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The influence of electrical current on Al-Si alloys crystallization

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Abstract

This paper handles about the effect of electrical current on the cast microstructure of Al-Si alloy. By the application of direct current during the solidification there is intended the refinement of result microstructure. The change of result microstructure and mechanical properties was investigated. By the application of direct and alternating electrical current during the Al-Si alloy solidification there were observed some changes in the microstructure. The dendrites size in primary alpha phase was not been change markedly by the affect of electrical current. There was studied the size change of eutectic silicon on the samples. Eutectic silicon in the influenced sample is the same as eutectic silicon without electrical current application, only its length is shorter. Electromagnetical force activated by the transmission of electrical current flows into the increase of activating energy at the diffusion of silicon atoms and the silicon content inside the grains will be increased. By the application of electrical impulses of direct current the forces are influencing the hardening melt, which character is different as by the application of static electrical current.

Keywords: Al-Si alloy; Crystallization; Electrical current.

1. Introduction

The development of machinery industry is connected with still growing requests and claims of customers on mechanical and physical material properties. At recent growth of energy costs and raw decrease it is necessary to have regard on economics and effectiveness of production. In foundry industry the new trends including energetically an economical expediency are signified by new progressive technology application with using of more qualitative materials. Physical and technological properties of cast materials depend not only of chemical composition, but also of structure character given by conditions of primary crystallization. Crystallization process is very sensible and can be effectively influenced by external interventions. In metallurgical praxis there are known physically-metallurgical progresses of modifications, inoculation and microalloying. Beside these classical progresses of influencing of primary crystallization the electromagnetically methodic start to assert. On the present there exist many ways to utilize the effects of alternating magnetically field on melted metal, resp. crystallization queue. These progresses use the force effect of whirling currents, rising from movement of magnetically fields vector brought into influenced volume. Lorentz´s forces are the main functional factor in all cases notwithstanding large heterogeneity of electromagneticall methods. These forces are elicited by interaction of magnetically and electrical current flowing through effected volume. Lorentz´s forces allow realizing of the melt lifting, melt transport or vibrations transfer into effected volume in dependence of device arrangement, of time flow of magnetically field or electrical current.

Beside electromagneticall field the influence of electrical current on melted metal was investigated. Effects influencing the macrostructure are explained with electrical field influence on heat field, ergo on direction of cooling gradients. Melt has got severalfold lower electrical conductivity as the solid phase has, and before the crystallization queue there is the zone with higher

concentration of admixtures and therefore with lower conductivity as ambient melt.

2. Experiment

The aluminum alloy Al-Si was chosen for the investigation of electrical current effect. This has large utilization mainly in automotive. The alloy AlSi7MgMn0,3 was used. In order to investigate effects on result macro- and microstructure the experimental casts were performed at the application of alternating and direct electrical current with current density of 0,0375 A/mm^2 a 0,1 A/mm^2 .

The casts were done in the laboratory in Department of Technological Engineering in University of Žilina. The scheme of measurement is shown on fig. 1.

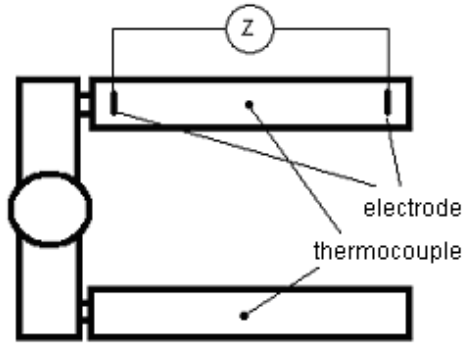

Fig. 1. Scheme of measurement

Casting temperature was 740°C ± 5°C. Crystallization influencing was in progress under different conditions:

- without electrical current effect
- direct electrical current was impacting during eutectic reaction
- alternating electrical current was impacting during eutectic reaction

direct electrical current was impacting in the form of electrical pulses.

The influence of direct electrical current on the process of alloy crystallization in sand mould and casting properties were investigated.

From the common cooling curve of used Al-Si alloy and from the constitution diagram aluminum-silicon the process of individual phases segregation was implied. Here it is applied, that the first phase solidified from melted alloy is the primary α-Al, the melt solidify as eutectikum at eutectic temperature after achieving of eutectic concentration, remaining volume solidify in the form of complicated phases.

Using of electrical current allows the reversible amount change of liquid and solid phase, it means the control of variables values of crystallization process. The physical and mechanical casting properties improve and their structure is anisotropic, what is not caused by heat field.

Melt present the short-circuit with minimal amount of rising heat and through the areas with lower conductivity the current with lower density and lower volume of heat is flowing. Providing that the phase interface liquidus-solidus and melt area in front of crystallization queue has lower electrical conductivity, the such consequence there should come to lower heating in such areas.

If during solidification the direct electrical current is used, the alloy solidification will be interrupt by the heat and electromagnetical force arising from the used electrical current. Liquid alloy is influenced by constant electromagnetic force. Force eventuates into increasing of activating energy at the diffusion of silicon atoms and increases the silicon volume inside of the grains. Most of silicon particles are arrange in the direction of growing into the final balanced direction, which is parallel or square to the force direction.

