A R C H I V E S
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F O U N D R Y E N G I N E E R I N G

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

ISSN (1897-3310)
Volume 9
Issue 3/2009

205 – 210

37/3

Water mist effect on cooling process and microstructure of silumin

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Received 20.04.2009; accepted in revised form 24.04.2009

Abstract

The paper presents the results of the process of crystallization and cooling of the AlSi11 silumin and temperature distribution in the wall of iron and bronze research casting die in the temperature field of 750 to 100°C in casting of the silumin with use of water cooling mist in the air at a pressure of 0.30 to 0.40MPa and the water from 0.35 to 0.45MPa. Showing the nature and rate of change of temperature in die casting and the formation of temperature gradient on the thickness of the die casting wall in the direction of the nozzle surface of the outer wall of the cooling die casting. Using derivation curves and regression equations there has been compared: the mean and instantaneous rates of crystallization and cooling cast in values of 750 ÷ 200°C. In addition, there are presented the differences arising from the microstructure change of the die's type and thickness of its walls, the thickness of cast and the fact of using cooling water mist. The conduct of the changes of the hardness of the cast as a result of the applied cooling method of the die casting. It has been shown that the use of water mist with a variability of the die's wall thickness in the cooling zone gives control of the crystallization process, microstructure and mechanical properties of the final silumin cast.

Keywords: Innovative materials and casting technologies, Cooling, Water mist, Die casting, Silumin

1. Introduction

The results represent a continuation of studies on quality improving of the casts making by die casting process to shorten the cycle of the process and improving the silumin casts' properties, that were casted in metal [1-3].

The objective of the study was to analyze the process of heat exchange and intensyfication of cooling of both the casting die and the cast in a specific area of crystallization temperature and cooling in a solid cast, and to research the possibility of crystallization controlling and cast microstructure obtained by means of cooling water mist. Based on previous research in the production of silumin casts by low prossure technology to research selected silumin AlSi11 and casting die made of cast iron EN-GJL-200 [4]. Moreover in order to increase the impact of water mist on casted silumin the casting dies was made of cast iron (λ=42÷57 W/(m*K)) and another one made of aluminum bronze BA1055 (λ=82 W/(m*K)) with reduced thickness wall [5]. At present commonly used the cooling method of casting die rely on taking away the heat with compressed air stream aim towards the special preparated place of external surface of casting die. The air has smal efectiveness of heat transfer and it couses that cooling process with air is power-consuming.

The essence of achiving of high effectiveness of cooling with use of the water mist is taking the heat away as a result of droplets water evaporation on the cooled surface. This way is increases the heat transfer repeatedly.

Achievement of the goal consists in researching of self-cooling process of casting die on the laboratory test stand and describing what is the influence on the heat transfer process, silumin's microstructure and mechanical properties the following factors:

cooling with water mist, metal of casting die, wall thickness and the initial heating temperature of casting die.

2. Experimental

In picture 1 the test stand scheme for examinations of cooling intensity was shown. The investigations consist in casted samples of AlSi11 silumin which the temperature was 750°C and they shaped as a plate with dimentions ϕ 150 x 20 mm. The research casting die was initial heated up to 200, 300 and 400°C.

The die was being put on the stand (4) in heat-insulating shield (3) with the possibility of the directional heat transfer with the surrounding only by the bare surface of the bottom wall. This surface was being cooled with stream of the water mist pointed with the nozzle (7). It's examinated two kinds of die's material that both have the same diameter 154 mm and were made of: EN–GJL-200 cast iron with thickness 20 mm and the second one - BA1055 bronze with 4 mm of wall thickness.

The temperature of the die was being measured at the same time with K - type thermocouples (5) puted in her vertical axis of symmetry in interval 15 mm of its thickness. The recording of the temperature was being kept with automatic KD7 recorder of the Lumel company with the frequency 2 per second and the accuracy 0.1°C with use the recorders: Lumel KD7 (6) and Z-Tech Crystaldigraph PC-2T computer aided (9).

