ARCHIVES of FOUNDRY ENGINEERING

ISSN (1897-3310)
Volume 9
Issue 4/2009

225 – 232

41/4

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

Plaster mould casting process of AlSi11 alloy

R. Władysiak* M. Pawlak
Department of Materials Technologies and Production Systems, Technical University of Lodz
1/15 Stefanowskiego Street 90-924 Lodz, Poland
* Corresponding author. E-mail address: ryszard.wladysiak@p.lodz.pl

Received 24.06.2009; accepted in revised form 06.07.2009

Abstract

The paper presents the results of the crystallization and cooling process of AlSi11 silumin in the plaster mould with TDA method and describes the impact of the preparation of plaster mould and liquid silumin on received microstructure and quality of casting. The effect of the pouring temperature of silumin on porosity and filling of mould cavity was investigated. The nature and rate of change of temperature in casting and the formation of the microstructure was shown by means thermal and derivative curves. Through the use of control samples in range of a thickness of 0.5 ÷ 4 mm confirmed the possibility of obtaining thin-walled silumin castings in pre-heated before plaster moulds. It has been proved that changing the parameters of pre-treatment moulds of gypsum, the pouring temperature and modification of silumin you can control the crystallization process, obtained microstructure and properties Rm, R_{P02} and HB.

Key words: Innovative materials and casting technologies, Gypsum casting process, Silumin, TDA method.

1. Introduction

Casting in plaster moulds is one of the methods for obtaining accurate castings made of alloys of Al, Zn, Cu and Mg with a mass of several grams to 150 kg. Using the weight of gypsum and ensuring adequate transmission or vacuum forms in the course of pouring it can be obtained wall thickness of casting less than 1 mm [1].
The gypsum moulds are widely used in dentistry, jewelery, and in modern methods of rapid prototyping [2]. Currently in the Department of Materials Engineering and Production Systems University of Lodz studies are conducted on optimizing the technology of gypsum mould and research of casting alloys with using of TDA method [3-7].
The purpose of this study was to examine the process of crystallization and cooling of silumin with TDA method, casting microstructure obtained in the plaster mould, and to explore the impact of the process of pre-forms preparation of mould and of silumin and also the ability of filling of mould cavity casting, porosity and mechanical properties: Rm, R_{P02} and HB of casting.

2. Experimental

The study used near-eutectic standard silumin AlSi11 content of silicon in the range of 11 ÷ 13% and on allowable pollution: Fe in the amount of 0.7 ÷ 0.8%, Mn - 0.5%, Cu - 0.8% and Mg - 0.3%. Silumin was melted and overheated in the range 650 ÷ 800 °C in the graphite crucible of induction caster INDUTHERM VC-500D in an atmosphere of argon.
Modification of silumin was made by persistent modifiers Sr, Ti B, which input into the crucible before melting with weighted metallic charge together. The analysis of crystallization process and cooling of AlSi11 silumin was made on the station that view was shown on a scheme in Figure 1.

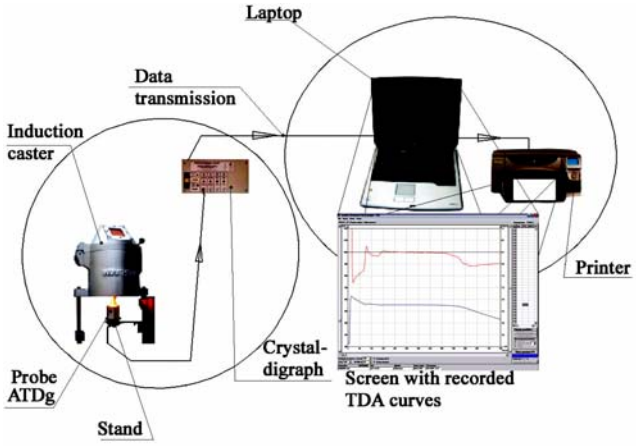


Fig. 1. Scheme of research station with using of TDAg probe

Cast silumin studied in the TDAg probe, which is drawn in Figure 3.

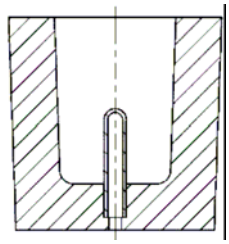


Fig. 2. TDAg probe [6]

This probe is made of gypsum "Prima-Cast" using a specially designed metal matrix. Probe after bounding of plaster was removed from the matrix and subjected to heat treatment immediately prior to the liquid metal pouring. In Figure 3 is shown the diagram process of heat treatment of plaster.

