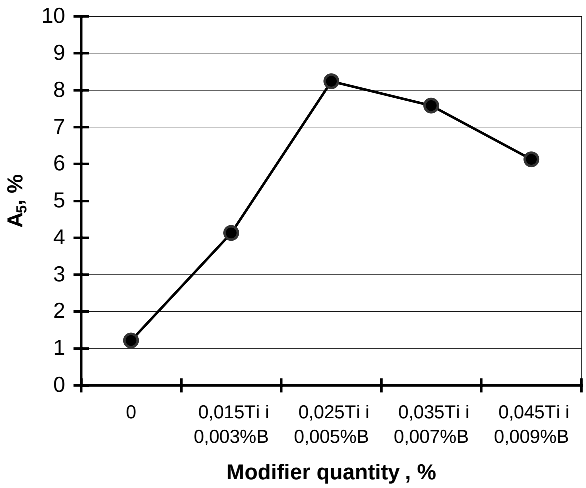
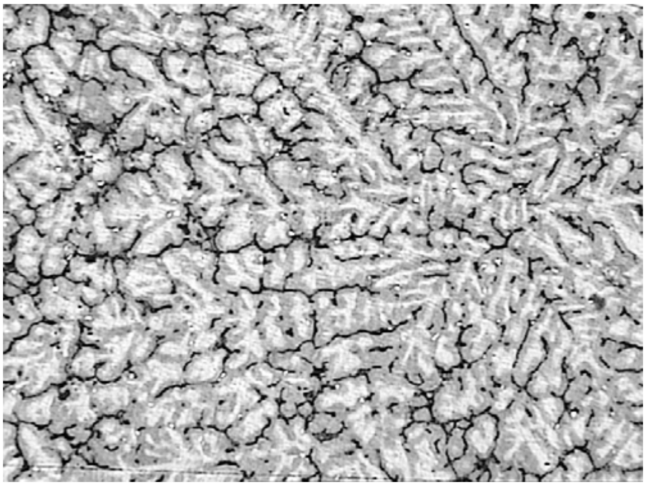
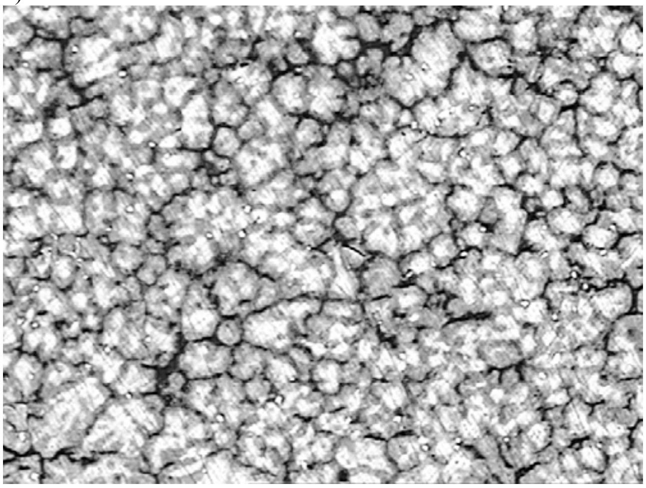


Fig. 2. The influence of Ti-B modifier quantity on elongation A_5 of ZnAl25Cu2 alloy

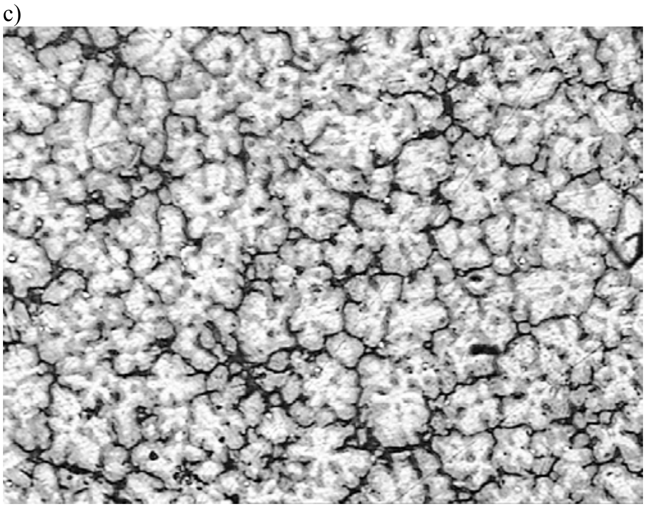
a)



b)



c)



d)

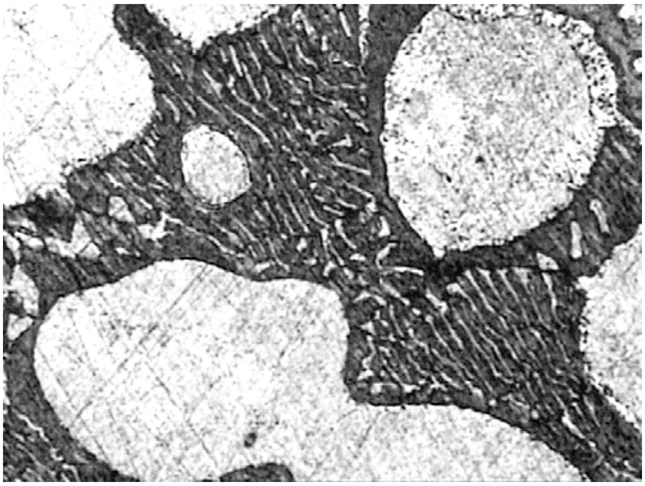


Fig. 3. The structure of ZnAl27Cu2 alloy: a) non-modified, magn. 50×, b) modified with 0.015%Ti and 0.003%B, magn. 50×, c) modified with 0.045%Ti and 0.009%B, magn. 50×, d) eutectoid within the interdendritic spaces, magn. 400×

The structure of castings made of ZnAl27Cu2 alloy is constituted by the α (Al-rich) phase, the η (Zn-rich) phase, and the ε phase ($CuZn_4$). The alloy matrix consists of α phase dendrites (Fig. 3a-3c), whereas the α+η eutectoid along with ε phase precipitates occupies the interdendritic spaces (Fig. 3d). The influence of titanium-boron modifier becomes apparent by the change in morphology of primary α phase crystals. Comparing the results of structural examination (Fig. 3a-3c) one can notice that the dendrites of the non-modified alloy are larger and their arms are longer. Their shape and size indicate the developed dendritic structure of the alloy. As a result of modification with AlTi5B1 master alloy the α phase occurs in the form of the non-oriented dendrites or separate rounded crystallites (Fig. 3b, 3c). Such globular structure of the α solid solution occurs in all modified alloys, no matter how much titanium-boron master alloy has been added.

The influence of the quantity of modifier on the morphology of crystals has been found generally not significant within the examined range from 0.015Ti and 0.003B to 0.045%Ti and 0.009%B. However it has been observed that the size of α phase crystals diminishes proportionally to the quantity of added modifier, but only to a small degree.

3. Final conclusions

1. An addition of titanium-boron master alloy to the ZnAl27Cu2 alloy affects its structure in a modifying way and causes an increase in its mechanical properties.
2. Castings made of ZnAl27Cu2 alloy modified with titanium and boron in the amount of 0.035% Ti and 0.007% B allow for achieving the strength of the order of 440 MPa at unit elongation equal to about 8%.
3. Changes in morphology of the primary α phase crystals take place as a result of the performed modification. Dendrites with widely outspread arms take the shape of rounded,

globular crystals. The size of the primary α phase crystals decreases with an increase of titanium-boron modifier quantity.

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