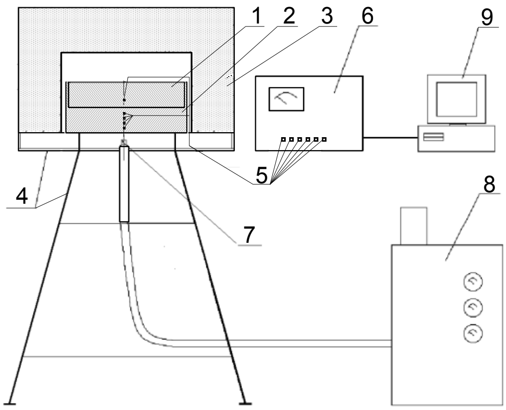

Fig. 1. Test stand scheme: 1 – cast, 2 – research casting die, 3 – heat-insulating shield, 4 – stand, 5 – thermocouples, 6 – temperature recorder, 7 – nozzle of cooling system, 8 – automatic cooling servo device, 9 – PC

The water mist was being generated in Automatic Cooling Servo (8). He lets to simultaneous dosing and spraying water in channel of the cooling system. Controlling cooling circumferences consisted in the change of the pressure of compressed air in the 0,20 to 0,45MPa range and of water from 0,25 to 0,50MPa. Demonstration stream of sprayed water and the starting cooling mist were shown in Figure 2. The investigations of influence of cooling on the microstructure and hardness were made adequately with use Opta-Tech otical microscope and a Briviscope with 2,5/62,5/30 test parameters. In this work the AlSi11 near-eutectic silumin was used. Its modification was made of strontium, titanium and boron.

Fig. 2. Stream of sprayed water (a) and water mist (b) obtained with use of designed rotary sprayer

3. Results

The paper examined the distribution of temperature in the cast and at the selected points of the researched casting die wall during the cooling process of the silumin cast with the use of cooling water mist at the air pressure from 0.30 to 0.40MPa and the water from 0.35 to 0.45MPa and in other case - without cooling.

Figure 3 presents the change in temperature and cooling rate of the iron cast and research casting die (Fig. 1) in normal conditions at the ambient temperature without additional cooling factors. The presented data show three main stages of the cooling process: 1 – cooling of the liquid silumin, 2 - α phase pre-eutectic crystallization (peak on the derivative curve) and then eutectic α + β, and 3 - cooling in the solid casting. Cast has reached a temperature of 200°C after 4630 s in this area at an average speed of 0,068°C/s. In addition, research shows that pre-heated casting die had 300 °C in every spot of the wall. After pouring the silumin, a temprature growth occurred, which reached the maximum of 516°C at the end of cast's crystallization. At the same time as the casting die was flooded, temperature gradient appeared. Recorded in 15 s the maximum temperature difference was 43°C and rapidly decreased to a value of 11 °C when the cristalization finished.

Figures 4 to 6 present respectively: the temperature distribution and cooling rate in cast and cast iron's die pre-heated to 200°C (Fig. 4,5) and 400°C (fig. 6). Water mist at the presure of 0,30/0,35MPa was used to cool it down. The data show that flooding metal into the casting die has increased its temperature by 30 to 110°C and also increased the temperature gradient in the wall. Due to the sudden temperature drop, the gradient raised even more when the cooling process started. Figure 5 shows that the temperature gradient in the casting die wall initially increased, reaching maximum in 13s and then declining. The calculated value of the average cooling rate in casting heated to up to 200°C is 1.32÷1.34°C/s at maximum speed, temporary 4÷5°C/s. Time of cooling to a temperature of 200°C varies from 373 to 382s. The comparison of the data presented in Figures 4 and 6 shows that the increase in pre-heated casting die from 200 to 400°C (Fig. 6) resulted in extension of: the process of silumin crystallization by 22 s and total time of casting cooling to a temperature of 200°C about 9s. Cooling speed change is, however, insignificant when compared to a total cristalization time in casting die that has not been pre-heated (Fig. 3). Thus, the use of water mist increases the cristalization speed and reduces the cooling many times. In contrast, increasing the initial casting die's temperature does only influence the cooling a little (cooling extends by 2,4%). It also illustrates the cooling rate of pre-heated to 400°C iron casting die that has been later coolled using water mist at the presure of 0,30/0,35MPa.

