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R. WŁADYSIAK*

EFFECT OF WATER MIST ON COOLING PROCESS OF CASTING DIE AND MICROSTRUCTURE OF AlSi11 ALLOY

WPŁYW CHŁODZENIA MGŁĄ WODNĄ NA PROCES STYGNIĘCIA KOKILI I MIKROSTRUKTURĘ SILUMINU AlSi11

The paper presents the results of crystallization and cooling process of research casting die with use of water mist compressed under 0.20÷0.45 MPa. It's shown the nature of changes of the temperature in AlSi11 casting and in casting die wall using the thermal and derivative curves and regression models. It's presented the change of the temperature in the crystallization and cooling down process of research areas of casting which wall thickness change in range 5÷15mm and solidification modulus 0.16÷0.3 cm.

It's shown the equipment used for making of water mist cooling the casting die and special designed rotational jet cooling for spraying of water.

It has been shown that the using of water mist and the changing wall thickness of the casting cooled pointwise lets you control the crystallization process, microstructure and quality of the silumin casting.

Keywords: Innovative materials and casting technologies, cooling, water mist, die casting, silumin

W pracy przedstawiono wyniki badań procesu chłodzenia kokili badawczej mgłą wodną o ciśnieniu w zakresie 0,20÷0,45 MPa. Zmianę temperatury w odlewie z siluminu AlSi11 i w ściance kokili pokazano za pomocą krzywych termicznych i derywacyjnych. Przedstawiono przebieg zmian temperatury w procesie krystalizacji i stygnięcia badanych obszarów odlewu o grubości ścianki w zakresie 5÷15 mm i module krzepnięcia w zakresie od 0,16÷0,3 cm. Pokazano urządzenie do wytwarzania mgły wodnej chłodzącej kokilę oraz efekt rozpylania wody za pomocą zaprojektowanego rozpylacza wirowego. Pokazano mikrostrukturę siluminu okołoeutektycznego uzyskaną w kokili chłodzonej mgłą wodną. Wykazano, że zastosowanie mgły wodnej oraz zmiana grubości ścianki odlewu chłodzonego punktowo pozwala sterować procesem krystalizacji, mikrostrukturą i jakością odlewu siluminowego.

1. Introduction

The results of the paper 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 [1-4].

The objective of the study was to analyze the process of heat exchange during 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.

An analysis of the literature shows that with increasing cooling rate increases the degree of fragmentation silumin dendritic grains [5] and decreases the size, cell spacing and microstructure changes from dendritic to grain [6].

Based on previous research in the production of silumin casts by low prossure technology to research selected silumin AlSi11 and casting die made of WCL steel.

Designed die's cavity consists of three interconnected areas with a wall thickness of 5÷15 mm and characterized by a great diversity of solidification modulus.

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

* DEPARTMENT OF MATERIALS ENGINEERING AND PRODUCTION SYSTEMS, TECHNICAL UNIVERSITY OF LODZ, 90-924 LODZ, 1/15 STEFANOWSKIEGO STR., POLAND

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

2. Experimental

The test stand shown schematically in Figure 1 and its actual status in Fig. 1.

The essence of this study was to silumin AlSi11 casting temperature of 750°C samples in pre-heated to the temperature ranging from 50 to 560°C research die.

Research casting die made of steel EN-X37CrMoV5-1. Castings which were made in the mould consisting of three power section with a wall thickness in the range of 5÷15 mm and solidification modulus in the range of 0.16÷0.3 cm. The casting die was cooled poinwise using three nozzles placed in cylindrical sockets near each above mentioned section of the casting. The temperature of casting die was measured simultaneously K-type thermocouples deployed in the casting die within 2 mm from the surface of each of the three sections of the casting and in the casting. Recording of the temperature was conducted with 0.1°C accuracy and 2 Hz frequency using registrars: KD7 and the company LUMEL Crystaldigraph PC-2T company Z-Tech.

