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Influence of melting and filtration processes on the structure and mechanical properties of aluminum alloys

M. Dudyk[a,*], J. Asłanowicz [b], L. Ościłowski[b]

[a] Faculty of Machine Technology and Automatization, Technical – Humanistic Academy, Willowa Str. No. 2, 43-300 Bielsko-Biała, Polska

[b] FERRO - TERM Sp. z o.o., Przybyszewskiego Str. No. 176/178, 93-120 Łódź, Polska

* Corresponding author. E-mail address: mdudyk@ath.bielsko.pl

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Abstract

In the article are presented the results of the study on the applied upgrading processes such as refining, modification and filtration of the near eutectics alloy EN AC- 44000, AlSi11, (AK11), cast into the chill. The upgrading processes applied to the said alloy caused, in comparison to the alloy which was not upgraded, significant differences in the shape of the crystallization curves, obtained in the graphic record of the ATD-AED method. It was demonstrated the existence of connections between the thermal and electric phenomena during solidification and crystallization of the studied silumin. The obtained results of the metallographic analysis showed the occurrence of the impurities within the alloy structure in the form of porosity and oxides following the metallurgical processing (in pig sows). The primary studies on microstructure of the cast ceramic filters have demonstrated the purposefulness of introduction of the filtration process to the technology of aluminum alloys manufacturing. The microstructures of the filters cast with the studied alloys illustrate the extent and deployment of the impurities retained (in the filter) during the process of samples casting for measurement of the mechanical strength properties. On the example of the near eutectics alloy AK11, it has been demonstrated, that in comparison to the refined alloy there is a possibility to obtain significant improvement of mechanical properties, and especially elongation A_5 and impact strength KCV.

Keywords: Innovation materials and casting technologies; Silumins; Crystallization; Structures; Filtration

1. Introduction

Correctly carried out control of melting and casting processes allow to obtain the optimal structure which mainly influences the quality of the cast machine parts.

Metallurgical operations – refining and modification - are currently most often used methods of structure refining in order to improve the mechanical properties of alloys in the country's aluminum alloy foundry practice [1, 2].

To improve the quality of the cast alloy are also introduced the filtration processes directly in the gating systems by means of the appropriately selected ceramic filters [4, 5].

High requirements demanded by designers for the cast machine parts are not fully realized as in the aluminum alloy casting houses is used, among others, the metallic charge made from the recycle stock (scrapped alloys of Al). In the machine parts cast from the aluminum alloys, next to undesired structure morphology, there are also present the impurities with hard particles (multimolecule oxides) [3].

In the study are also presented the relevant tests and the obtained results which demonstrate a possibility of improvement of mechanical properties of the cast aluminum alloys made from the charge stock of unsatisfactory quality.

2. Methodology of the study and results

In the study, the alloy from the metallurgical processing, EN AC – 44000, AlSi11, (AK11) was used.

For this silumin grade, during melting, the metallurgical operations were carried out, such as refining – using hexachloroethane and modification – with strontium master alloy.

The filtration processes were performed using the foam filters made by FERRO - TERM in Łódź [4].

Simultaneously with the study of the alloy crystallization using the method ATD - AED, the samples were cast for measurement of the mechanical properties (R_m, A_5, HB and KCV) as well as for determination of the chemical composition.

The test stand which was developed and constructed, presented in the study [6], enabled the registration of the crystallization processes in the aluminum alloys using the ATD – AED method – without the filtration processes or, alternatively, using the filtration processes.

The graphic record of the crystallization curves for the alloy AK11, obtained by means of the ATD – AED method, after the performed upgrading processes – refining, refining and modification as well as filtration, are shown in the figure 1.

The influence of the applied melting processes for the studied alloy AK11 on changes in the structure are shown in the figure 2.

The metallographic studies of the samples cast for strength measurements directly from the alloy melted from the pig sow showed occurrence of the internal defects.