The plaster mixture "Prima-Cast" formulated in the vacuum blender "St. Louis" with distilled water is placed on water-gypsum proportion 0.4. Prepared liquid plaster poured into the mass matrix in a vacuum conditions.

Plaster moulds for casting probes Rm and control strapes for testing shape mapping were made with using of lost wax patterns. Pouring its of the liquid metal takes place with using a vacuum during the process.

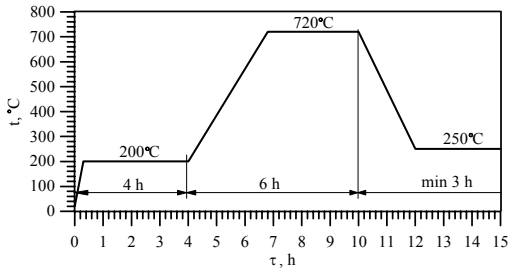


Fig. 3. Thermal treatment scheme of plaster moulds and probes

The design of the mould allows for the simultaneous pouring of control samples consisting of three strapes with a thickness of 0.5, 0.8 and 4 mm.

Mechanical property tests were carried out adequately: Rm and R_{P02} - on the Instron strength machine, and hardness HB – on Briviskop using the parameters for measuring 2.5/62.5/30.

3. Results

Figure 4 gives curves of TDA and the characteristic points of the crystallization process of AlSi11 silumin casted from temperature 775 °C in gypsum probe preheated to 250 °C. The data shows that silumin crystallization begins at a temperature of tA = 572 °C with preeutectic nucleation of α phase. Rising of its dendrites causes appearing the maximum thermal effect in temperature tB = 573 °C.

Further crystallization of α (area ABCD) increases the concentration of silicon in liquid metal at the other with decreasing temperature to tD = 565 °C creates good conditions to initiate crystallization of eutectic mixture α + β (Area DEFG). Crystallization of the silumin ends at a temperature tG = 517 °C.

Figure 5 presents TDA curves of AlSi11 silumin modified with strontium, titanium and boron pouring with temperature 775 °C. Its crystallization similarly to unmodified silumin (Fig. 4) consists of two stages: preeutectic α phase crystallization and the subsequent eutectic α + β mixture. The comparison of TDA curves (Fig. 4 and 5) shows that the modification siluminu by Sr, Ti and B increases the temperature likwidus tA = 577-572 = 5 °C and causes a small reduction in the beginning of crystallization temperature of α + β silumin eutectic tD = 565-563 = 2 °C.

These effects confirm the validity of the modification and they are caused by delivery pads of α phase crystallization: TiB_2 and Al_3Ti. Their presence reduces the liquid metal superfusion required for nucleation of phase α and thus recorded liquidus temperature is higher than without the modification. Secondly, addition of strontium to liquid alloy bonds the phosphorus as a Sr_3P_2 compound and thus eliminates the ALP compound - pads of eutectic nucleation. Consequently the superfusion of temperature necessary to initiate the crystallization of α+β eutectic increases. It's reflected on the TDA curves as lower tD temperature.

Figure 6 presents TDA curves of AlSi11 silumin pouring into the probe at a temperature of 725 °C. The research shows that the liquid is characterized by overheating equals 167 °C. The value is relatively high because together the reduction of pouring temperature from t_p 800 °C to 725 °C took place lowering the liquidus temperature of silumin tA from 572 to 558 °C. This is probably due to reduction of heat entering the liquid metal in addition to the pre-heated to a temperature of 250 °C probe. Consequently, it increases the speed of cooling of liquid silumin and makes greater the value of superfusion Δt. Crystallization process described on the curves also includes these thermal effects, which was shown in Figures 4 and 5. Here they occur in the lower ranges of temperature, adequately: α phase crystallization (area ABCD) t = 558 ÷ 552 °C and α + β eutectic (area DEFG) t = 552 ÷ 516 °C.

In Figures 7 and 8 presents the pouring temperature t_p effects on characteristic TDA points of temperature and time of unmodified silumin's crystallization.