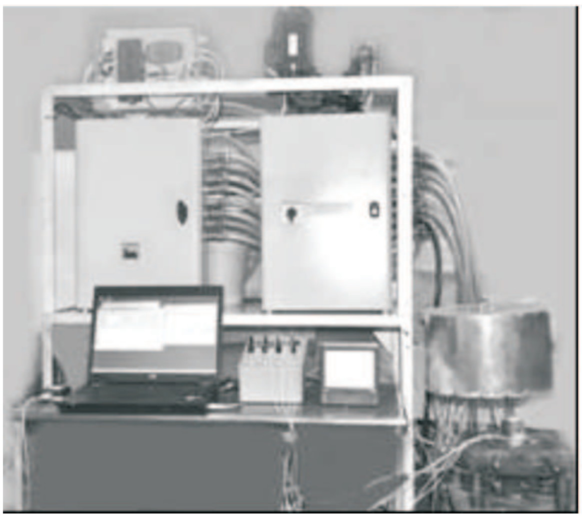

Fig. 1. Research stand

The water mist was being generated in multichannel cooling device. It 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 0,45 MPa range and of water from 0,25 to 0,50 MPa. Demonstration stream of sprayed water and the starting cooling mist were shown in Figure 2. The investigations of influence of cooling on the microstructure was made adequately with use MA200 the optical microscope.

The evaluation was performed by microstructure observation and computer analysis of images. Size of β phase precipitates in the eutectic $\alpha+\beta$ and α preeutectical denrites are the arithmetic average of 5 measurements made in a representative sample microstructure area. Moreover, the volume dendrites α was determined by measuring the length of arms of the first level.Technical Investigations used silumin neareutectic AlSi11, whose chemical composition and phase, crystallization and properties described in the literature [7,8].

a) b)

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 0.40 MPa and the water from 0.35 to 0.45 MPa and in other case - without cooling.

In Fig. 3 was shown the effect of time on the temperature and cooling rate of casting runner and the research casting die initial heated to a temperature of 50°C uncooled. The data showed that cooling the casting took place in an average speed of 1.7°C/s reaching the 141s temperature of 200°C.

In the first stage after pouring with the silumin of the mould follows the cooling down to liquidus temperature of the alloy. The process reaches a speed of about 70 K/s. Crystallization of the silumin was recorded on the cooling curve t = f(τ) and derivational dt/d =f'(τ) starts with preeutectic nucleation phase α.

Its presence is clear from the content of 10,3÷11,2% Si (hypoeutectical) silumin tested and the phenomenon of asymmetric coupled growth zone of Al-Si eutectic.

According to him after supercooling silumin begins nucleation and growth of dendrites α solid solution, then the liquid saurates with silicon and it enter into the growth zone of compressed,which crystallizes in the β phase and its phase α [8].

Crystallization process ends after 34 sec while casting cooling rate increased more than 10 K/s.

During this period the temperature in the test points of the die increases. Cooling of casting die characterized by low average rate throughout the range of values.

Figure 4 shows a view of the casting obtained by the process described in Fig. 3 The study shows that these conditions obtained in the castings have a high number of typical casting defects [9]. They occur primarily shrinkage defects in the surface of the wall collapsing part of a thick cast iron weight with the largest and most solidification module Mk = 0.3 cm. In addition, changes in cross-sectional areas between the parts of casting revealed shrinkage depression of wall and the incomplete representation of the shape of the end of the thinnest part of the casting. The observed defects in the external and internal porosity disqualified of the cast.

From the Fig. 5 studies cast microstructure obtained in research die, which describes the cooling process in Fig. 3 shows that the microstructure consisted of silumin preeutectically crystallized α phase dendrites and the eutectic lamellar $\alpha+\beta$. There is a large heterogeneity of the microstructure, in which the size of dendrites α and lamellar distance λ of $\alpha+\beta$ eutectic changing times.

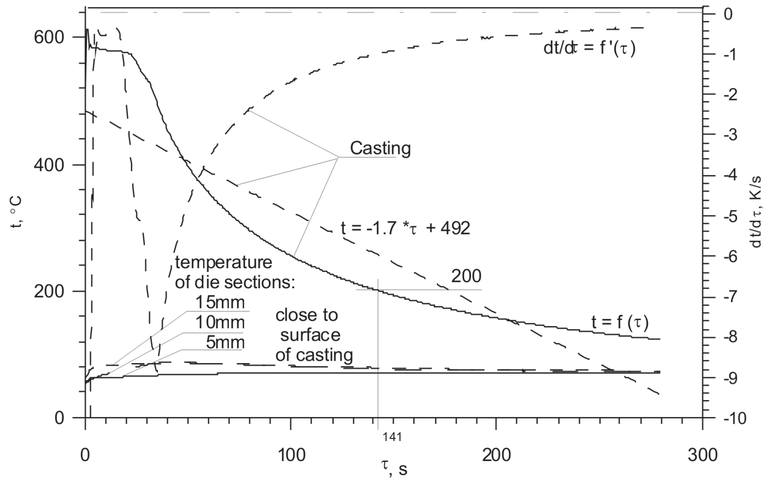

Fig. 3. The influence of time on the temperature and cooling rate of casting and casting die initial heated to 50°C

