ARCHIVES
of
FOUNDRY ENGINEERING

ISSN (1897-3310)
Volume 15
Issue 1/2015

105 – 108

19/1

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

Effect of Sr and Sb Modification on the Microstructure and Mechanical Properties of 226 Silumin Pressure Casts

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Received 27.06.2014; accepted in revised form 22.07.2014

Abstract

The work presents the effect of strontium and antimony modification on the microstructure and mechanical properties of 226 silumin casts. The performed research demonstrated that strontium causes high refinement of silicon precipitations in the eutectic present in the microstructure of the examined silumin and it significantly affects the morphology of eutectic silicon from the lamellar to the fibrous one. Sr modification also causes an increase of: the tensile strength „R_m" by 12%; the proof stress „$R_{p0,2}$" by 5%; the unit elongation „A" by 36% and the hardness HB by 13%. Antimony did not cause a change in the microstructure of the silumin, yet it caused an increase in R_m and HB by 5%, in $R_{p0,2}$ by 7% and in A by 4%.

Keywords: Theoretical basics for casting processes, Pressure casting, Modification, Mechanical properties

1. Introduction

The works [1-3] present the results of the investigations of the effect of selected technological conditions for the preparation and casting of 226 silumin on the course of its crystallization and obtained structure. The examined technological conditions were:: the soaking time „τ_s" and the soaking temperature „t_s" in a holding furnace, as well as the amount of the introduced Sb and Sr modifiers. The examinations were implemented under the production conditions of The Innovative and Implementation Enterprise Wifama-Prexer Limited. For examining the crystallization process of 226 silumin, the thermal and the derivative analysis (TDA) were applied. The TDA method is also used for investigating the crystallization process of iron, copper, magnesium and cobalt alloys [4-7]. Independently of the applied technological conditions for the preparation and casting of 226 silumin, the TDA curves show three phase crystallization thermal effects. They are the successive effects of the crystallization of the primary phase α, the ternary eutectic $\alpha+Al_9Fe_3Si_2+\beta$ and the quaternary eutectic $\alpha+Al_2Cu+AiSiCuFeMgMnNi+\beta$. The TDA tests showed the effect of the technological conditions for the preparation and casing of 226 silumin on the temperature values of the beginning and end of the transformations occurring in this alloy. Increasing both the soaking time and the soaking temperature in the holding furnace causes a decrease of the crystallization end of the eutectics present in the microstructure of 226 silumin. This is probably connected with the increase in the amount of impurities in the liquid silumin soaked in the holding furnace, as a result of its increasing contact with the ambient air as well as its reactivity with the gases present in the air, together with the increase of the soaking temperature.

Introducing a modifier in the form of Sr causes a decrease of the temperature of the crystallization beginnings of these eutectics. Strontium introduced into the silumin binds the phosphorus in phase Sr_3P_2. The phosphorus present in silumins forms the phase AlP, which constitutes an active plate of the silicon crystallization. And so, after the Sr introduction, the liquid silumin has no silicon crystallization plates in the form of the AlP compound. As silicon is a component phase of both the ternary and the quaternary eutectic present in 226 silumin, in order to cause their crystallization, after introducing 226 silumin, we need higher overcooling. This causes a temperature decrease of the crystallization beginnings of both eutectics [8].

In the case of antimony modification, there is an increase of the crystallization end of the ternary eutectics. The introduction of Sb into the silumin causes intense phosphorus precipitation in the gaseous form. Antimony also causes the formation of the AlSb compound of a higher density, which makes it drop to the bottom of the crucible and causes the gas cavities and the Al_2O_3 oxide being pushed to the mirror of the liquid metal. And so, we can generally assume that Sb causes degassing and purification of the silumin, which, in turn, may cause a temperature increase of the crystallization end of the ternary eutectic $\alpha+Al_9Fe_3Si_2+\beta$.

Neither of the examined technological factors of the preparation and casting of 226 silumin causes systematized changes in the cooling rate of alloy „K".

The microstructure tests were performed with an ATD-10PŁ tester [9]. Regardless of the applied technological conditions, we obtained analogous microstructures of the examined silumin in respect of the phases, which correspond to that presented in the description of the TDA tests. For all the non-modified silumins, similar microstructures were obtained also in regard to the morphology. The latter consists of dendrites of phase α and the following eutectics: ternary $\alpha+Al_9Fe_3Si_2+\beta$ and quaternary $\alpha+Al_2Cu+AiSiCuFeMgMnNi+\beta$, in which phase β has a lamellar form. The introduction of 0.3% Sr into the silumin causes a change in the morphology of phase β present in the eutectics from the lamellar to the fibrous one, at the same time, causing refinement and decrease in the distance between the Si lamellae in the eutectics. A smaller amount of modifiers did not assure a full modification effect. The introduction of 0.1% Sr caused a decrease in the size of the Si lamellae in the eutectics and a decrease in the interfacial distance. An increase of the Sr concentration by 0.2% caused a partial change in the morphology from the lamellar to the fibrous one. Introducing 0.1% and 0.2% Sb did not affect the microstructure of the cast. The aim of this work is to examine the effect of the Sr and Sb modification of 226 silumin on the microstructure and mechanical properties of pressure casts.

