Physicochemical preparation of the AlSi11 alloy for castings of fire-fighting equipment

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Abstract

The paper presents results of reaction kinetics investigation of crystallization processes of refined, modified with Sr and Sb as well as filtered silumin destined to casting of fire-fighting equipment. It has been determined an effect of performed upgrading processes of: refining, modification and filtering on changes of mechanical properties (Rm, As, HB and KCV) of the AlSi11 (AK11) alloy. There were performed metallographic examinations of the upgraded alloys and flooded foamed filters. It has been proved, that developed and set into production upgrading technology of the AlSi11 (AK11) alloy enables casting of fire-fighting equipment, complying with requirements of the European Union.

Keywords: Aluminum Fire-Fighting Equipment, Silumis, Refining, Modification, Filtering

1. Introduction

High mechanical, technological and operational requirements imposed by domestic and foreign recipients of aluminum castings destined for fire-fighting equipment have forced producers of these alloys to introduce a modern manufacturing technologies.

Castings for fire-fighting equipment produced from aluminum alloys should be characterized with a suitable:

- High mechanical properties (Rm, As, HB and KCV).
- Tightness with respect to flowing media.
- Roughness.
- Easiness and reliability of connection with other fire-fighting equipment components.

Manufactured up-to-now from domestic charge materials (pig sows) aluminum castings of fire-fighting equipment not fully comply with requirements of national and EN standards. It concerns mainly a castings poured into permanent moulds and pressure casting dies.

Within Polish foundry industry are commonly used, during melting, a suitable metallurgic processes aimed at obtaining of a predetermined properties, demanded by national and foreign standards [1, 2].

Pig sows used to production of reliable castings, where metallic charge materials containing aluminum scrap have been used, require implementation of refining and modification processes of liquid metal.

To enable possibly maximal purification of the alloy from oxides and non-metallic inclusions, prior casting into mould one should perform processes of filtration [6].

Mentioned above upgrading processes of aluminum alloys were implemented during melting of the AlSi11 (AK11) alloy destined to production of reliable castings for fire-fighting equipment.
2. Methodology and results of the tests

Production of aluminum castings destined to fire-fighting equipment, according to requirements of the PN - EN 1706 (2001) standard, is presented on example of permanent-mould castings of a suction sleeve coupler according to the PN-91/M-51031 standard, and fire hydrant attachment according to the PN-91/M-51038 standard, produced from the EN AC-44000, AlSi11 (AK11) alloy.

Shape and appearance of the fire-fighting equipment’s castings are shown in the Fig 1.

Permanent-mould castings of aluminum fire-fighting equipment poured directly after melting of the pig sows from AlSi11 (AK11) alloy not fully comply with requirements imposed by the PN-91/M-51031 standard, i.e. strength and tightness of the castings most of all.

To obtain higher mechanical properties, comparing with the actual ones, after melting of the pig sows one performed suitable upgrading processes of the AlSi11 (AK11) alloy. For this purpose, after melting of the pig sows from the investigated alloy in electric resistance furnace, one performed refining with use of “Alraf” preparation.

Liquid alloy, refined in two separate electric furnaces, underwent the modification: with AlSiSr10 master alloy or metallic antimony.

Using the alloys upgraded in such way, one poured a test samples to mechanical, metallographic and chemical analysis tests, with and without filtration process during their pouring [6].

Moreover, in order to have confirmation of correctness of the performed metallurgical processes, one investigated a course of kinetics of the crystallization, using method of Thermal Derivative and Electric Derivative (ATD - AED) method [5].

In the Fig. 2 are shown microstructures of the AlSi11 alloy, obtained in result of the implemented processes of refining and modification with strontium or antimony.

In the Fig. 3 are shown graphical records of the crystallization curves: temperature curve, $t = f(\tau)$, and electric conductance curve, $\sigma = f(\tau)$, in function of time, as well as their first order derivatives according to the ATD - AED method, for the AlSi11 alloy after refining and modification with strontium or antimony.

Effect of the accomplished upgrading processes on changes visible on crystallization curves, graphical record of the ATD - AED method, is confirmed by obtained microstructures. Microstructures of the investigated alloy, obtained in result of the upgrading processes, illustrate very distinct differences in shape of crystallized, basal phases (dendritic crystals - phase $\alpha$ and eutectic mixture - $\alpha + Si$), constituting structure of the casting.

High differences in morphology of structures and kinetics of crystallization of the AlSi11 alloy, arisen in result of performed metallurgical processes have an effect on changes of mechanical properties.

In course of the investigations performed earlier one pointed out that in case of commercial alloys there exits a possibility that the impurities can have form of oxides and non-metallic inclusions [3, 4, 6, 8]. Analysis of the obtained test results proves necessity of accomplishment of filtration processes during casting process of reliable machinery components.

In the Fig. 4 are shown microstructures of flooded ducts of foamed filter with visible, blocked impurities after filtering of the alloy.

Effect of the upgrading method on changes of mechanical properties ($R_m$, $A5$, HB and KCV) of the AlSi11 alloy, destined to fire-fighting equipment castings, is illustrated in form of bar charts in the Fig. 5. Numerical values constitute arithmetic mean from three poured samples.
Fig. 2. Microstructures of the upgraded AlSi11 alloy: a – refined alloy, b – alloy modified with strontium, c – alloy modified with antimony
Fig. 3. Comparison of crystallization curves of the AlSi11 (AK11) alloy after modification with strontium and antimony

![Graph showing crystallization curves with labels for Sr and Sb modifications.]

\[ \tau = 3.64 \]
\[ t = 558.45 \]
\[ \sigma = 5.01 \]

Fig. 4. View of the flooded filter and microstructure with blocked impurities after process of filtering of the AlSi11 (AK11) alloy:

a) cross-section of the flooded filter, b) shape and distribution of blocked impurities

![Images of microstructures.]
3. Summary

Developed research methodology and test results obtained on base of this methodology enable preparation of the AlSi11 (AK11) alloy destined to casting of reliable fire-fighting equipment from pig sows.

Performed investigations concerning development of the most advantageous upgrading processes of the AlSi11 (AK11) alloy, enable production of a castings which feature mechanical and technological properties required by the PN-91/M-51031 and PN-91/M-51038 standards (Fire-fighting equipment). However, to obtain mechanical properties required by the PN-EN 1706: 2001 standard, during melting it is necessary to perform modification with strontium or antimony.

After modification of the alloy with Sr or Sb, comparing with refined alloy, one obtained upgraded structure. Eutectic mixture $\alpha + Si$, differing each other with respect to shape, has been crystallized within interdendritic spaces of the phase $\alpha$. It contains reduced in size morphology of eutectic silicon, significantly impacting on growth of the mechanical properties.

Modification of the alloy has confirmed its significant effect on change of kinetics of crystallization processes of the investigated silumin. Extend and character of the obtained changes is seen on curves of graphical records of the ATD - AED method.

Developed and set into production upgrading technology of the AlSi11 (AK11) alloy enables casting of fire-fighting equipment, which complies with requirements of the European Union.
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References