From data shown in Figure 7 results that with lowering the pouring temperature takes place the reducing the temperature of both periods of the crystallization: of the preeutectic α phase and also of the α+β eutectic mixture. Solidus temperature has the smallest change in the tested range of silumin. It is the ΔtG= 12°C.

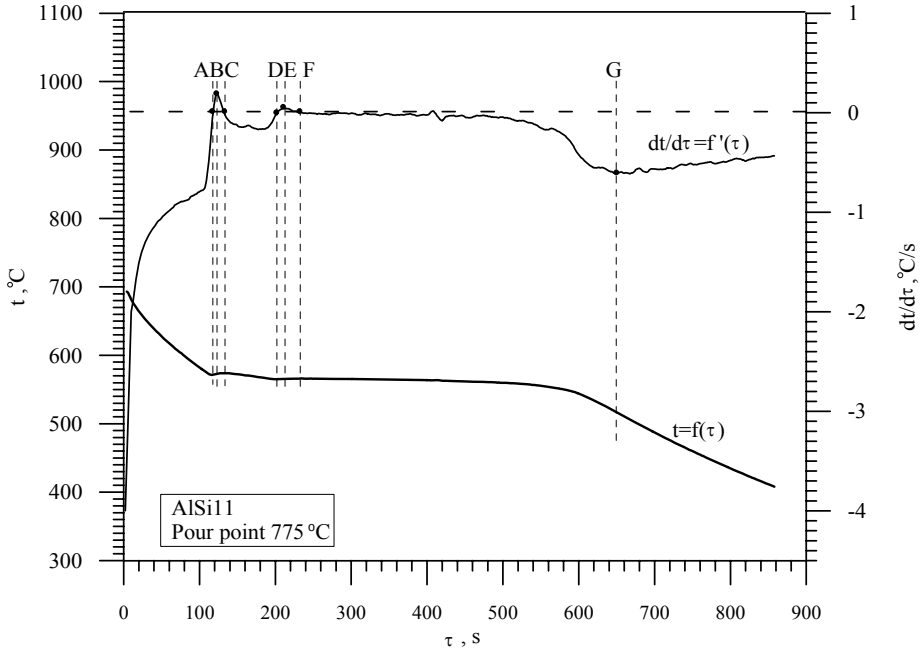
The data shown in Figure 8 shows that the reduction of pouring temperature of silumin from 800 ÷ 725 °C reduces by 7 s the crystallization of eutectic α+β and by14 s crystallization all of the silumin's sample.

The comparison of the data presented in Figures 7 and 8 shows that the change of pouring temperature of silumin in tested field much more strongly affected on the temperature of the characteristic points of TDA curve than on their time.

Figure 9 presents the results of research silumin's microstructure casted in gypsum ATDg probe. The data shows that the microstructure consists preeutectic crystallized α phase dendrites, large quantities of α+β eutectic, and the few existing inclusions of AlFeMnSi phase (c, d). In addition, the observation shows that reducing the pouring temperature increases fragmentation of the microstructure while growth of the temperature promotes rystallizing of granular silicon grains in the microstructure of silumin. The modification with Sr, Ti, B has a change of the morphology of β phase from plates to the fibrous one and sharply revealed preeutectic dendrites of α phase.

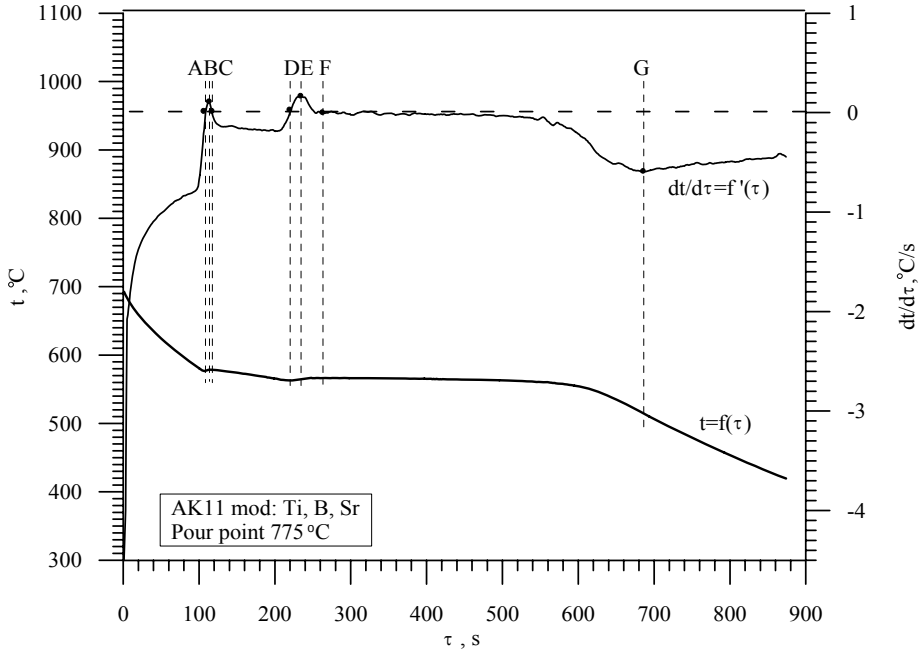
Figure 10 presents the results of testing the impact of pouring temperature of silumin in the range tp = 650 ÷ 800 °C and the thickness of the casting wall for shape mapping and a porosity of casting.