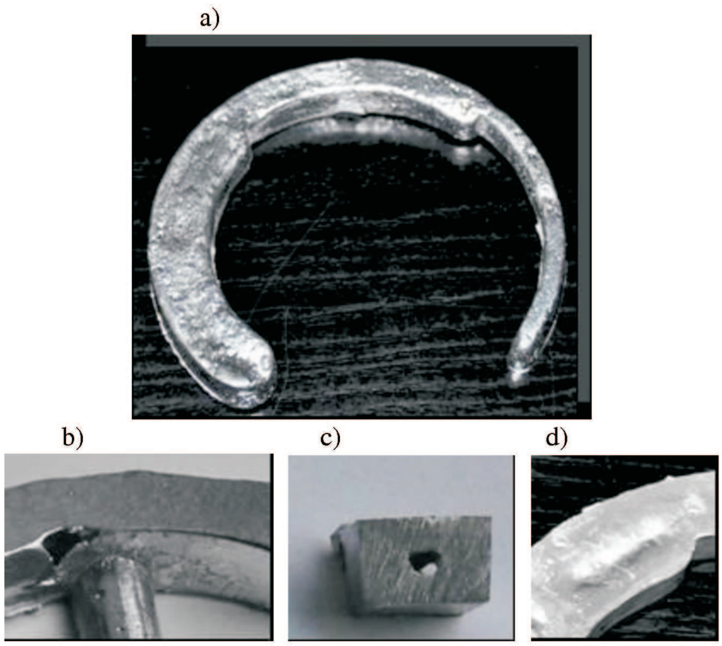

Fig. 4. Examples of defects in castings received research die pre-heated to 50°C uncooled: a – rounded edges throughout the casting and rough surface of the casting, b, c – at the infusion systolic cavity inlet and inside the cast (hole), d – the collapse of a flat wall socket casting that make it

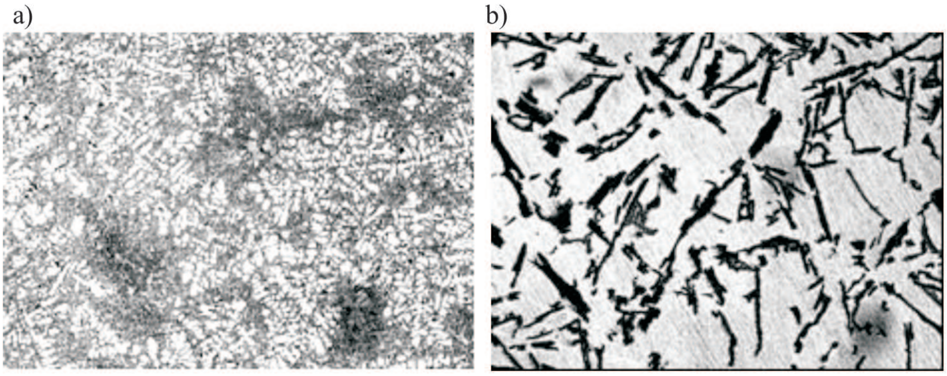

Fig. 5. Microstructure of casting made of AlSi11 silumin in research casting die initial heated to 50°C uncooled. Dendrites of preeutectic α phase and $\alpha + \beta$ eutectic. Magnification a) – x50, b) – x500

Figure 6, 7, and 8, 9 shows respectively the impact of time on the temperature of casting die close to tested casting sections (Fig. 6, 8) and silumin casting in his runner and in the tested sections of the casting (Fig. 7, 9) while they are cooling down after the initial heating of casting die to a temperature 450°C (Fig. 6 and 7) and 560°C (Fig. 8, 9) using a cooling water mist at a pressure of 0.30/0.35 MPa. Pointwise cooling implemented in stages with the use of three separate cooling circuits that run in a different order.