2. Test methodology

The tests involved the use of 226 silumin was used. The range of the chemical composition of the examined silumin is presented in Table 1.

Table 1.
Chemical composition range of silumin

Chemical composition, %							
Si	Cu	Zn	Fe	Mg	Mn	Ni	Al
8.51 ÷ 9.28	2.08 ÷ 2.51	1.05 ÷ 1.09	0.75 ÷ 0.81	0.30 ÷ 0.33	0.19 ÷ 0.24	0.11 ÷ 0.14	residue

The silumin was melted in a gas-heated shaft furnace with the capacity of 1.5 tons. After the flushing, the silumin was deslagged and next transported to the holding furnace, where Sr and Sb modifiers were introduced one by one in the amount of 0.3%. After the modifier had been dissolved, the silumin was used to make casts of a roller blind casing lid. The dominating thickness of the cast wall equaled 2 mm. The casts were made with the use of a pressure machine with a cold horizontal pressure chamber. The metal in the furnace was refilled every hour. The casts were sampled for the time of one full hour every 10 min. After three refills of the holding furnace. We also made an analogous series of non-modified silumin casts. 3 samples for the strength test were cut out of each lid cast. The samples' section was rectangular with the dimensions of 2 mm/10 mm. This section is recommended by the standard for pressure cast strength tests [10]. The tensile tests were performed with the use of a testing machine Instron 3382, with the tension rate of 1 mm/min. The tensile test determined the following: the tensile strength R_m, the proof stress $R_{p0.2}$ and the unit elongation A.

The hardness HB tests were conducted by means of a Briviskop HPO-3000. The applied ball's diameter was d=2.5 mm and the load was 613 N.

Tests of the microstructure of the pressure casts were also performed with the use of an optical microscope Eclipse MA200 by Nikon. The microsections were etched with 4% HF aqueous solution.

3. Test results

Table 2 shows the results of the examinations of the basic mechanical properties of 226 silumin.

Table 2.
Basic mechanical properties of 226 silumin pressure casts

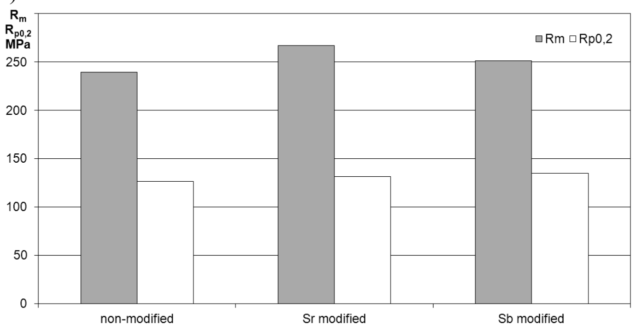
Siluminu state	Mechanical properties			
	R_m, Mpa	$R_{p0,2}$, MPa	A, %	HB
Non-modified	239	126	2.5	102
Sr-modified	267	132	3.4	115
Sb-modified	251	135	2.6	107

The tests conducted within the frames of this work did not show any effect of the soaking time of 226 silumin in the holding furnace on its basic mechanical properties. And so, the values of the examined mechanical properties of both the non-modified and Sr and Sb-modified silumin constitute a mean value for all the examined soaking times after three refills of the holding furnace.

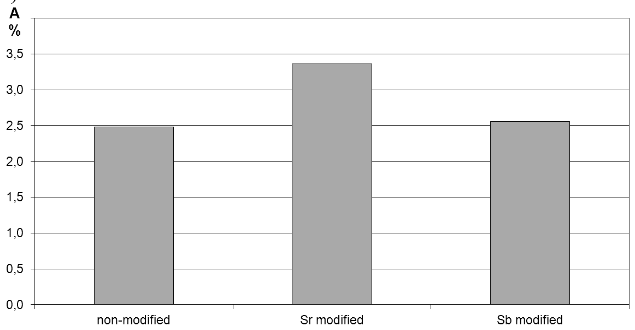
226 silumin is described in the DIN standard [11]. Its equivalent in the Polish standard [10] is silumin AlSi9Cu3(Fe). According to the standard [10], the basic mechanical properties of the pressure casts of the examined non-modified silumin equal: R_m = 240 MPa, $R_{p0.2}$ = 140 MPa, A < 1% and HB = 80. The tested values $R_{p0,2}$; A and HB for the non-modified silumin (Tab. 2) diverge from those given in the standard, especially in the case of the unit elongation A. The examined value of A of the non-modified silumin is over twice as high as the value given in the standard. The introduction of both Sr and Sb into the silumin

caused an increase of both its strength and plastic properties. The differences in the examined properties of the non-modified silumin and the one after modification are presented in Figures 1(a-c).