The data demonstrate that the casting of the control samples in terms of temperature tp = 725 ÷ 800 °C in the form of gypsum initially preheated to a temperature of 250 °C allows to obtain a full representation of the shape of the casting with a thickness of 4 mm, 0.8 mm and 0 , 5 mm. Reducing the temperature to tp = 650 °C causes a misrun casting of sample with a thickness of 0.5 mm. From observation of the cross-section of TDA samples results that silumin has a porosity dispersed on the whole section and its size increases with increasing pouring temperature of silumin.



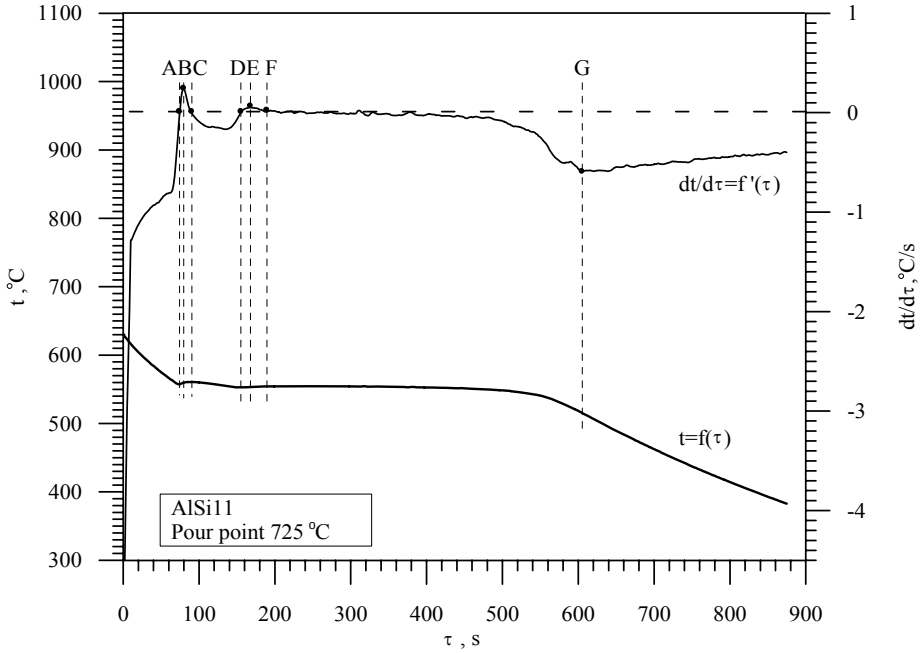
	τ, s	t, °C	dt/dτ, °C/s
A	148	572	0
B	153	573	0,2
C	162	574	0
D	232	565	0,1
E	243	565	0
F	262	566	0
G	679	517	-0,6

Fig. 4. TDA curves of AlSi11 silumin poured from temperature 775°C



	τ, s	t, °C	dt/dτ, °C/s
A	124	577	0
B	128	578	0,1
C	132	578	0
D	235	563	0,2
E	250	564	0
F	268	565	0
G	699	516	-0,6

Fig. 5. TDA curves of AlSi11 silumin modyfied with Sr, Ti i B poured from temperature 775°C



