

Improving Quality of the EN AC-43300 (AlSi9Mg) Alloy Destined for Castings of a Pump Casings

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Abstract

Among non-ferrous alloys, the aluminum alloys have found the most widespread applications within foundry industry. Hypoeutectic silumin of the AlSi9Mg grade is commonly used for large, heavy duty machinery castings with complicated shape and high strength. From technical point of view, tendency to creation of coarse structure can be considered as a drawback of such alloy, what can have adverse effect on properties of the alloy. To obtain optimal structure of the castings and to assure improvement of their mechanical properties, the most effective treatment to perform is modification. Quality of performed modification treatment depends on proper dosing of inoculant and maintaining suitable temperature and time of keeping the alloy before pouring.

In the paper are presented test results of crystallization course of refined and modified silumin of the EN AC – 43300 (AlSi9Mg) grade, used in castings of pump casings. It has been determined an effect of performed processes of refining and modification on the mechanical properties (R_m , A_5 , HB and KCV), additionally, metallurgical tests of the alloy have been performed. Basing on analysis of obtained results, the most advantageous modification variant, which is suitable for castings of pump casings and complying with requirements of customers, has been selected.

Keywords: Mechanical properties, Silumins, Refining, Modification, ATD-AED

1. Introduction

High mechanical, technological and operational requirements made by domestic and foreign recipients of poured components made from aluminum force the producers to introduction of modern technologies of production. Castings produced from such aluminum alloys, pump casings mainly, should be characterized by:

- high mechanical properties (R_m , A_5 , HB and KCV),
- high leak resistance,
- adequate surface roughness.

The castings of pump casings produced up-to-now from domestic furnace charge (pig sows) do not fully comply with demands put by domestic and especially foreign customers. In foundry industry of aluminum alloys, during melting of the charge, very often are implemented suitable metallurgical processes to obtain predetermined properties of the castings, imposed by national and foreign standards [1, 2, 3]. The pig sows with low technological properties used to production of heavy duty castings require implementation of refinement treatments of liquid metal (refining and modification treatments).

Modification process of silumins, due to its importance in production of the castings, has been widely discussed by many authors [1, 2, 4, 5]. Structure of Al-Si eutectic mixture after

correct modification is typical of minimal interfacial spacing of eutectic mixture, rounding of their outlines and a higher portion of dendritic crystals of plastic phase α [6]. The strontium belongs to chemical elements assuring permanent modification of silumins. Its action consists in neutralization of the AlP molecules located in liquid silumin through creation of the Sr_3P_2 compound [7]. In practice, quantity of introduced Sr amounts to about 0,04-0,07% [1].

In the paper is presented usage of the strontium as the inoculant, added during melting of the EN AC-43300 (AlSi9Mg) alloy, destined to production of the castings for casings of heavy duty pumps to sewage system installations.

2. Methodology of the research

The investigations have been commenced from selection of a producer of the pig sows characterized by low price and timely deliveries. Next, it has been performed initial tests of mechanical properties of the pig sows from the selected producer. Obtained values of the mechanical properties of very complicated casings of the pumps (Figure 1), do not satisfy requirements concerning mechanical, operational and technological properties, as well as do not comply with requirements of the PN-EN 1706:2011 standard.

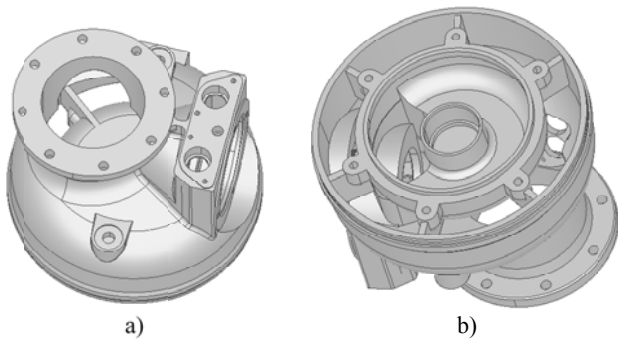


Fig. 1. Casing of the pump: a) external view, b) view of interior of the pump

To improve mechanical properties of the pig sows from the AlSi9Mg alloy it has been used suitable processes of refining and modification. The refining process was performed before each modification treatment with use of the ALRAF preparation in quantity of 0.4% mass of the charge, while the modification treatment with the AlSr10 inoculant (10% of the strontium) [1, 2, 8, 9]. To identify the most advantageous quantities of the inoculant it has been performed modification with additives 0.04%, 0.06% and 0.08% of the Sr with respect to mass of metallic charge. Test pieces to the tensile and impact strength were produced in sand moulds from prepared in such way alloy.