From the data (Fig. 6, 8) shows that the filling of the die with liquid silumin at temperature of 750°C rises in temperature of casting die areas in the range of 8÷23°C. Starting of pointwise cooling of the die causes on the thermal curves an immediate increase in cooling rate of cooling and low cooling effect on neighboring areas of casitng die.

The studies presented in Fig. 6 and 7 at the time cooling started at the moment Ms_1 in die socket close to the area of the casting wall thickness 5mm and then starting points and Ms_1 Ms_2 started cooling areas with a wall thickness of 10mm and 15mm respectively.

The study shows that the cooling of individual areas of the casting is done with a different cooling rate. Cooled slowly drip supplying the casting runner casting with liquid metal, thus allowing it to compensate for casting shrinkage. As a result of filling of casting die with use of silumin about temperature 750°C areas with a wall thickness: 5mm, 10mm and 15mm it reached maximum values in the range of 582-627°C and then rapidly decreased. The solidification of tested sections of the casting lasted from 9 to 13 seconds before ending up 20 seconds of the test process, although the casting runner was still in the liquid state. As a result, had acquired a cast of well done 5mm thick and 10 mm parts and shrinkage defects of the wall 15mm.

The studies presented in Fig. 9 and 10 at the time cooling started at $Ms_{1,2}$ point in casting die socket close to areas of casting with a wall thickness 15mm and 10mm and then from the point of cooling area Ms_3 began with a wall thickness 5mm, which ended at the point Mf_3.

The comparison studies show that raising the temperature of casting die preheat to 560°C lengthened the solidification process of tested areas given the opportunity to cast a greater cooling effect on the crystallization point areas of the casting. Used a sequence of cooling circuits particularly affected areas casting thicknesses 15mm and 10mm, causing them to effectively reinforcement the liquid metal from the casting runner.

The comparison of presented in Fig. 3, 6-9 processes of casting and cooling of casting die that apply multichannel cooling system combined with the impact point of cooling factor in the sockets, you can control the cooling process of casting die and casting in a large range of the instantaneous rate of cooling.

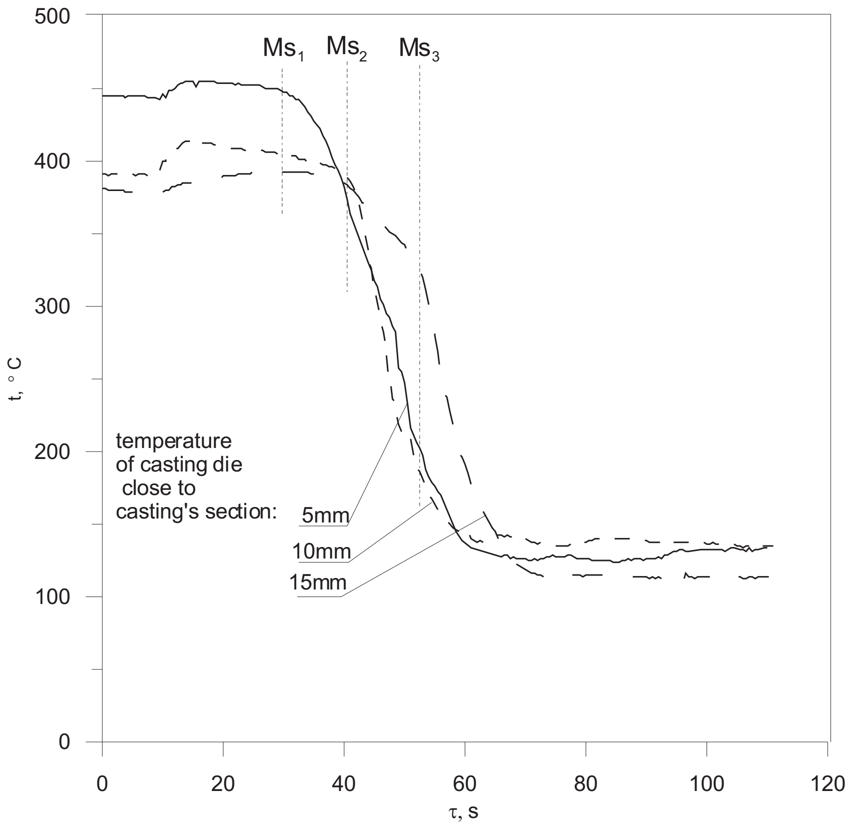

Fig. 6. The influence of time on the temperature of research casting die close to research casting's sections initial heated to 450°C and cooled with 0.30/0.35 MPa water mist