	τ, s	t, °C	dt/dτ, °C/s
A	90	558	0
B	96	559	0,2
C	106	561	0
D	171	552	0,1
E	184	553	0,1
F	203	554	0
G	620	508	-0,5

Fig. 6. TDA curves of AlSi11 silumin poured from temperature 725°C

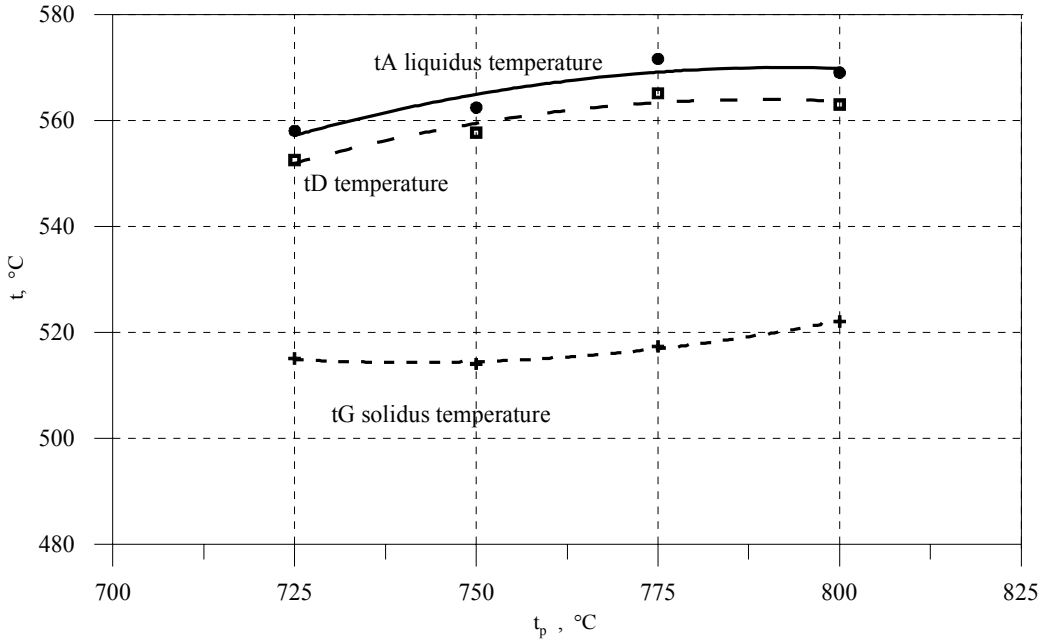


Fig. 7. Effect of silumin pouring temperature on temperture of TDA characteristic curve points

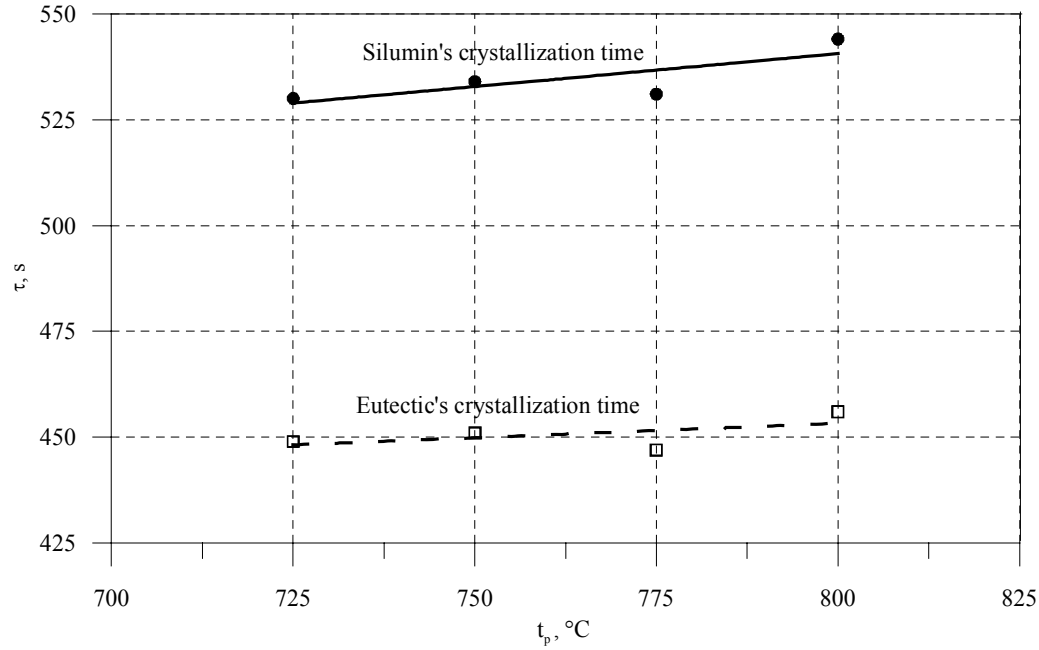


Fig. 8. Effect of silumin pouring temperature on time of TDA characteristic curve points