Tensile strength R_m , the elongation A_5 and the hardness tests of the test pieces were performed according to the PN-EN ISO 6892-1:2010P and PN-EN ISO 6506-1:2014P standards, while tests of the impact strength were performed with use of test pieces

shown in the Fig. 2. Fivefold repeatability was used during each test.

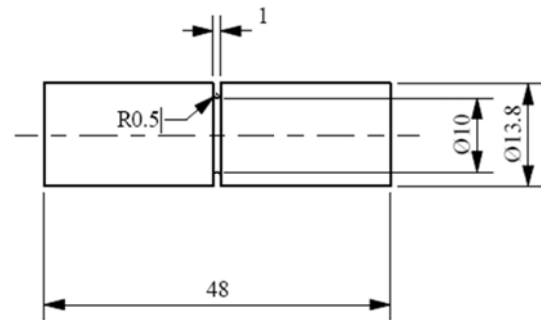


Fig. 2. Shape and dimensions of the test piece to the impact strength KCV test.

Simultaneously with pouring of the test pieces, using a special analyzer it has been performed tests of kinetics of crystallization process, implementing method of the Thermal-Derivative and Electro-Derivative (ATD - AED) methods [10,11]. The specimens to testing of chemical composition were also poured from the same alloy. Analysis of chemical composition was performed with use of inductively coupled plasma spectrometry method on optical emission spectrometer of the Optima 4300 Dv type produced by PerkinElmer. The metallographic tests were performed on microsections produced from shoulders of the test pieces with use of optical microscope of the Neophot 32 type.

3. Description of obtained results

Chemical composition of the alloy from the pig sows used in course of test of the mechanical properties and kinetics of crystallization processes, and in the metallographic tests, is shown in the Table 1. After modification treatment, content of the Sr increased from 0.03 to 0.08% depending on quantity of added inoculant.

Table 1.

Chemical composition of the AlSi9Mg alloy from the pig sows					
Chemical composition / mass %					
Si	Cu	Zn	Fe	Mg	Ni
9.41	0.18	0.05	0.64	0.20	0.01
Mn	Pb	Ti	Sn	others	Al
0.42	-	0.18	-	0.01	rest

Obtained average values of the mechanical properties for the AlSi9Mg alloy from the pig sows and after treatments of refining and modification with the following quantities of strontium: 0.04%, 0.06% and 0.08% Sr of mass of metallic charge, are presented in the Figure 3.

Analysis of obtained results of the mechanical properties has shown that the AlSi9Mg alloy, after modification with 0.06% Sr of mass of metallic charge featured the highest tensile strength

$R_m=173$ MPa, the highest elongation $A_5=5.1\%$, the highest hardness - 54 HB and the highest impact strength $KCV=70$ kJ/m².

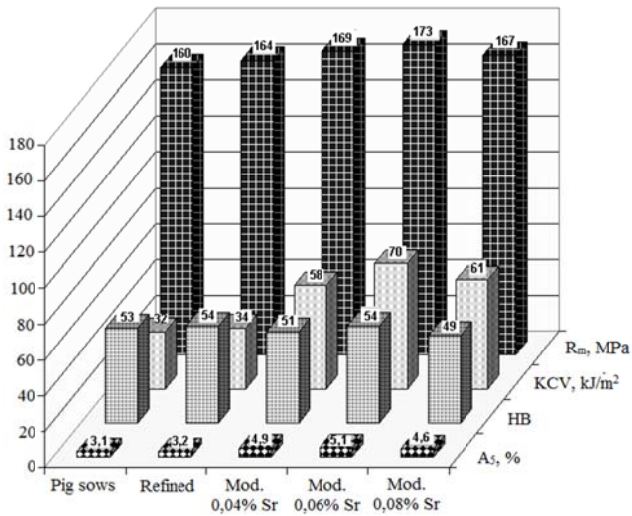


Fig. 3. Mechanical properties of the AlSi9Mg alloy from the pig sows after refining and modification with different quantities of strontium

Comparing to the mechanical properties of the refined alloy it is seen a slight increase of the tensile strength R_m , increase of the elongation A_5 with more than 59%, the impact strength KCV with about 106%, with maintaining values of the hardness HB at the same level.