Figure 7 shows how the temperature changes in the function of time(nieprecyzyjnie). It also illustrates the cooling rate of pre-heated to 400°C iron casting die that has been later coolled using water mist at the presure of 0,30/0,35MPa.

Concluding from the presented data, the initial rapid phase of liquid silumin cooling develops a quick die's temperature growth to 612°C, which is even higher than liquidus temperature of the used silumin. Started then cooling of casting die rapidly receives heat causing fast crystallization of pre-eutectic α phase which is reflected first of inflection on the derivative curve. Following the crystallization of the α + β eutectic is much faster compared to samples casted in die made of cast iron (Fig. 3, 4, 6). It's ending the crystallization in time 130s with a maximum instantaneous rate of cooling 5.8°C/s. The linear regression equation set for a range of temperatures 750 ÷ 200°C shows that the average cooling rate of casting is 1.78°C/s and it is the highest among the surveyed cooling processes at the work. Also, cooling of the casting to a temperature of 200°C is the shortest, and is equel to 286s.

The analysis of casting die thermal curve shows that the temperature in the course of the thin wall of bronze die reflect stages its cooling and crystallization process of silumin cast. However, after 72 s the casting die stabilizes the temperature in the range 16÷21°C, although casting is during crystallization eutectic α + β, which ends in the 138s instantaneous rate of 5.6°C/s. The temperature is 200°C when the test reaches the casting 286 °C. This time is shorter by 25% compared to tests in siluminu cast iron kokili presented in Figures 4 and 6.

Figure 8 (a-f) presents the test-cast microstructure in research casting die of silumin unmodified and modified the Sr, Ti and B. The research shows that the microstructure consists of isolated pre-eutectic dendrites α phase (Fig. 8a ÷ f) and eutectic plates (Fig. a÷c) or fibrous (Fig. d ÷ f) α + β.

Shown in Figure 8a microstructure of silumin casted into cast iron's die without cooling is thick-lamellar. Both the size dendrites phase α and β plates phase often exceeds the value of 100μm. The cooling water mist parameters 0.30/0.35MPa resulted in the fragmentation of it several times (Fig. 8b). Silumin chilled cast in bronze die not (Fig. 8c) and after modification (Fig. 8d) indicates a further reduction in size of crystallizing phases.

From the drawings submitted 8e, f microstructures shows that reducing the thickness of the casting 20 to 10mm along used cooling with water mist intensified the cooling process of casting and the die leading to fragmentation of the largest and homogenization of silumin's microstructure.

In Figure 9 the effect of casting distance from the axis (the axis of the nozzle cooling) on the hardness HB is presented of silumin in cast iron die initially preheated to 400°C and chilled by water mist at a pressure 0.30/0.35MPa. The data demonstrate that the use of cooling water mist increased hardness of casting from 56 to 67 HB. From an analysis of the hardness in a direction perpendicular to the axis of the nozzle cooling shows that the use of cooling changes the sign of the hardness gradient. Cast mist chilled water hardness shows the greatest cooling in the vicinity of the point in the axis of symmetry of casting, while unchilled - at its outer edge.

