Physico-chemical characteristic of aluminum alloy castings manufactured with cores containing fly ash as a base material

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Abstract

Castings were poured from PA9 aluminum alloy. Cores in the form of standard cylindrical specimens were made from the core mixture based on fly ash of the identified chemical and granular composition. The binder for the fly ash-based core mixture was chemically modified, hydrated sodium silicate. From the ready test castings, specimens were cut out for metallographic examinations and evaluation of morphology in the examined microregions. The structure was examined under a NEOPHOT 32 metallographic microscope using metallographic polished sections etched and unetched. For the specimen surface morphology evaluation a STEREOSCAN 420 scanning electron microscope and SE1 detector were used. The X-ray microanalysis was made on an EDS LINK ISIS 300 microanalyser. The fly ash was observed to have no major effect on the structure and chemical composition of castings.

Keywords: Innovative foundry materials and technologies, Fly ash, Aluminum alloy, Structure.

1. Introduction

In traditional approach, moulding mixtures are based on sands of different mineralogical compositions, which determine their physical and chemical properties. The base materials used most frequently are silica sands of an acid reaction. However, in some specific cases, depending mostly on the type of the alloy cast, it is necessary to use sands of a basic reaction (e.g. magnesite, chromite-magnesite), or sands of a neutral reaction (e.g. sillimanite, mullite, corundum, olivine, zircon) [1]. The resources of natural raw materials are shrinking, while human interference in the natural environment is more and more drastic. The use of properly processed, full-value waste as a base material for moulding mixtures can protect natural resources and bring considerable savings in mining of the raw minerals. One of such waste materials is the fly ash of hard coal or brown coal. The studies done recently [2,3] have indicated that it can be an alternative solution to the moulding sands used so far, acting as a substitute not only more friendly to the environment but also more profitable. To determine what effect the chemical composition of fly ash used as a base material for core mixtures may have on the chemical composition of castings poured from an aluminum alloy, the structure of test castings was examined and their phase composition was identified.
2. Making test castings

Castings were poured from an aluminum alloy of the following composition: Cu – 1.6; Mg – 2.0; Mn – 0.5; Zn – 6.0; Cr – 0.2; Al - rest, at a temperature of 720 °C. The thickness of casting walls was 20 mm; the casting weighed 1.1 kg (Fig.1). Cores were made in the form of standard cylindrical specimens of dimensions φ50 x 50 mm. They were prepared from a mixture based on fly ash of the chemical composition given in Table 1, while binder was chemically modified, hydrated R145”S”/MC1.0 sodium silicate of modulus $M = 2.1$ and the density of 1.45 g/cm$^3$. The content of the silicate binder in the core mixture was 6 wt.% in respect of fly ash. Cores made from the mixture of the above stated composition were thermally hardened at a temperature of 300 °C for 1.5 hours. Moulds were made from the moulding mixture based on standard silica sand, while binder was hydrated R145”S”/MC1.0 sodium silicate (the Floster technology).

![Fig. 1. Typical dimensions of a test casting](image1)

Table 1.

<table>
<thead>
<tr>
<th>Chemical composition of the investigated fly ash</th>
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<tbody>
<tr>
<td>SiO$_2$</td>
</tr>
<tr>
<td>Al$_2$O$_3$</td>
</tr>
<tr>
<td>Fe$_2$O$_3$</td>
</tr>
<tr>
<td>CaO</td>
</tr>
<tr>
<td>MgO</td>
</tr>
<tr>
<td>Na$_2$O</td>
</tr>
<tr>
<td>K$_2$O</td>
</tr>
</tbody>
</table>

3. Metallographic examinations and evaluation of the test casting morphology

From the ready test casting, specimens were cut out for metallographic examinations and evaluation of morphology in the examined microregions (Fig.2). For structure examinations and taking of photographs, a metallographic NEOPHOT 32 microscope was used. The examinations were done on etched and unetched metallographic sections. The metallographic sections were etched in M1AI reagent according to Polish Standard PN-75/H-04512. The results of metallographic examinations are shown in Figures 3 and 4.

The specimen surface morphology was examined under a STEREOSCAN 420 scanning electron microscope under the following conditions: accelerating voltage – 25kV, specimen current – 300 pA, SE1 detector. The X-ray microanalysis was made on an EDS LINK ISIS 300 microanalyser. The results of the examinations in the form of microphotographs and EDS spectra with relevant descriptions are shown in Figures 5 to 8.

![Fig. 2. The spots where specimens were taken from the test casting for metallographic examinations and evaluation of morphology in the examined microregions](image2)

![Fig. 3. Microstructure of test casting in Al_1 region. Section etched in 1% HF, 500x](image3)
Fig. 4. Microstructure of test casting in Al_2 region. Section etched in 1% HF, 500x

Fig. 5. Specimen from Al_1 region: a – morphology of the examined microregion (2400x), b – EDS spectrum points 1, c – EDS spectrum points 2

Fig. 6. Specimen from Al_2 region: a – morphology of the examined microregion (500x), b – linear distribution of elements in microregion a

Fig. 7. Specimen from Al_2 region. Morphology of the examined microregion (500x) and surface distribution of selected elements
4. Conclusions from the investigation

An analysis of the distribution of concentration of the selected constituents of the alloy used for test casting did not reveal the presence of detectable microsegregations in peripheral zones Al_1 and Al_2 on the test casting cross-section adjacent to cores. The microsegregation of constituents to a residual liquid during alloy solidification was responsible for the formation of complex eutectics on the grain boundaries. The observed microstructure is typical of a PA9 type alloy. Taking the above into consideration it can be stated that the presence of fly ash used as a base material for moulding mixture does not cause any changes in the microstructure and morphology of a test casting poured from aluminum alloy.

References