a)



b)



c)

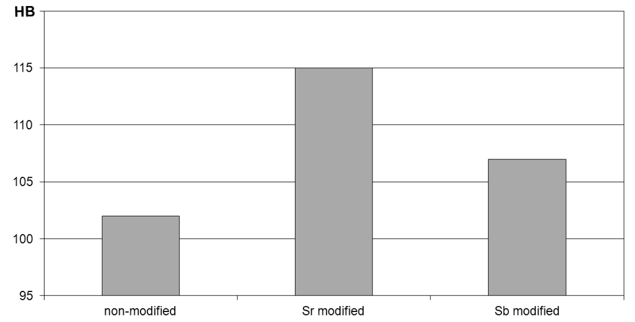
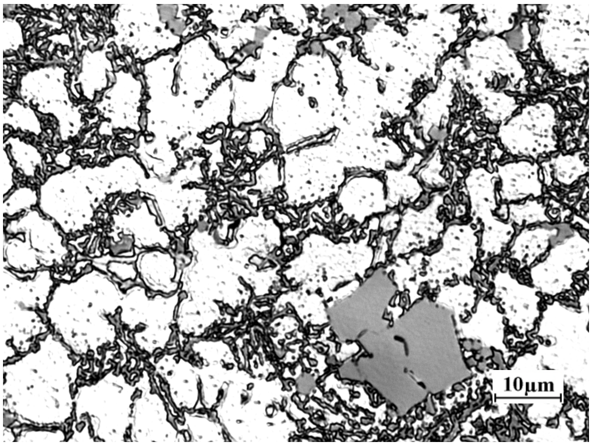


Fig. 1 (a-c). Comparison of examined properties: R_m (a); $R_{p0.2}$ (a); A (b) and HB (c) of 226 silumin – non-modified and modified with Sr and Sb

Table 2 and Figure 1 suggest that the highest values of R_m; A and HB were obtained for the 226 silumin modified with strontium, whereas the antimony modification caused a higher increase in the proof stress $R_{p0,2}$ than in the case of the Sr modification. From the presented data we can infer that Sr modification causes an increase of: R_m by 12%; $R_{p0,2}$ by 5%; A by 36% and HB by 13%. Sb modification caused an increase of R_m and HB by 5%; $R_{p0,2}$ by 7% and A by 4%. The high increase of the proof stress and the significant increase of the tensile strength and the HB hardness after the Sr modification point to the validity of applying this procedure in pressure casting.

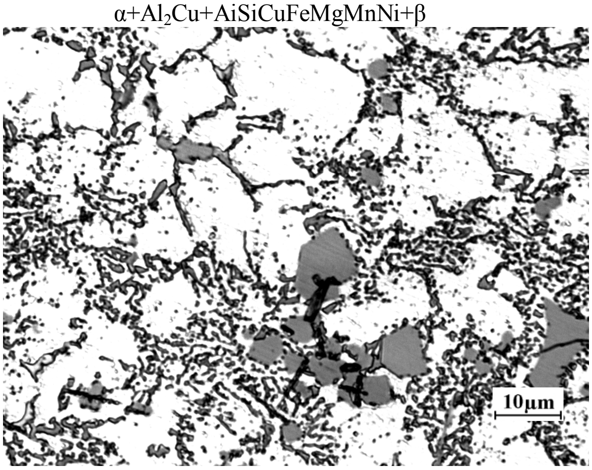
Figure 2 (a-c) shows the microstructure of the examined 226 silumin - non-modified and after Sr and Sb modification.

a)



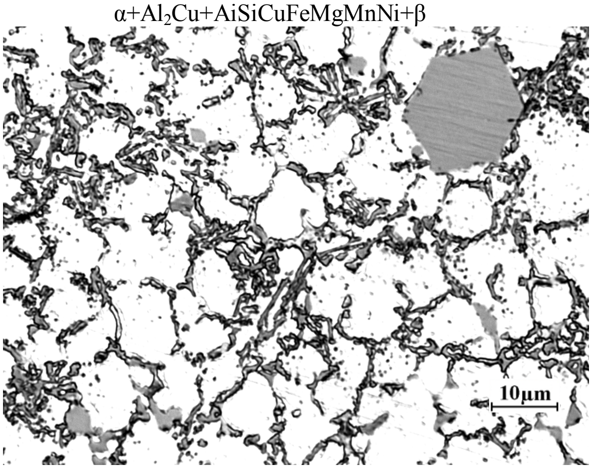
Microstructure: α, α+$Al_9Fe_3Si_2$+β, α+Al_2Cu+AiSiCuFeMgMnNi+β

b)



