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Structure analysis of Al cast alloy

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Materials

ABSTRACT

Purpose: The developed design methodologies both the material and technological ones will make it possible to improve shortly the quality of materials from the light alloys in the technological process, and the automatic process flow correction will make the production cost reduction possible, and - first of all - to reduce the amount of the waste products.

Design/methodology/approach: Castings were analysed in the paper of car engine blocks and heads from the Al-Si-Cu alloys of the AC-AlSi7Cu3Mg type fabricated with the “Cosworth” technological process. In this work the AC-AlSi7Cu3Mg alloy structure was investigated, of this alloy samples were cut of for structure analysis of the cylinder part as well of crankshaft of a fuel engine. The investigation show a difference in the (phase) structure morphology as a result of cast cooling rate.

Findings: On the quality of casting has influence the walls thickness of car engine elements’.

Practical implications: In the metal casting industry, an improvement of component quality depends mainly on better control over the production parameters.

Originality/value: The value of the applied methodology was to correct identify the casting effects that occurred during the casting process.

Keywords: Metallic alloys; Al-Si-Cu; Al structure

1. Introduction

Aluminium alloys are especially preferred in designs thanks to their good mechanical properties and possibility to make very complicated castings with high service properties. Thanks to the contemporary casting and heat treatment technologies, castings from the aluminium alloys have the suitably high mechanical properties and simultaneously decrease the part weight. Therefore, there are more and more frequently used in the means of transport industry [1-3, 8].

These alloys have become popular in automotive industry owing to their low weight and some casting and mechanical qualities. The main component of aluminum alloy casting is Si. The eutectic structure in Al-Si casting alloys and Si concentration largely affect the porosity (pore volume) [4-7].

In recent years together with the development of the car industry and the desire for lowering the energy consumption of production processes, tendencies have appeared to return to casting alloys in sand moulds made on highly efficient automatic lines. The examples of using such solutions can be very often used technologies like Cosworth, CPS, BAXI and HWS. These technologies ensure filling the sand moulds with the elevated pressure and reduce oxidation of the applied aluminum alloys. The usage of highly efficient automatic cast lines has made it necessary to work out a fast, cheap and precise estimation method of the quality of cast alloys [8,9].

The modification of Al alloys causes relatively the biggest difficulties. It is common knowledge that the modification of alloys influences the number of nuclei in terms of their decrease, increase or passivation. Harmful elements, in turn, cause the cast porosity, lowering significantly their mechanical properties [10-14].

2. Materials and experimental procedure

Examinations were carried out on the car engine elements’ castings, i.e., blocks and heads from the AC-AlSi7Cu3Mg (EN 1706:2001) aluminium.

The castings were done according to Cosworth method, which is a technical solution used for serial production of high-quality car castings. In this process a liquid metal is pumped up to the form, which is above the crucible of holding furnace, with the help of electromagnetic pump, and the metal solidifies in a little hypertension (Fig.1). The process mould fill is controlled by computer system (Fig.2).

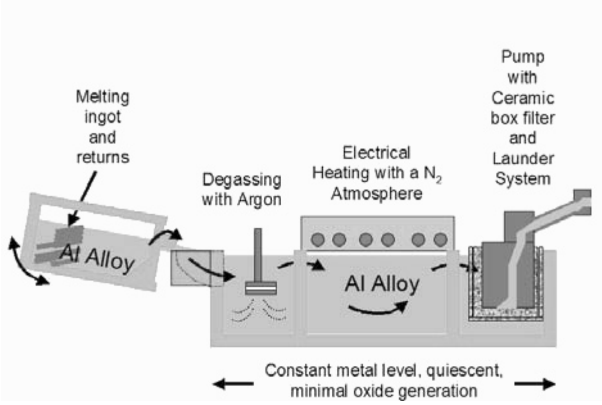

Fig. 1. The methodology of Cosworth castings process [15]

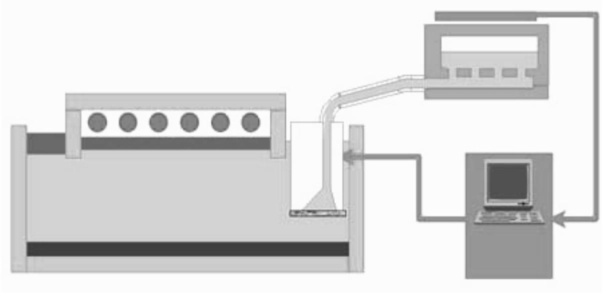

Fig. 2. Closed loop control system for mould fill [15]

To determine interrelations between the chemical composition and structure of aluminum Al-Si-Cu cast alloys that influence the quality of casts as results of different cooling rates, the following research has been done:

- structure of alloys using the light microscopy MEF4A supplied by Leica (etching 30% HBF_4 and NaOH). The microscope was connected to an image analysis system Leica-Qwin,
- structure of alloys using the scanning microscopy as well as EDS X-ray microanalysis together with surface decomposition. Metallographic investigation were performed also using the scanning electron microscope DSM 940 supplied by OPTON.