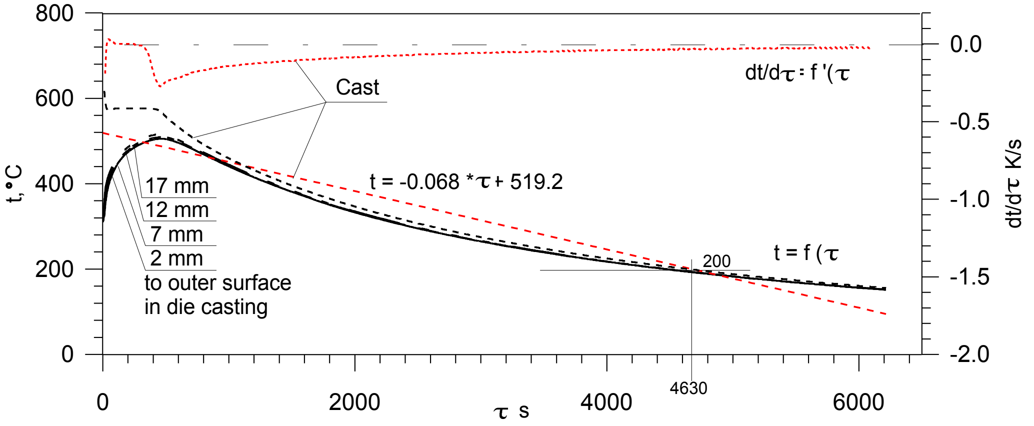

Fig. 3. Temperature and self-cooling rate of cast and casting die made of cast iron without cooling

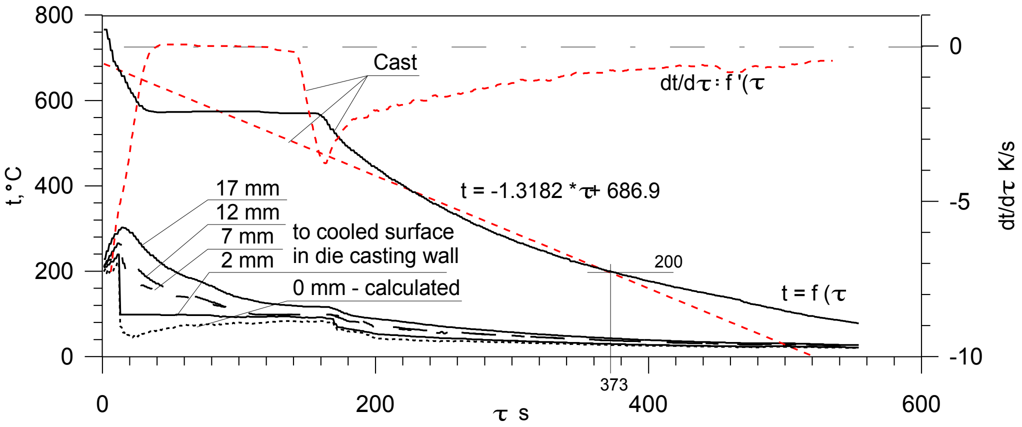

Fig. 4. The influence of time and distance from external surface of casting die on the temperature and cooling rate of cast and the die initial heated to 200°C and cooled with used of 0.30/0.35MPa water mist

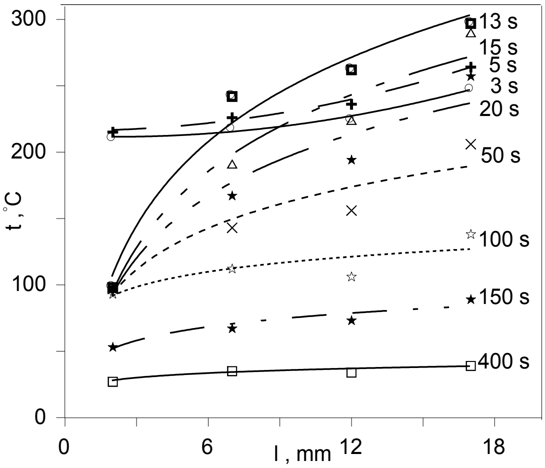

Fig. 5. The influence of distance from cooled surface and of cooling time on the change of temperature of die initial heated to 200°C and cooled with used of 0,30/0,35MPa water mist