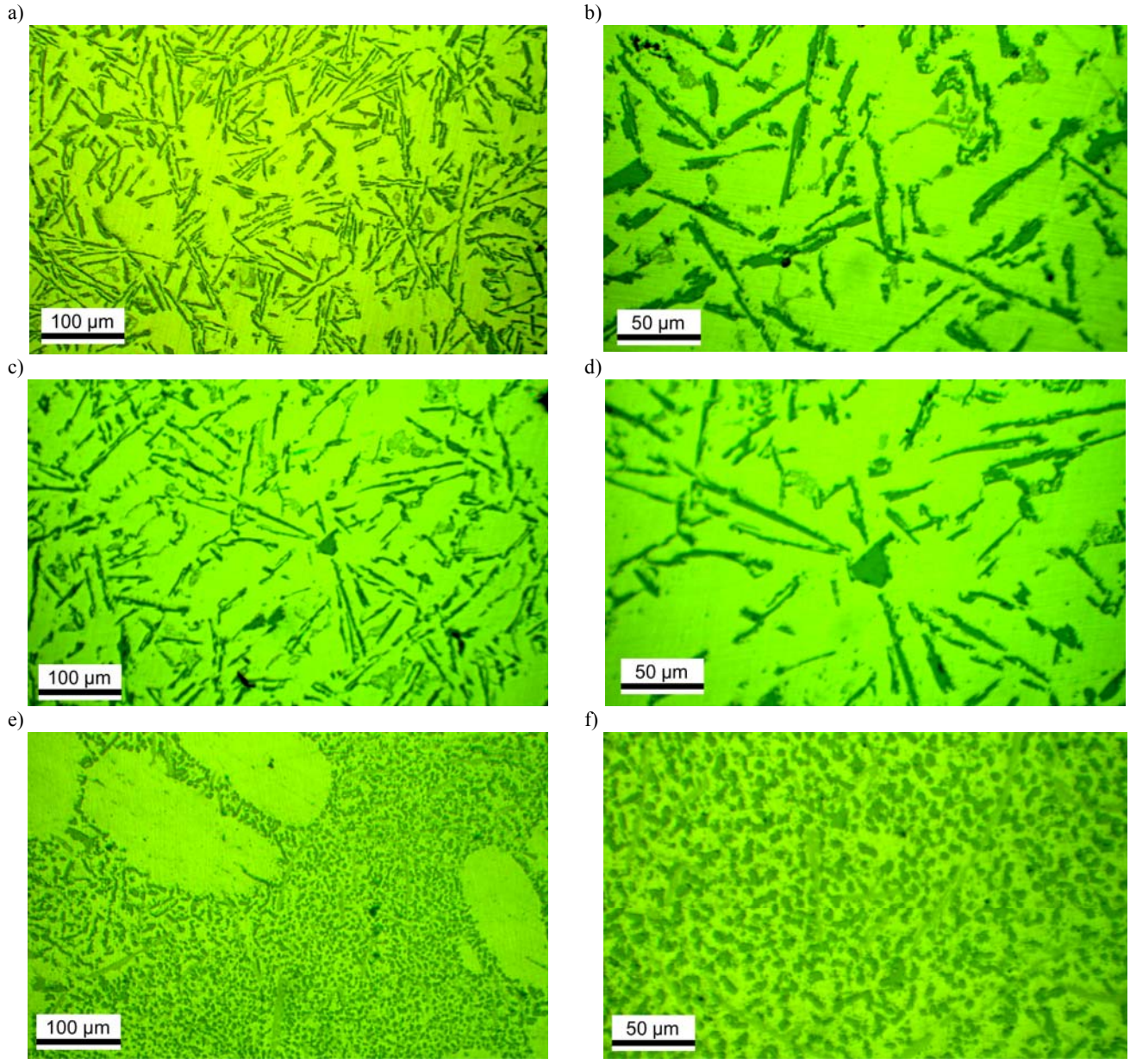


Fig. 9. Microstructure of AlSi11 alloy poured into the ATD sample with various pour point:
a,b) – t_p= 725 °C; c,d) t_p= – 800 °C; e,f) t_p= – 775 °C modified with Sr, Ti and B.
Microstructure consists dendrites of α phase, plates or fibres (e, f) of α+β eutectic and AlFeMnSi phase