3. Discussion of the experimental results

The structure of the examined aluminum and silicon cast alloys consists of two basic phases and the matrix made out of α solid solution. The difference in the cooling rate caused by diversified thickness of cast walls influences the size of grains as the increase of the cooling rate causes the decrease of grains in the examined casts (Fig.3, 4).

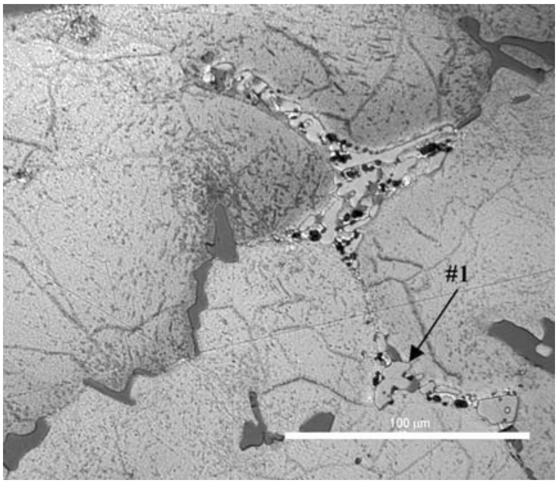

Fig. 3. Light microscope image of structure of the cast alloy- (#1 - Al_2Cu)

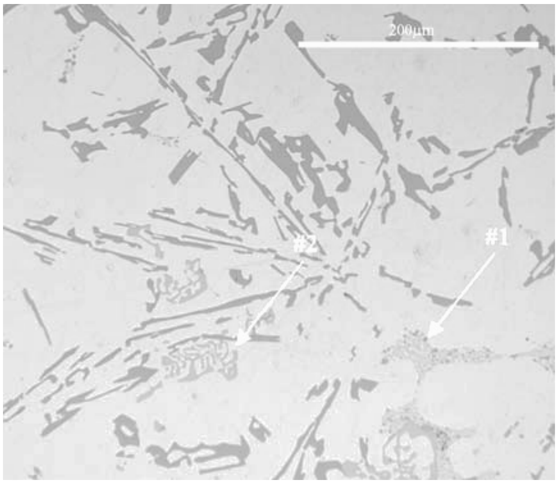

Fig. 4. Light microscope image of structure of the cast alloy- (#1 - Al_2Cu, #2 - $Al_{15}(MnFe)_3Si_2$)

The scanning microscopy structure of the examined aluminum alloy are presented on Fig. 5a. Examinations of the chemical composition with the pointwise methods reveal occurrences of the alloy phases (Fig. 5b, c).

Because of the degree of complexity of the structure of the car engine block there are different thicknesses of wall, the reason why the alloy soldifies at different cooling rates what directly influences the temperature of phase changes taking place during the crystallization as well as the kind, number and distribution of crystallized phases, and consequently the quality of the casting (cast porosity among others) (Fig. 6).

a)

b)

c)

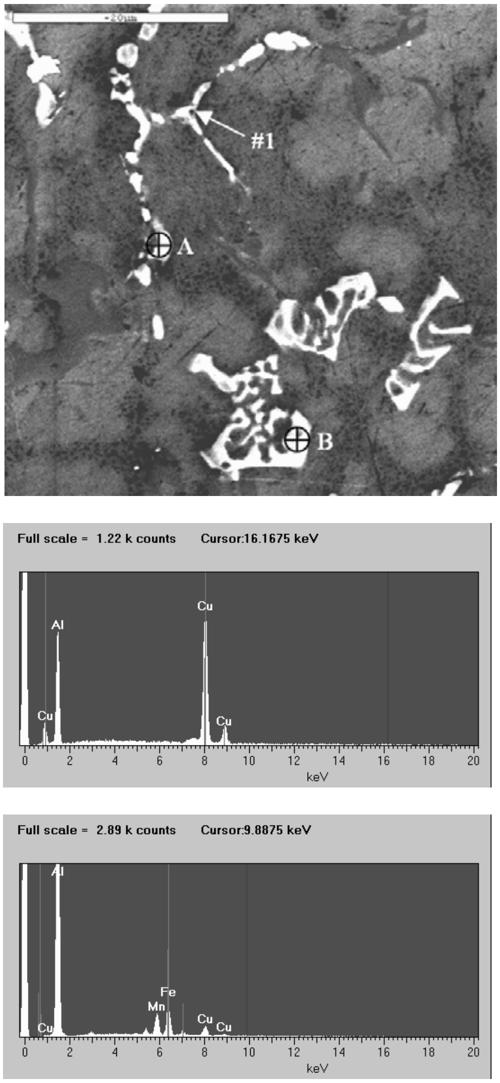

Fig. 5. SEM of the AC-AlSi7Cu3Mg aluminium alloy; a) structure of the cast alloy (#1-Al_2Cu), b) spectrum of the pointwise chemical composition analysis in A an Fig. 5a, c) spectrum of the pointwise chemical composition analysis in B an Fig. 5a

