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Microstructure analysis of the automotive Al-Si-Cu castings

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Abstract

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

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 shows a difference in the (phase) structure morphology as a result of cast cooling rate.

Keywords: Automotive casting; Structure of materials; Al-Si-Cu

1. Introduction

A characteristic feature of aluminum is its significant capability to create many alloys with different metals and to obtain diversified properties in these alloys. This feature is responsible for a wide use of aluminum alloys and the constant growth of their usage in the industrial production. Low melting temperatures of aluminum alloys and good technological properties of the majority of alloy groups have created an opinion that the alloy technology is relatively easy and does not require special attention in the range of preparing a liquid metal as well as the structure of the casting mould. In fact, in case when one wants to obtain, out of particular alloy groups, the adequately high alloy properties, the strict technological discipline needs to be followed to avoid flaws or lowered properties. Because of good cast properties, aluminum alloys can be used for casts with sophisticated shapes and showing quite significant differences in wall thicknesses. The structure of alloys is usually dense, especially in case of alloying into the metal forms, and these casts show big tightness [1-5,9,13,14].

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 [6-8,11,12,15].

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 [2,10].

2. Materials and experimental procedure

Examinations were carried out on the car engine elements' castings (Fig. 1), i.e., blocks (Fig. 2 and heads from the AC-AlSi7Cu3Mg (EN 1706:2001) aluminium alloy (Table 1).
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 in a magnification range of 500 - 2000x.
- phase composition and crystallographic structure was determined by the X-ray diffraction method using the DRON 2.0 device with a Cobalt lamp, voltage 40 kV.

3. 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 and 4). Examinations of the chemical composition with the pointwise methods reveal occurrences of the alloy phases (Fig. 5)

Table 1
Chemical composition of AC-AlSi7Cu3Mg aluminum alloy

Mass fraction of the element, %							
Si	Cu	Mg	Mn	Fe	Ti	Zn	Ni
6,5-8	3-4	0,3-0,6	0,2-0,65	≤0,8	≤0,25	≤0,65	≤0,3

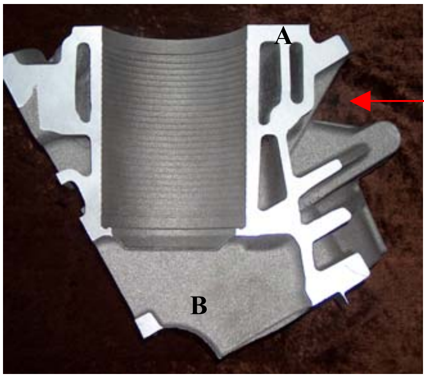

Fig. 1. The fragment of a section of car engine block

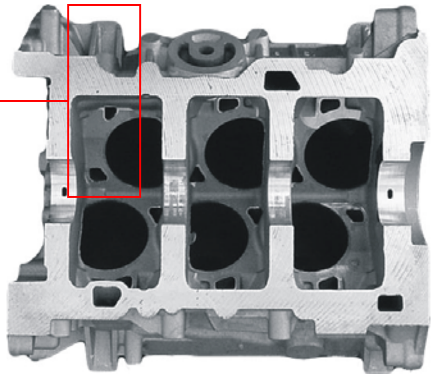

Fig. 2. The pictures showing a car engine blocks

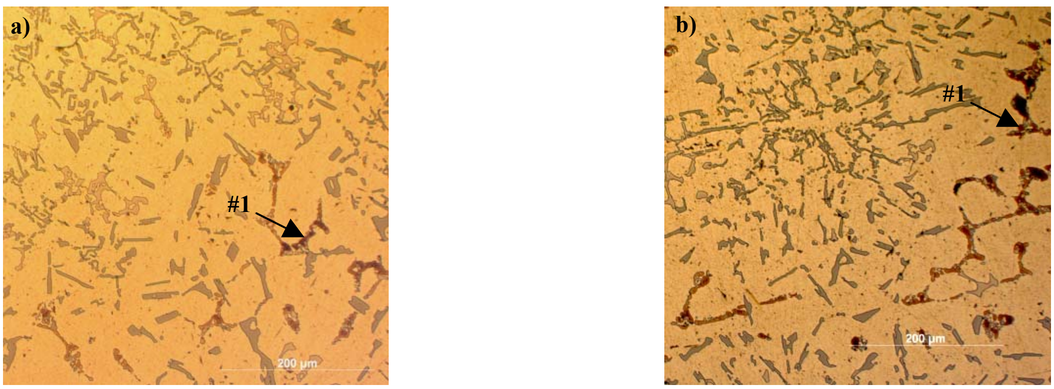

Fig. 3. Light microscope image showing structure of the cast alloy – (#1 – Al_2Cu), etching NaOH: a) in point A an Fig. 1, b) in point B an Fig. 1