Within using of electrical impulses during solidification such forces arise, which have the character of vibrations. The surrounding of solidified melt is from the electrical view complex of conductors and microvolumes with different electrical conductivity, through which the current with different density is flowing and the largeness of rising forces will be different. Forces will not influence the melt as a unit, but their effect will be located into the areas with different electrical conductivity.

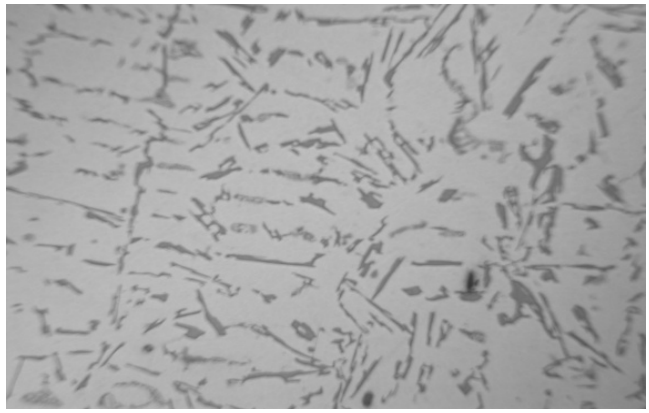

Fig. 2. Microstructure of Al-Si alloy without effect of electrical current, 100x ext, etched with 0,5% HF

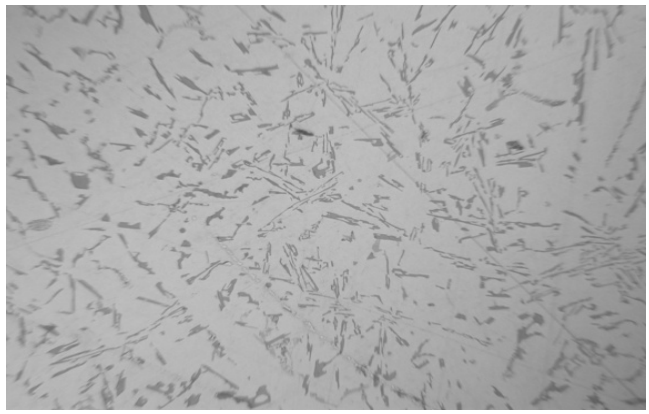

Fig. 3. Microstructure of Al-Si alloy influenced by direct electrical current of 15 A, 100x ext, etched with 0,5% HF

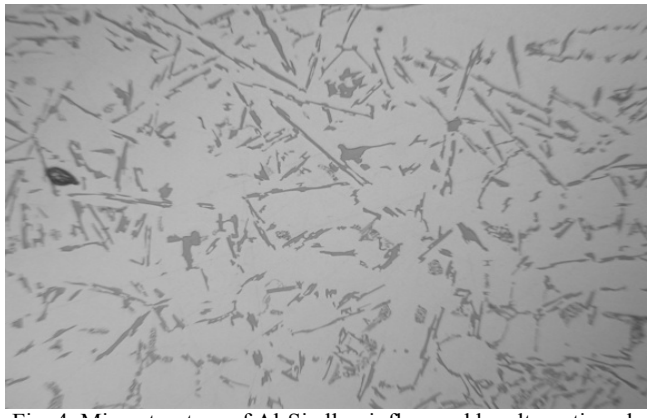

Fig. 4. Microstructure of Al-Si alloy influenced by alternating el. current 15 A, 100x ext, etched with 0,5% HF

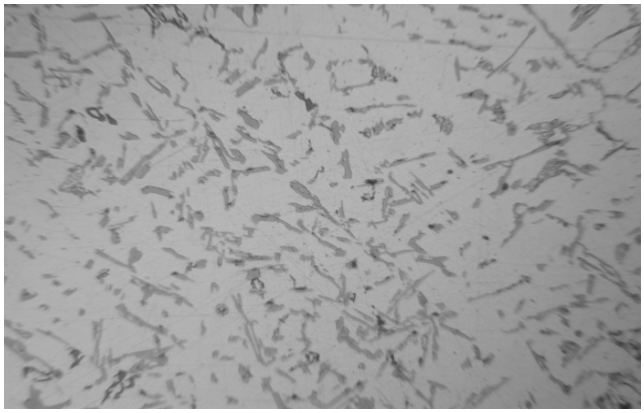

Fig. 5. Microstructure of Al-Si alloy influenced by alternating el. current 15 A in the form of impulses, 100x ext, etched with 0,5% HF

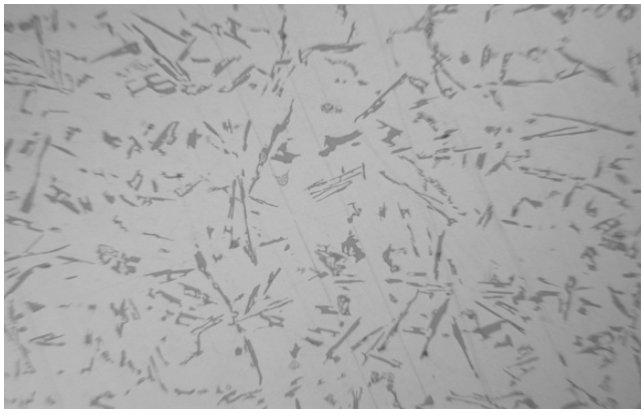

Fig. 6. Microstructure of Al-Si alloy without effect of electrical current, 100x ext, etched with 0,5% HF