Effectiveness of performed processes of refining and modification of the investigated alloys has been confirmed with use of the ATD-AED method [3, 10, 12-14].

Form of crystallization curve, of the thermal t and electric σ

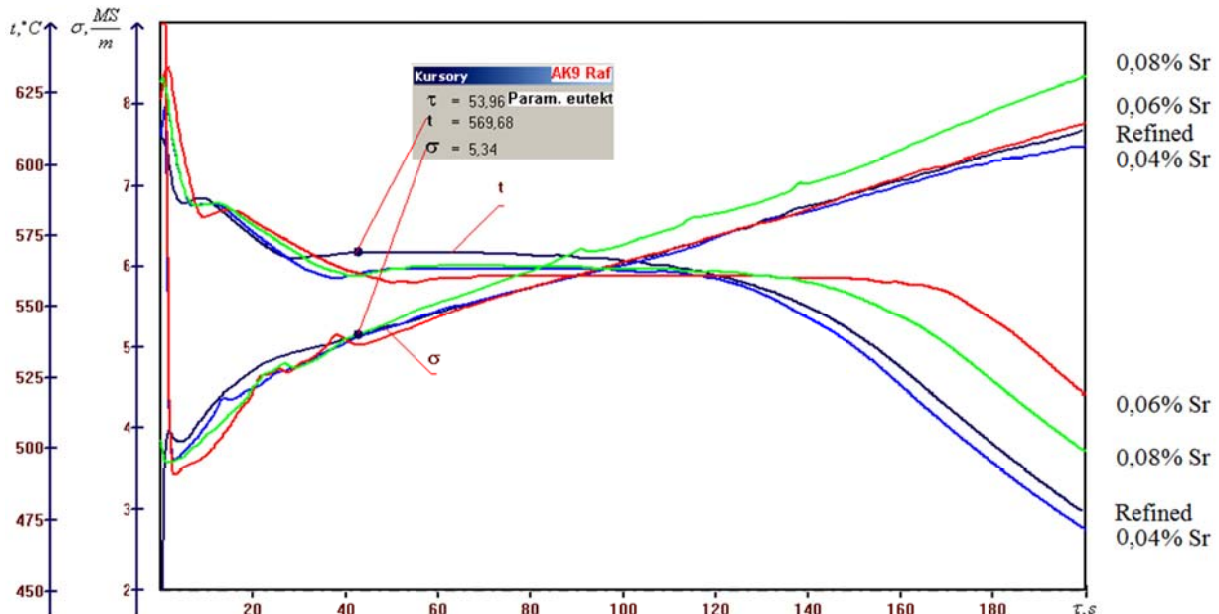


Fig. 4. Comparison of crystallization curves of the AlSi9Mg alloy, refined and modified with different quantities of strontium

curves, as well as their derivatives $dt/d\tau$ and $d\sigma/d\tau$, recorded during solidification and cooling, for the alloy directly remelted from the pig sows, and the alloys modified with different quantities of the strontium are presented in the collective Figure 4, while in case of the alloy modified with addition of 0.06% Sr, illustrating the most advantageous mechanical properties, in the Fig. 5.