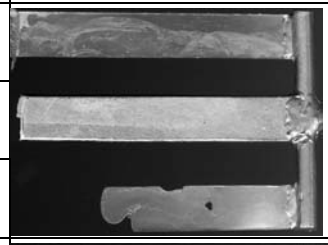
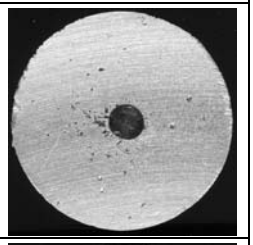
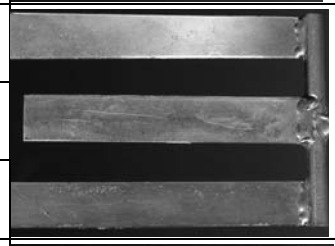
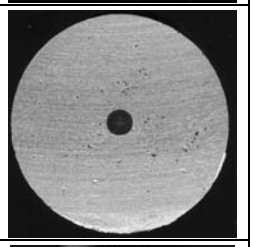
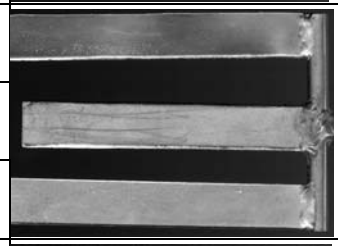
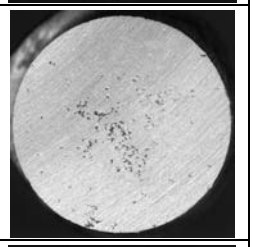
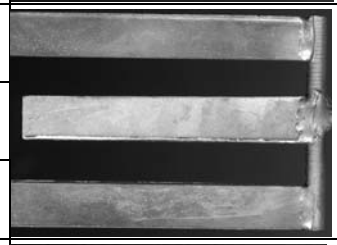
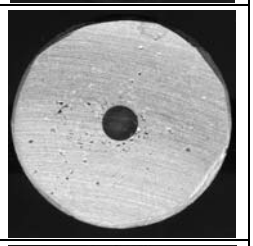
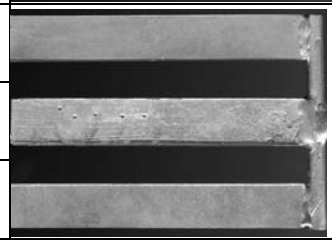
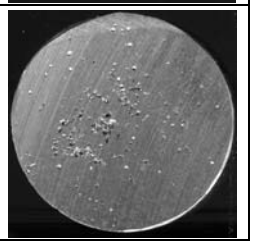
L.p.	t_p, °C	Samples		Samples
		g, mm	Shape mapping	Porosity
1.	650	4		
		0,8		
		0,5		
2.	725	4		
		0,8		
		0,5		
3.	750	4		
		0,8		
		0,5		
4.	775	4		
		0,8		
		0,5		
5.	800	4		
		0,8		
		0,5		

Fig. 10. Effect of pouring temperature and thickness of casting wall on shape mapping of casting

Figure 11 presents the results of testing the effect of pouring temperature of the silumin on mechanical properties: Rm, Rp_{02} and HB. The research shows that reducing the temperature of t_p in the range of 650 to 800 °C causes an increase in property values in the range adequately: Rm: 112 ÷ 129 MPa, Rp_{02}: 81 ÷ 92 MPa and HB: 53 ÷ 67. In addition, the tensile strength Rm was characterized by a large variance of values. The reason probably was pores concentration in the part of the strength samples.