Microstructure: α, α+$Al_9Fe_3Si_2$+β, α+Al_2Cu+AiSiCuFeMgMnNi+β

c)



Microstructure: α, α+$Al_9Fe_3Si_2$+β, α+Al_2Cu+AiSiCuFeMgMnNi+β

Fig. 2 (a-c). Representative microstructures of 226 silumin pressure casts: non-modified (a), after Sr modification (b) and after Sb modification (c)

The data presented in Fig. 2a suggest the presence of the primary phase α and the eutectics of high silicon dispersion in the lamellar form, in the microstructure of the non-modified silumin. The strontium modification (Fig. 2b) caused an even higher refinement of the eutectic silicon and a significant change of its morphology into the fibrous one. Introducing antimony into the silumin did not assure significant changes in its microstructure. All the presented microstructures shown in Fig. 2 also contain Si precipitations with the morphology close to the faceted one. Precipitations of this type generally occur as a primary phase in hypereutectic silumins. In the examined hypoeutectic 226 silumin, their presence proves a highly non-equilibrium course of its crystallization, caused by the highly intense collecting of heat from the thin-walled cast by the pressure casting die. Phase α, crystallizing with high overcooling, causes the Si atoms to be pushed to the liquid and thus the latter's high oversaturation by this element. Faceted Si precipitations crystallize from the oversaturated liquid, bordering on the dendrites of phase α.

4. Conclusions

From the data included in the work we can draw the following conclusions:

- Sr modification causes a significant refinement of eutectic Si precipitations in 226 silumin and a large change of their morphology from the lamellar to the fibrous one,
- Strontium also causes a significant increase of the strength properties of pressure casts,
- Sb modification does not cause changes in the microstructure of the examined silumin,
- Antimony causes a slight increase in R_m; A and HB as well as a significant increase of $R_{p0,2}$ of the examined pressure casts.

Acknowledgements

The project was financed from the means of the National Centre for Research and Development in the years 2013-2014 as project UDA-POIG.01.04.00-10-079/12.

References

[1] Szymczak, T., Gumienny, G. & Pacyniak, T. (2014). Effect of the Hold Time and Temperatureon Characteristic Quantities of TDA Curves. *Archives of Foundry Engineering*. 14(1), 113-116.

[2] Gumienny, G., Szymczak, T. & Pacyniak, T. (2014). Effect of Modification on Characteristic Values of TDA Curves. *Archives of Foundry Engineering*. 14(spec. 1), 91-96.

[3] Szymczak, T., Gumienny, G. & Pacyniak, T. (2014). Selected Aspects of Nitrogen Refinement of Silumin 226. *Archives of Foundry Engineering*. 14(3), 99-102.

[4] Pietrowski, S., Pisarek, B., Władysiak, R., Gumienny, G. & Szymczak, T. (2009). TDA curves of metals alloys and the control of their quality. In Szajnar J. *Advances in Theory and Practice Casting*. Katowice – Gliwice, PAN. 345- 377.

[5] Pisarek, B.P. (2013). Model of Cu-Al-Fe-Ni Bronze Crystalization. *Archives of Foundry Engineering*. 13(3), 72-79.

[6] Rapiejko, C., Pisarek, B., Czekaj, E. & Pacyniak, T. (2014). Analysis of the Crystallization of AZ91 Alloy by Thermal and Derivative Analysis Method Intensively Cooled in Ceramic Shell. *Archives of Foundry Engineering*. 14(1), 97-102.

[7] Kacprzyk, B., Szymczak, T., Gumienny, G. & Klimek, L. (2013). Effect of the Remelting on Transformations in Co-Cr-Mo Prosthetics Alloy. *Archives of Foundry Engineering*. 13(3), 47-50.

[8] Pietrowski, S. (2001). Silumins. Lodz: Technical University of Lodz publisher.

[9] Pietrowski, S., Walczak, W., Pisarek, B. & Władysiak, R. (2011). Possibilities of obtaining and controlling high-quality pressure castings. *Archives of Foundry Engineering*. 11(3), 125-142.

[10] PN-EN 1706:2011. Aluminium and aluminium alloys. Castings. Chemical composition and mechanical properties.

[11] DIN 1725-2:1986-02. Aluminium alloys, casting alloys; sand casting, gravity die casting, pressure die casting, investment casting. Katowice – Gliwice, PAN