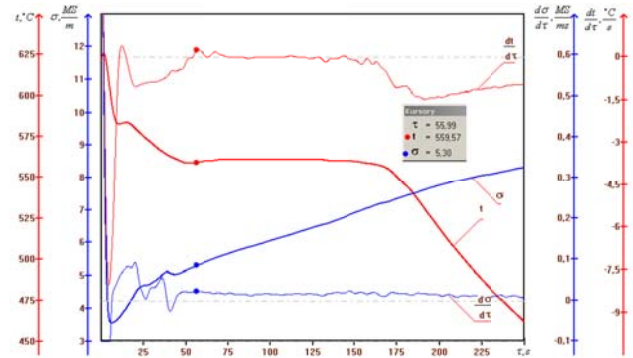


Fig. 5. Crystallization curves of the AlSi9Mg alloy refined and modified with additive of 0.06% Sr

The most beneficial addition of the inoculant, i.e. 0.06% Sr, has resulted in decrease of crystallization temperature of the eutectic mixture $\alpha + Si$ from $t=570^\circ C$ to $t=560^\circ C$ (Fig. 4 and 5), what is pointing at crystallization of modified structure of the investigated alloy. To confirm beneficial effect of refining and modification treatments of the investigated alloy it has been taken photographs of the microstructure.

In the Fig. 6 are shown microstructures of the AlSi9Mg alloy after refining and modification with strontium in quantities of 0.04%; 0.06% and 0.08% Sr of metallic charge.

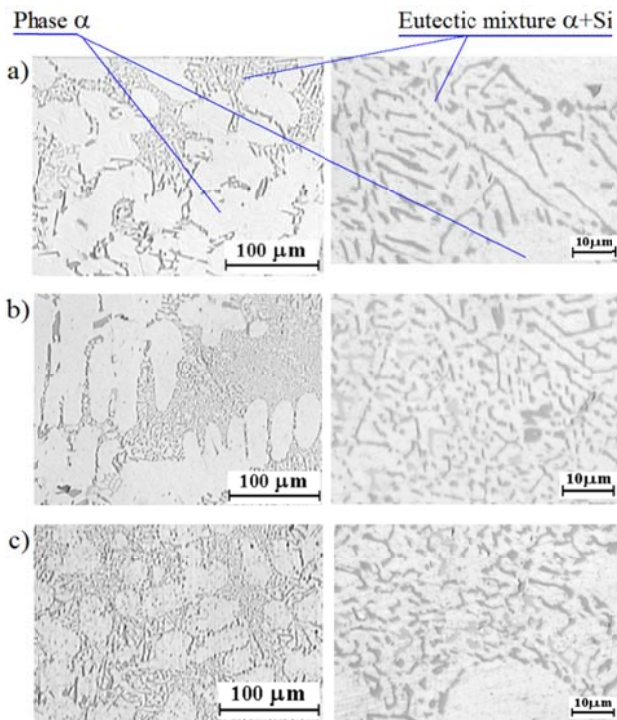


Fig. 6. Microstructures of the AlSi9Mg alloy after refining and modification with additives of Sr: a) 0.04% Sr; b) 0.06% Sr; c) 0.08% Sr

Performed metallurgical tests of the microstructures (Fig.6) have confirmed that the AlSi9Mg alloy after refining and modification with addition of 0.06% Sr features the most beneficial shape of the eutectic mixture α +Si and the phase α . Process of the modification clearly affects the form of precipitations of silicon, which changes from lamellar to fibrous.

4. Conclusions

Based on performed tests of the mechanical properties (R_m , A_5 , HB and KCV) and microstructural tests of the AlSi9Mg alloy after refining and modification treatments it has been confirmed that:

- the most beneficial addition of the inoculant, with respect to the mechanical properties, amounts to 0.06% Sr of mass of metallic charge, while the alloy after modification with the same amount of strontium has featured the highest tensile strength $R_m=173$ MPa, the elongation $A_5=5.1\%$ and the hardness 54 HB, and the highest impact strength $KCV=70$ kJ/m²,
- in result of modification with 0.06% Sr of mass of metallic charge it has been observed increase of the tensile strength R_m and increase of the elongation A_5 with more than 59%, the impact strength KCV with about 106%, maintaining the hardness HB at unchanged level comparing to the alloy after the refining treatment,

- increase of the elongation and the impact strength, while maintaining the same level of the hardness, results from the most advantageous form of the eutectic mixture α +Si and the phase α .

Performed investigations have shown that metallurgical treatments suitably performed at the stage of preparation of liquid alloy can enable production of casings of the pumps with considerably higher strength, fulfilling requirements of the PN-EN 1706:2011 standard.

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