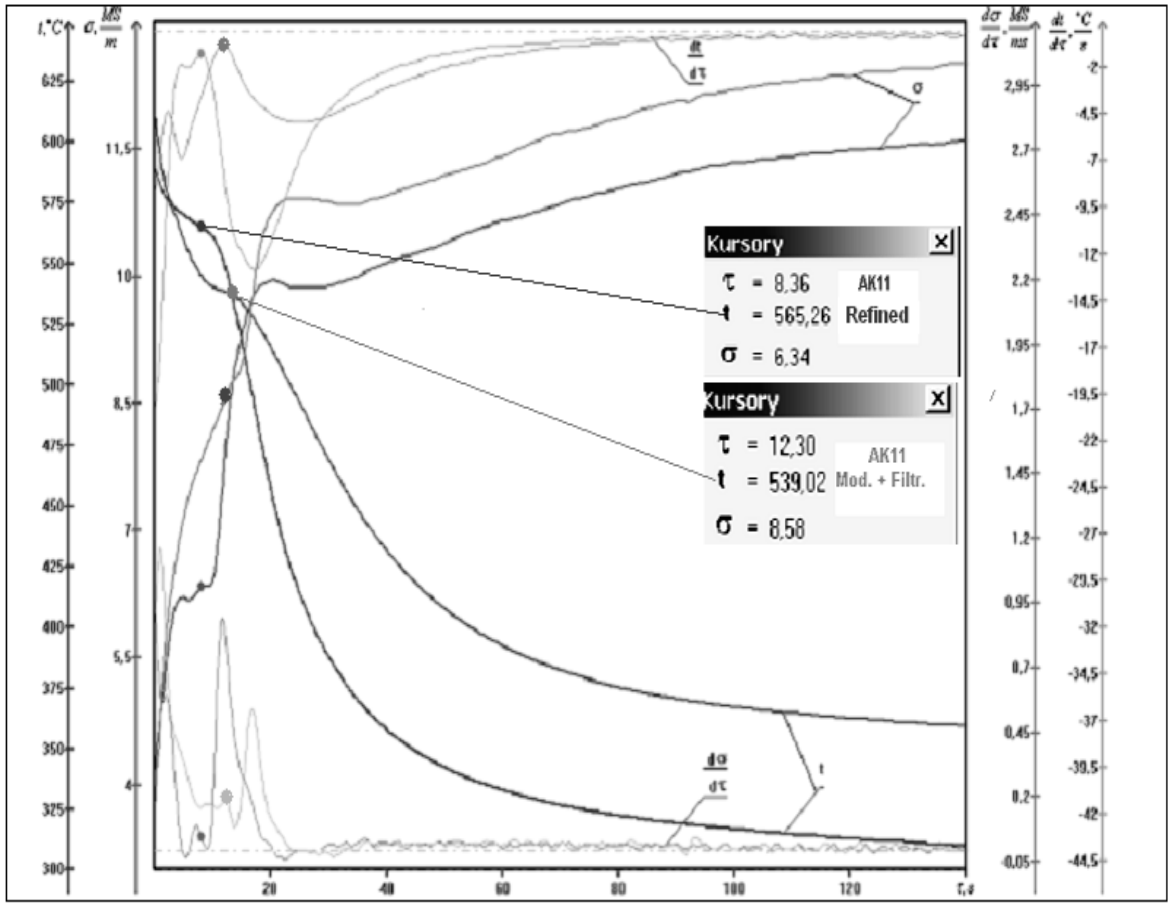
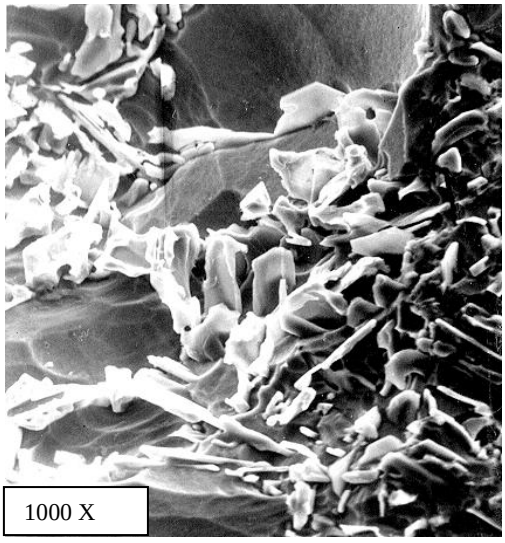