As a result of research done on elements' surface decomposition and X-ray quantity microanalysis using the spectrometer of dissipation of energy, the presence of main Si, Cu, Mn and Fe alloy additions has been confirmed which form phases in Al-Si-Cu alloy (Fig. 7).

4. Conclusions

The assurance of adequate properties of usable and technological elements made during the casting process is dependent on obtaining the right structure of casts i.e. proper type, number and position of made in the crystallization process phases as well as the size and shape of their particles. The obtained

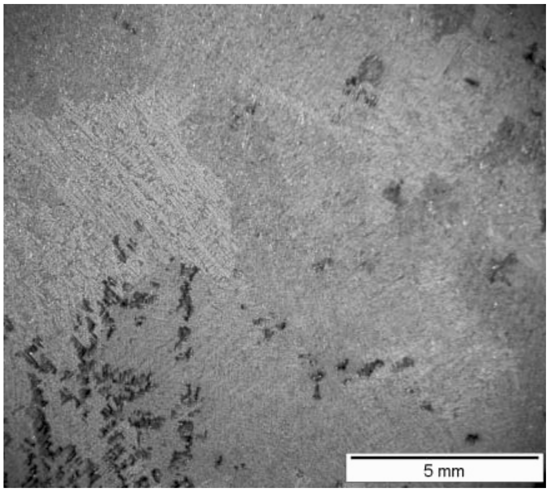

Fig. 6. Light microscope image of structure (porosity) of the Al-Si-Cu cast alloy

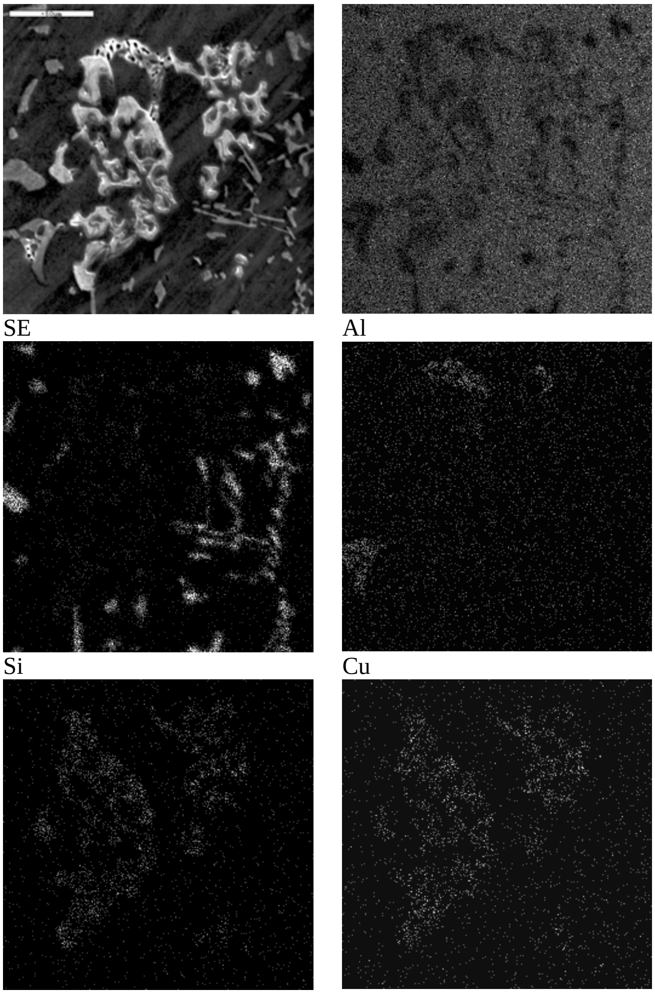

Fig. 7. The elements' surface decomposition in Al-Si-Cu alloy

Because of the degree of complexity of the structure of the car engine block there are different thicknesses of wall, the reason why the alloy solidifies at different cooling rates what directly influences the temperature of phase changes taking place during the crystallization as well as the kind, number and distribution of crystallized phases, and consequently the quality of the casting (cast porosity among others).

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