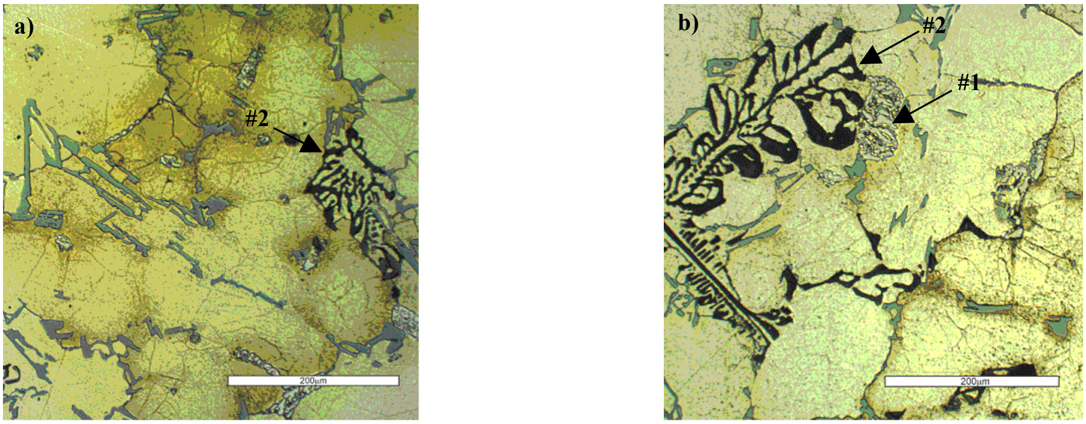

Fig. 4. Light microscope image showing structure of the cast alloy – (#1 – Al_2Cu, #2 – $Al_{15}(MnFe)_3Si_2$), etching 30% HBF_4: a) in point A an Fig. 1, b) in point B an Fig. 1

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.6).

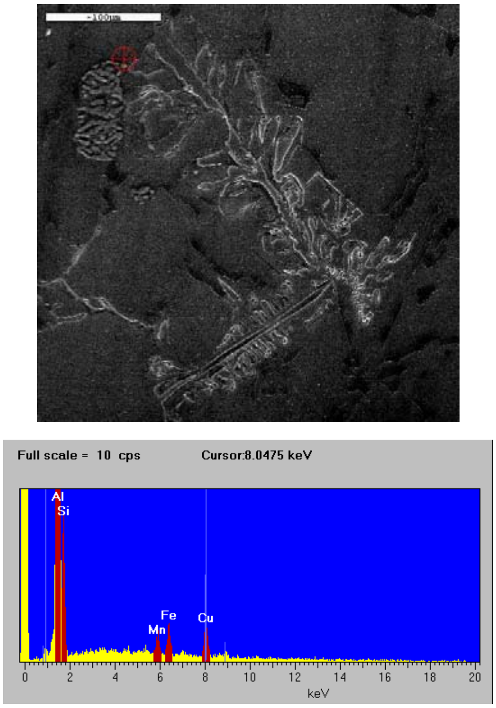

Fig. 5. Structure of the AC-AlSi7Cu3Mg aluminium alloy; a) structure – SEM, b) spectrum of the pointwise chemical composition analysis

The observations of microstructure made by a scanning electron microscope as well as the examinations of X-ray microanalysis confirm the presence of α+β eutectic in the examined alloys and allow to assume that there are also ternary eutectics.

4. Conclusion

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 structure of castings is influenced by the process of crystallization which is dependent on the chemical composition of the alloy as well as crystallization parameters like cooling rate and the degree of superheating the liquid.

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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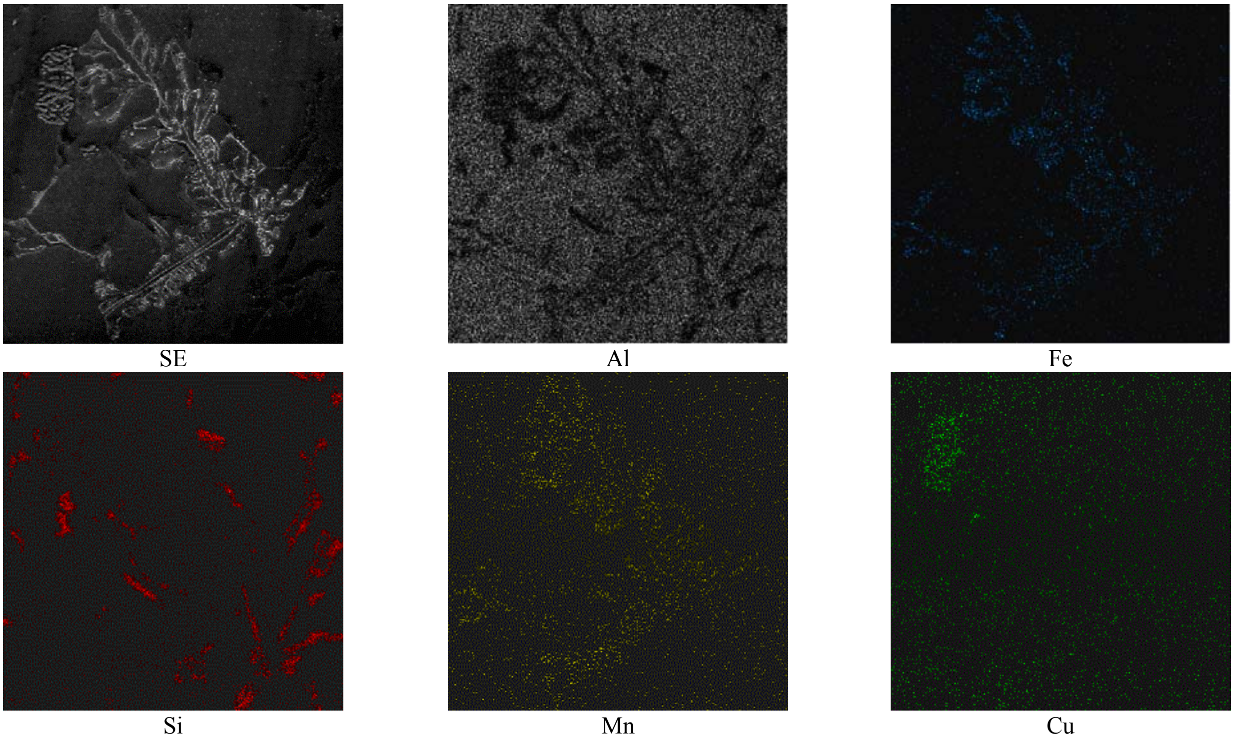

Fig. 6. The elements' surface decomposition in Al-Si-Cu alloy

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