Fig. 1. Graphic record of the crystallization curves for the alloy AK11 after carried out metallurgical operations

a)



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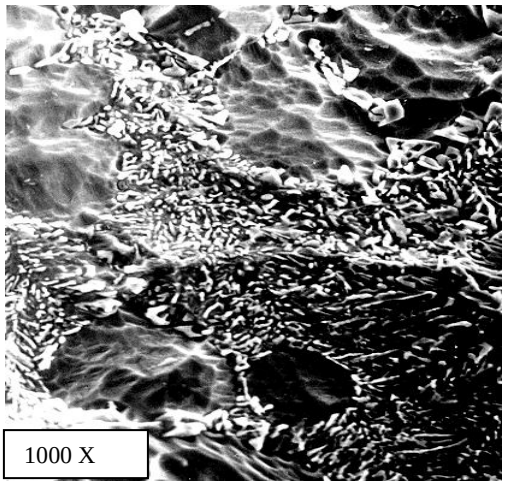

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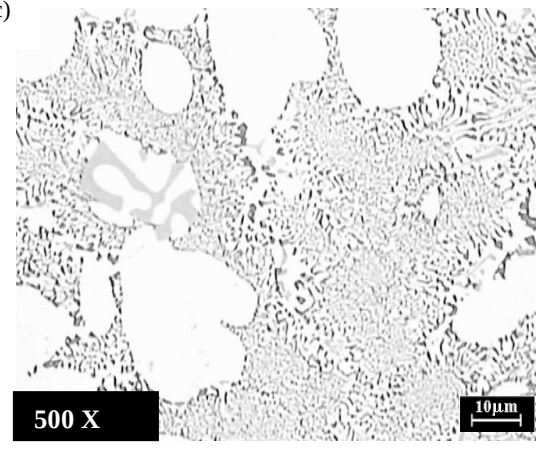
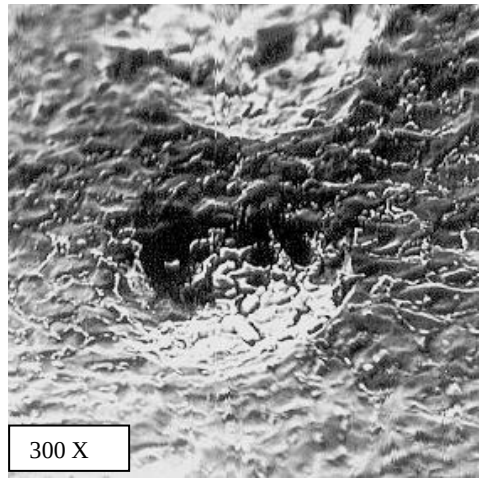


Fig. 2. Microstructures of the alloy AK11: a – refined alloy, b – refined and modified alloy, c – refined, modified and filtrated alloy

The figure 3, illustrates the defects which occurred within the castings the form of the gaseous porosity and oxides.

a)



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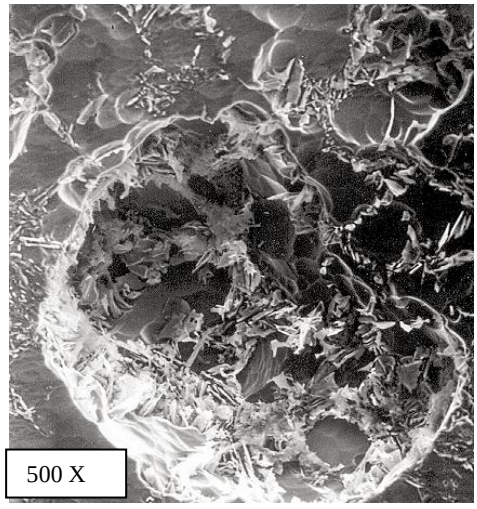

Fig. 3. Internal defects in the microstructure of the alloy AK11, cast directly from the pig sows: a – gaseous porosity (bubbles), b – gaseous – shrinkage porosity and the oxide film

The primary results of the study for the alloy AK11 show the microstructures of the foam filters cast with this alloy after the performed filtration processes.