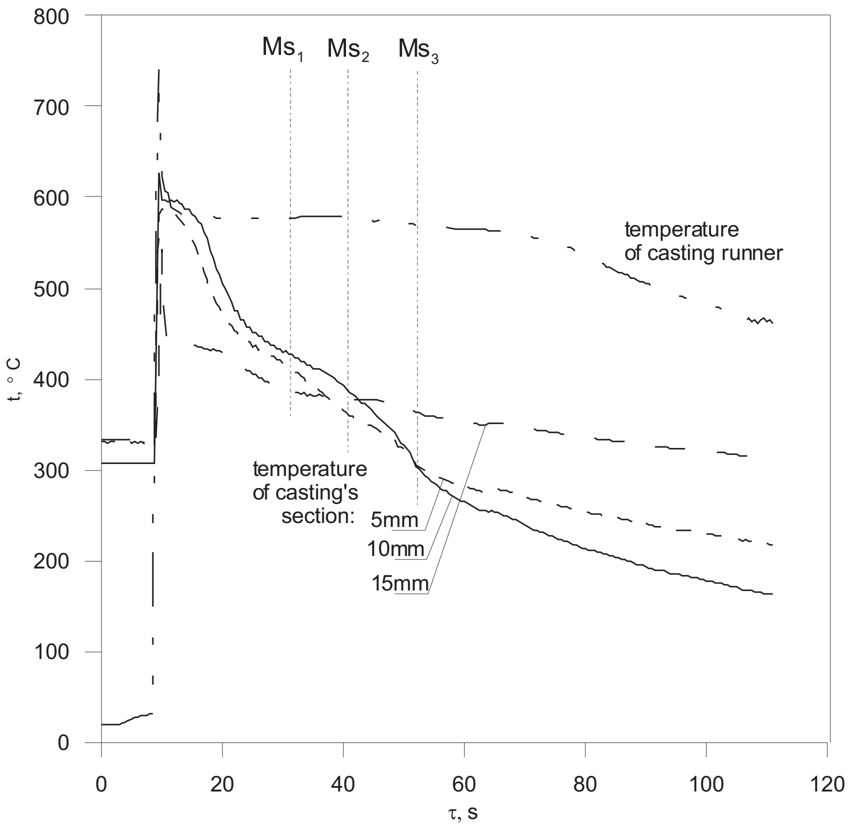

Fig. 7. The influence of time on the temperature of silumin casting in research casting's sections occur in casting die initial heated to 450°C and cooled with 0.30/0.35 MPa water mist

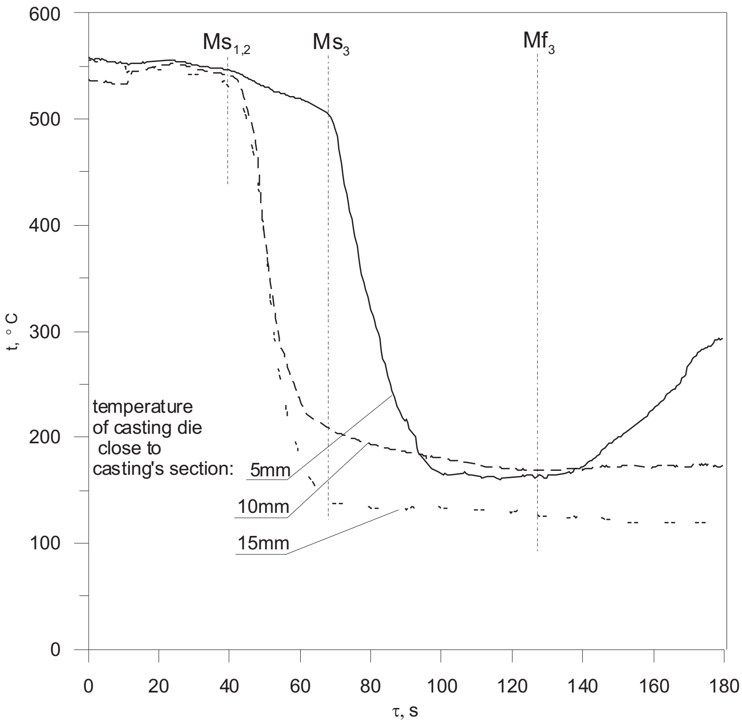

Fig. 8. The influence of time on the temperature of research casting die close to research casting's sections initial heated to 560°C and cooled with 0.30/0.35 MPa water mist