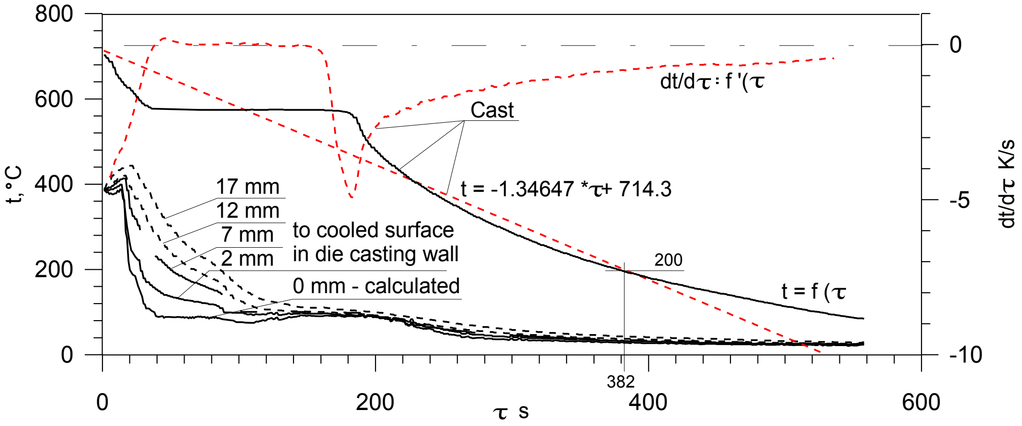

Fig. 6. The influence of time and distance from external surface of casting die on the temperature and cooling rate of cast and the die initial heated to 400°C and cooled with used of 0.30/0.35MPa water mist

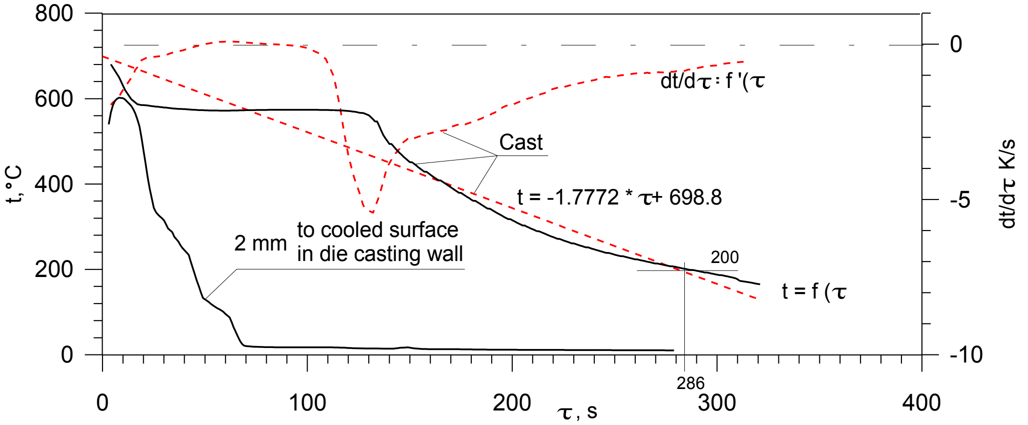

Fig. 7. The influence of time on the temperature and cooling rate of cast and the casting die made of bronze initial heated to 400°C and cooled with used of 0.30/0.35MPa water mist