The microstructures presented in the figure 4 illustrate the shapes and deployment of the retained impurities as well as the crystallized phases – solid solution α, eutectics (α + Si) and secondary phases.

The result of the performed melting and filtration processes is significant change in mechanical properties. Comparison of the obtained changes in mechanical properties in the form of the bar diagram are presented in the figure 5.

a)

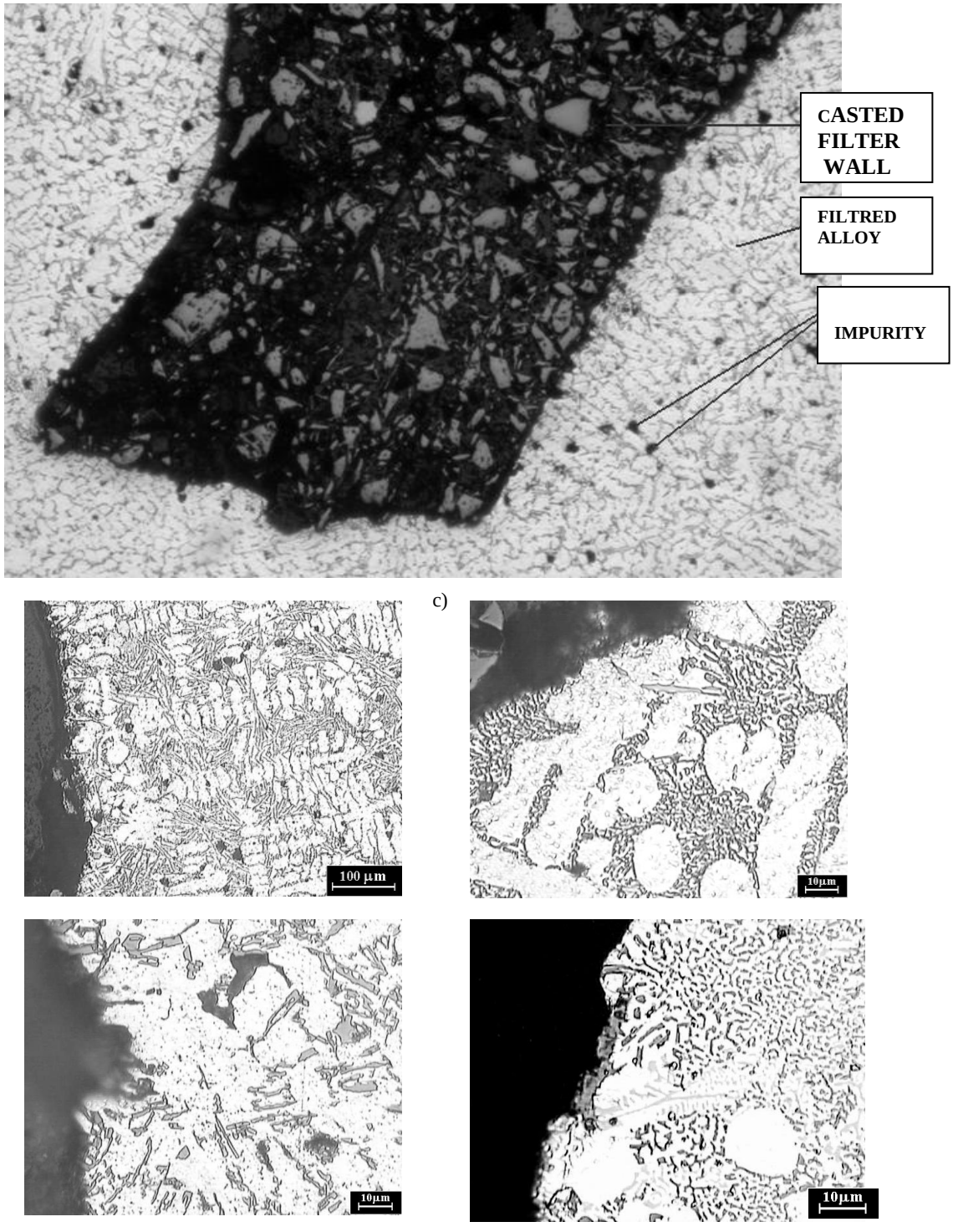

Fig. 4. Microstructures of the filters cast with the alloy AK11: a- form and distribution of impurities in the casted filter, b –retention of the impurity in the refined alloy, c – retained impurities and the secondary phases which occurred in the modified alloy