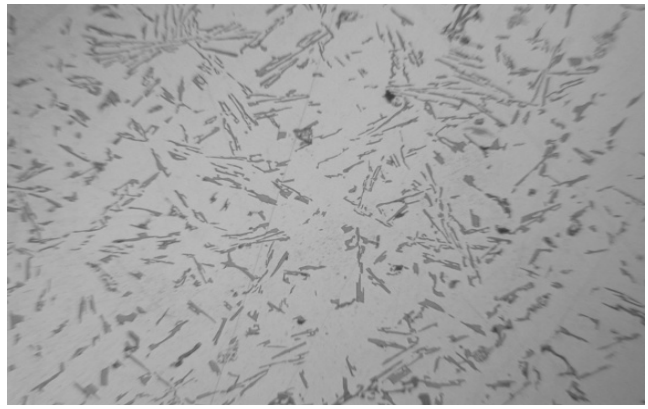

Fig. 7. Microstructure of Al-Si alloy influenced by direct electrical current of 40 A, 100x ext, etched with 0,5% HF

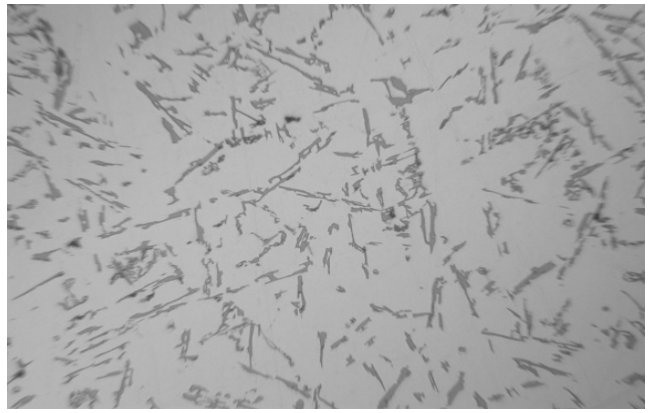

Fig. 8. Microstructure of Al-Si alloy influenced by alternating el. current 40 A, 100x ext, etched with 0,5% HF

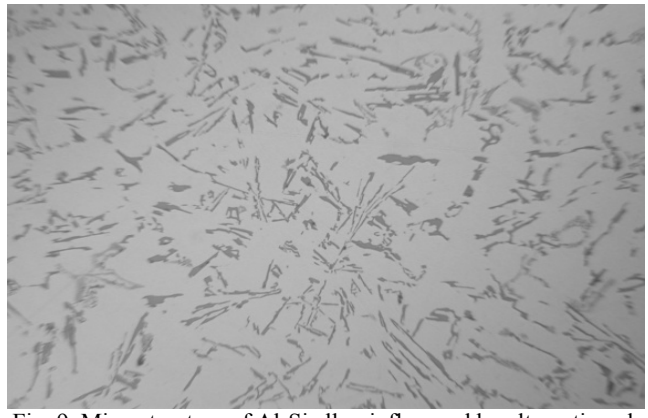

Fig. 9. Microstructure of Al-Si alloy influenced by alternating el. current 40 A in the form of impulses, 100x ext, etched with 0,5% HF

3. Results

Experimental results are documented on figures 2 and 9. Microstructure is built with alpha phase segregated as white dendrite shapes and delta phase composed with solid silicon solution with different volume of other elements. In the alloy microstructure without electrical current influence there is eutectic silicon segregated in the shape of coarse-grained needles or flakes. Alloy microstructure impacted with direct or alternating electrical current is finer. During the solidification the electrical current replaced the energy arising in the forming nucleus, what has increased their relation in liquid alloy.

By the application of direct electrical current the alloy solidification is influenced by constant electromagnetically force, which ended into increase of activating energy of silicon atoms. In the microstructure there has come to shortening of silicon particles.

In contrast to direct current, by the application of alternating electrical current the direction and force is changing periodically. Variable voltage faces to melt vibration and interruption of solidification process. Silicon particles were unsettled by the influence of oscillation developed from the electromagnetically force.

At the melt impact of direct electrical current in the form of impulses the electromagnetically force is affecting on the melt, and its direction is constant similarly as at direct current utilization. The size of this force is changing from the zero value to maximal value, whereby comes to interruption of solidification process as at utilization of alternating electrical current. Microstructure of such influenced alloy shows similar features as microstructure influenced by direct and alternating current.

4. Conclusions

We can observe, that there can come to changes in the microstructure at the impact of crystallization with the electrical current. Such changes have positive effect on alpha phase segregation – there come to dendrites refinement. Shortening of eutectic silicon particles has positive influence on final mechanical properties used alloy.

Acknowledgement

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