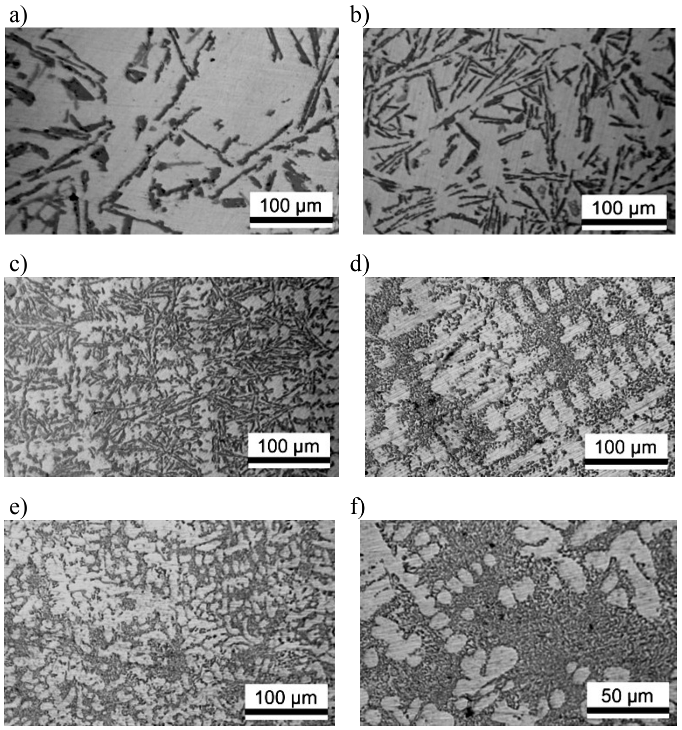

Fig. 8. Microstructure of AlSi11 silumin (α dendrites, α+β eutectic) unmodified (a,b,c) and modified with Sr, Ti, B (d, e, f), casted in casting die made of cast iron (a,b) and of bronze (c, d, e, f), without cooling (a) and cooled with water mist under pressure 0.35/0.30MPa (b, c, d, e, f). Wall thickness of the cast: 20 mm (a, b, c, d) and 10 mm (e, f).

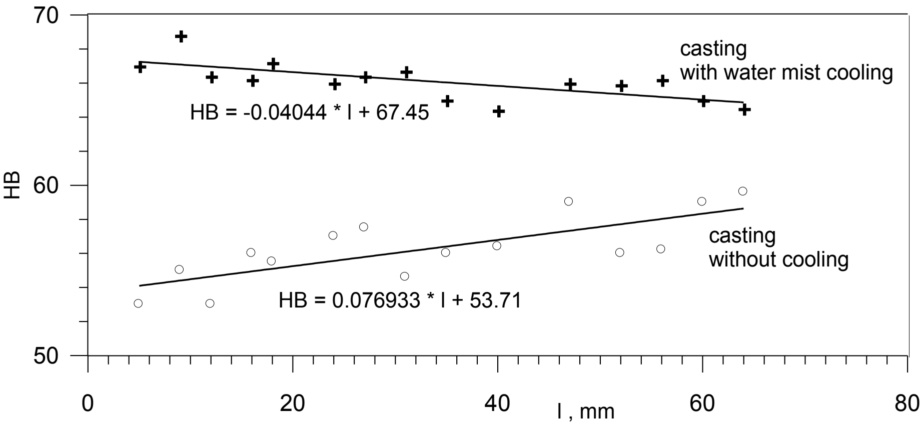

Fig. 9. The influence of distance from cast axis of symetry (axis of cooling nozzle) on brinell hardness of silumin casted into the cast iron's casting die initial heated up to 400°C and cooled with 0.30/0.35MPa water mist

4. Conclusions

The following conclusions result from described examinations:

- the change of material, wall thickness and temperature of initial heating of casting die chilled water mist allows to control the intensity of incoming heat casting die in the desired area and casting cooling and crystallization,
- the use of thin-wall casting die with increased thermal conductivity will increase the intensity of cooling water mist and reduces crystallization of silumin,
- cooling with water mist under pressure 0.30/0.35MPa of the sample increases the rate of crystallization and cooling silumin casting causing fine-granularity as a consequence of the homogeneity of microstructure of casting,
- cooling mist of water under pressure 0.30/0.35MPa as a result of improving the quality of cast microstructure allows to control and to increase hardness HB of casting.

References

[1] R. Władysiak: Zastosowanie mgły wodnej w procesie odlewania kół samochodowych, Archiwum Odlewnictwa nr 22, (2006), 552-561.

[2] R. Władysiak: Intensyfikacja procesu odlewania kokilowego kół samochodowych - Conference proceedings „Polish Metallurgy in Years 2002-2006", Comitee of Metallurgy, (2006), 359-366.

[3] R. Władysiak: Reengineering of permanent mould casting with lean manufacturing methods, Archives of foundry, v. 7, issue 3, (2007), 205-212.

[4] R. Władysiak: Water mist effect on heat transfer coefficient in cooling of casting die, Archives of foundry, v. 8, issue 3, (2008), 227-236.

[5] S. Wiśniewski, T. S. Wiśniewski: Wymiana ciepła, WNT (2000).