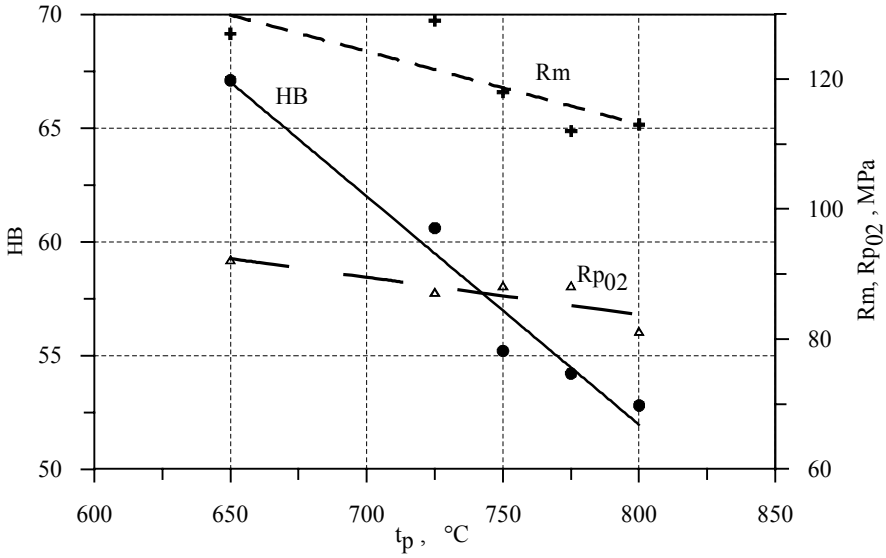


Fig. 11. Effect of pouring temperature on mechanical properties: Rm, Rp_{02} and HB

4. Conclusions

The following conclusions result from described examinations:

- an increase of pouring temperature of silumin between 725 to 800 ° C increases the pre-eutectic crystallization, extends the entire crystallization of silumin and slightly increases of the solidus and liquidus temperature,
- modification of the siluminu using Ti, B and Sr increases the liquidus temperature by 6 ° C, decreases the solidus temperature by 3 ° C and causes fragmentation of the silumin microstructure by increasing the amount of α phase dendrites and fibrous α + β eutectic crystallization,
- the temperature equal to 725 ° C is the optimal pouring point of liquid AlSi alloy for gypsum moulds . Obtained castings show a complete mould cavity filling and good dimensional accuracy and clean the surface of the wall thickness 0.5÷4 mm,
- silumin casted in plaster mould has a low immediate tensile strength Rm while the temporary yield Rp_{02} = 87.9 MPa meet the requirements of Polish standards for castings produced in sand,
- with TDA method can control the crystallization process of AlSi11 alloy casted in the plaster moulds.

Acknowledgements

The work was made as a part of the research project No. N N508 3886 33 financed by funds for science in the years 2007-2010 by the Polish Ministry of Science and Higher Education

References

[1] L. Lewandowski: Materiały formierskie Akapit , Warszawa 1997
[2] H. Kaneshige: Molding of Cylinder Head Materials by the Lost-Wax Casting Process Using a Gypsum Mold, Mitsubishi Motors Technical Review, N°. 14 (2002) 56-59.
[3] M. Pawlak: Wpływ temperatury i czasu wygrzewania na właściwości związanej gipsowej masy formierskiej. Polska metalurgia w latach 2002-2006. Komitet Metalurgii PAN, AKAPIT, Kraków (2006), 287-293.
[4] M. Wiktorski, M. Pawlak, Z. Niedźwiedzki: Badanie derywatograficzne kompozycji gipsowych stosowanych na formy gipsowe w odlewnictwie precyzyjnym. Archiwum Odlewnictwa, PAN, 2004, Vol. 4, N° 13, 225-232.
[5] M. Pawlak, Z. Niedźwiedzki: Dilatometric studies of plaster sandmix in raw and heat treated state, Archives of Foundry, Polish Academy of Science, 2008, Vol. 3, N° 8, 145-148.
[6] B. Pisarek, M. Pawlak: The thermal analysis and derivative bronzes cast to plaster moulds, Archives of Foundry Engineering, Vol. 9, Issue 3, July-September 2009, 159-168
[7] R. Władysiak: Research of Crystallization kinetics and Dynamics as basis of silumins quality assessment. Acta Metallurgica Slovaca, Slovak Academy of Science in Košice, 2/2002 (2/2), Ročnik.8, p. 175-181