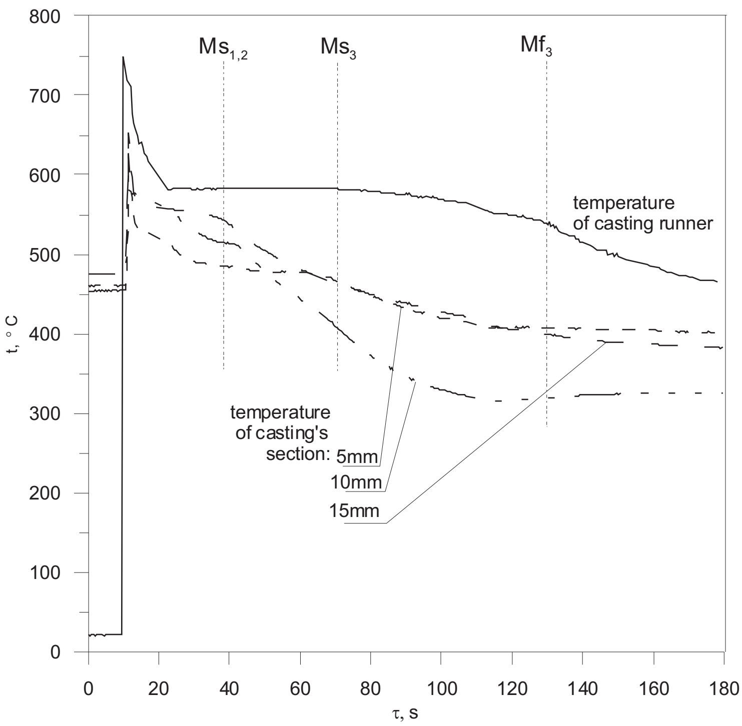

Fig. 9. The influence of time on the temperature of silumin casting in research casting's sections occur in casting die initial heated to 560°C and cooled with 0.30/0.35 MPa water mist

Figure 10 shows fragments of casting, together with cross sections from which samples were taken for testing the microstructure obtained in the casting process described in Fig. 9. Research shows that the casting well-received the cavity shape of casting die.

Casting surfaces are flat and and edges are sharp – do not show concavity, so significant for the shrinkage defects. Comparison of castings in Fig. 4 and 10 show that the application point multichannel cooling water mist can prevent the formation of casting defects in the form-section and variable wall solidification modulus casting.

In Fig. 11 (a-f) was shown the microstructure of unmodified silumin AlSi11 at its characteristic sections: 5mm (Fig. 11a, b), 10mm (Fig. 11c, d) and 15mm (Fig. 11e, f). The research shows that the microstructure consists of isolated preeutectic α phase dendrites and the eutectic lamellar $\alpha+\beta$.

Shown in Fig. 11a, b) the thinnest part of the casting wall thickness of 5 mm and 0.16 cm solidification modulus is characterized by extremely high dispersion of the microstructure. The size of α phase dendrites present in the test section is less than 0.3mm. β eutectic phase (Fig. 11b) are compact in the shape of short plates.

The increase in wall thickness of casting up to 10 mm and a solidification module of 0.25 cm (Fig. 11c, d) causes in the microstructure of the silumin increase of size of β in eutectic $\alpha+\beta$.

A further increasing of wall thickness of casting (15 mm Mk = 0.3 cm) causes a further increase in α dendrites and increased lamellar of eutectic $\alpha+\beta$. The study shows that the casting has a small porosity and high homogeneity of the microstructure.