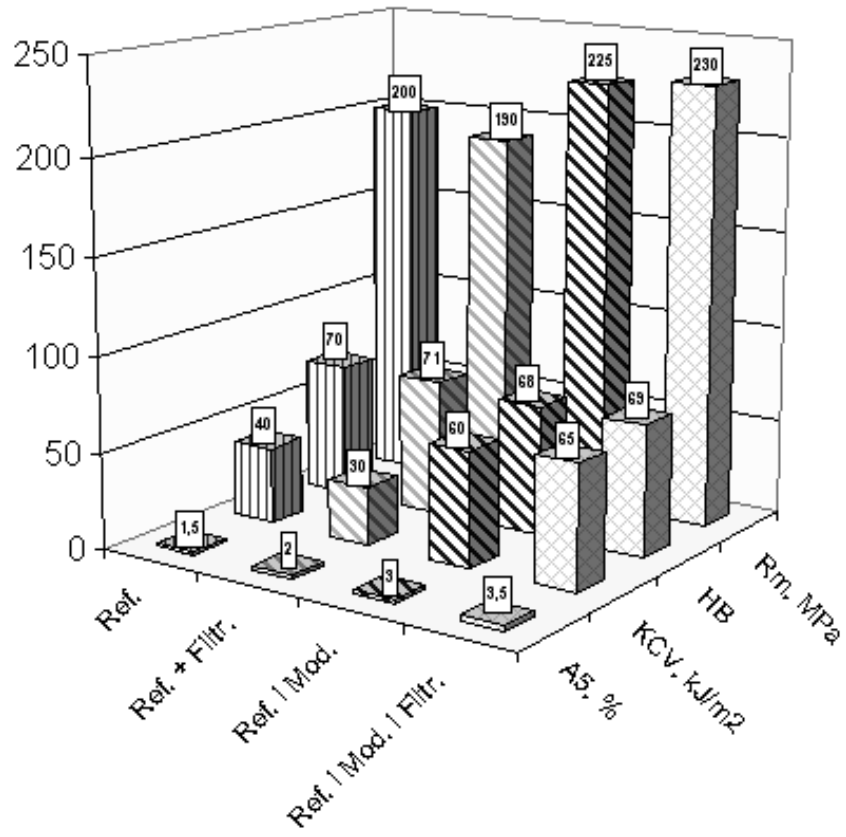

Fig. 5. Comparison of the mechanical properties for the alloy AK11

3. Conclusions

The results obtained from the carried out studies indicated for the possibility to obtain significant improvement of the structure and mechanical properties of the castings made from the charge stock (pig sows) which do not fully comply with the requirements of customers.

The different crystallization curves obtained in the graphical record of the ATD-AED method confirm the upgrading of the alloy AK11 after having carried out the melting and casting processes, fig.1.

Beneficial influence of the applied operations is confirmed by the obtained modified structures of the studied alloy, fig. 2 b and c.

In comparison to the refined alloy AK11, the strength R_m and elongation A_5 increased over 100%, while impact strength KCV – over 50% , fig. 5.

The filtration processes should be applied to the alloys which were previously modified, as for the alloy which were refined only, there is no improvement in mechanical properties.

The metallographic analysis showed occurrence of porosity and oxides in the samples made for mechanical strength measurements, cast directly from the pig sows of the alloy AK11, fig. 3.

The microstructures obtained from the channels of the ceramic filters cast with the studied silumin, show the shapes and deployment of the retained impurities as well as the crystallized intermetallic phases. The impurities and secondary phases retained in the filter may have significant influence on deterioration of the quality of the cast machine parts, fig. 4.

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