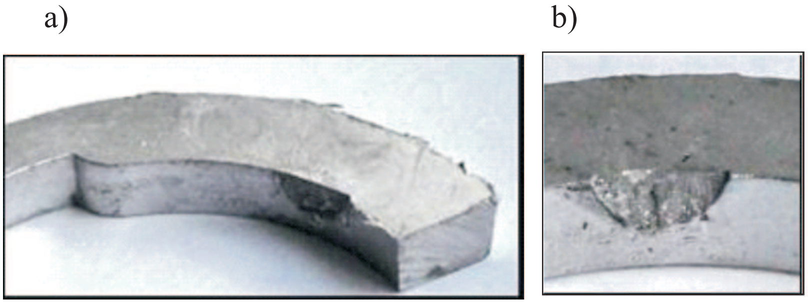

Fig. 10. Fragments of casting received in research die initial heated up to 560°C and cooled with water mist. Magnification: a) -x2, b) x5

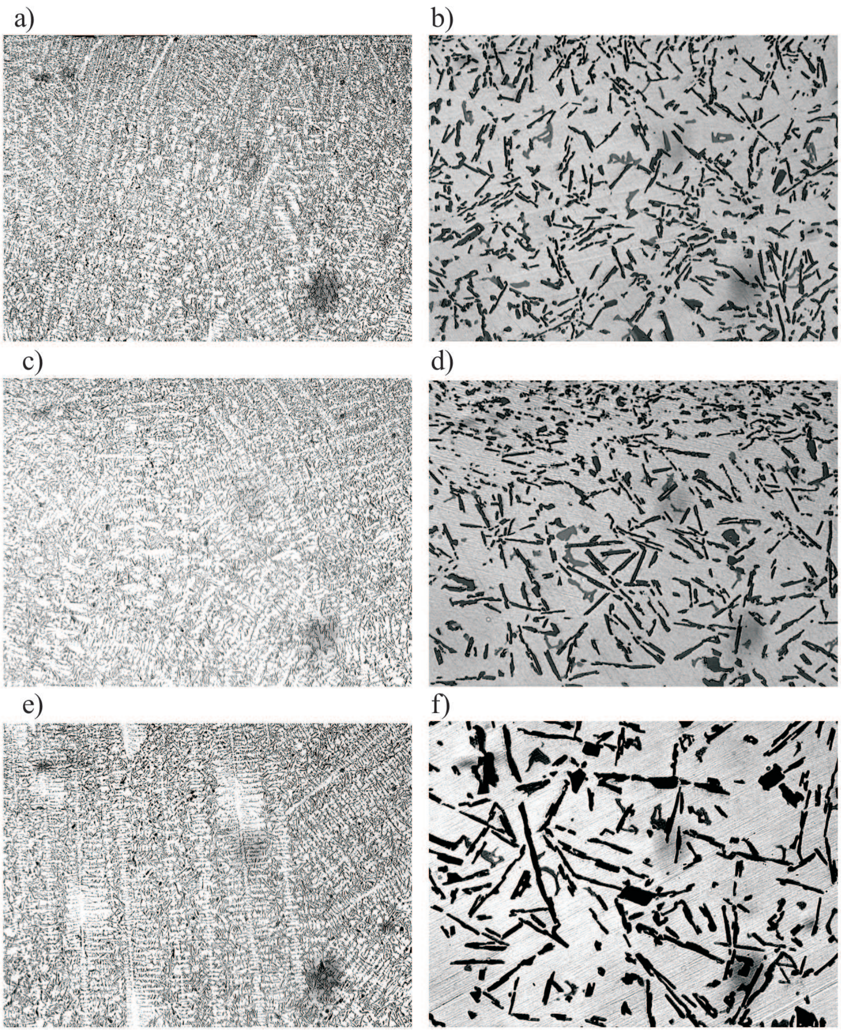

Fig. 11. Microstructure of casting made of AlSi11 silumin in research casting die initial heated to 560°C and cooled with water mist in wall thickness areas: a, b) – 5mm, c, d) – 10mm, e, f) – 15mm. Dendrites of preeutectic α phase and $\alpha+\beta$ eutectic. Magnification a, c, e) – x50, b, d, f) – x500

From comparison of the presented processes of casting and cooling of casting die and observation of macro-and microstructure of castings results that apply multichannel cooling system combined with the impact point of the cooling medium can guide the process of cooling of the die and casting a large range the instantaneous of cooling rate.

4. Conclusions

The following conclusions result from described examinations:

– the change of wall thickness and temperature of initial heating of casting die chilled by water mist allows to control the intensity of heat receiving in the desired area of the casting and casting die,
– casting of silumin AlSi11 in a steel shaped casting die chilled with water mist under pressure 0.30/0.35 MPa increases the quality of the casting and prevents shrinkage defects,
– water mist cooling of the casting increases the rate of crystallization and cooling of the silumin casting and consequently causing size-reduction and homogeneity of the microstructure of casting.

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