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The Use of Innovative Ceramic-Carbon Bonded Filters Used for Filtration of Liquid Alloys and Evaluation of the Filtration Efficiency

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Abstract

Extremely intense development of civilization requires from foundry casting technologies very high quality and not expensive castings. In the foundries, there are many treatments that allow increasing of the final properties of produced castings such as refining, modification, heat treatment, etc. One of the methods of increasing the quality of the casting by removing inclusions from the liquid alloy is filtration. The use of ceramic-carbon foam filters in filtration process is still analysed phenomenon that allows improving the final properties of castings. A modern method of research, testing and synthesis of innovative chemical compositions allows improving the properties of such filters. In the paper the evaluation of application properties of developed ceramic-carbon bonded foam filters is presented. The quality of the foam filters is evaluated by Computer Tomography and foundry trials in pouring of liquid metal in test molds. Additionally computer simulations were made to visualize the flow characteristics in the foam filter. The analysed filters are the result of the research work of Foundry Research Institute and the Institute of Ceramics and Building Materials, Refractory Materials Department in Gliwice.

Keywords: Ceramic-carbon filters, Filtration, Computer tomography, Simulations

1. Introduction

Filtration of alloys in the casting process is designed to remove inclusions such as slag, oxides, molding material, the materials of the furnace, etc. from the surface of the liquid metal. Currently, filters are available in the form of strainers, honey-comb filters, wire-mesh, and foam. The filtration process is used in the foundry industry for many years, however, there are research works still carried out on the filters with a higher yield, thermal and mechanical strength properties. In the initial phase of the casting process the filter is exposed to the thermal shock in a temperature range of 1400°C - 1650°C for steel alloys in about 30s per tonne of liquid metal [1,2]. Because of that the material of the filter should have a maximum strength under such extreme conditions. Simultaneously there is an effect of impact of the front stream of liquid metal on the surface of the filter. Therefore, the materials also need to have sufficient mechanical properties. The porosity of the filters presented in the article is in the range of 75-95%. The filtering mechanism takes place by entire volume [3]. The filtration process can be divided into three phases. The first phase of filtration takes place with maximum efficiency. The surface and the internal structure of the filter is stopping the inclusions. After a certain time, which is dependent on the amount of inclusions present in the liquid melt are coagulated on the surface of the filter and form a so-called filtration cake, which causes partial flow blocking. As a result of the accumulation of inclusions and expansion of the filtration cake the flow of liquid metal through the filter is blocked [4]. The additional effect of the liquid flow through the filter is the calming of the melt flow. In Figure 1 there is a diagram of filtration process [5].

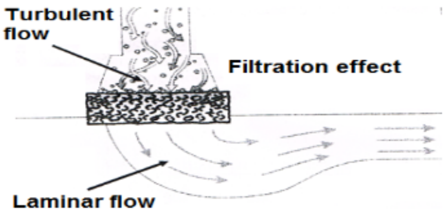

Fig. 1. An example of filtration process, the filtration cake formation and calming of the flow [5]

2. Foundry trials

The following studies have been performed on a series of ceramic-carbon bonded foam filters with different chemical compositions. Analysed suspensions and ceramic slurries are part of an ongoing research project so in the article there will not be provided a full chemical composition. After the analysis of physicochemical and rheological properties of the suspensions the batch of foam filters was prepared for trials in the foundry conditions. In the pouring trials the foam filters was evaluated of their resistance to thermal shock and impact strength of flowing liquid metal. Trials were conducted with steel alloy with 1600 ^{o}C pouring temperature. The 50 kg in the first trial and in the second trial 100 kg of liquid metal was poured. In Figure 2 the test molds with ceramic-carbon foam filters are presented.

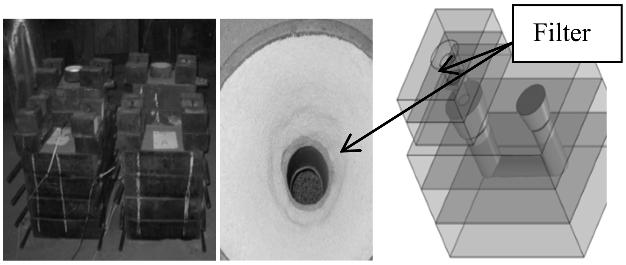

Fig. 2. Prepared molds for pouring trials, CAD model with marked filter nest

Conducted trials allowed determining the actual strength of the filter. The shock caused by a sudden increase of temperature and the strength of the impact of the liquid metal front where tested. The Figure 3 presents the pouring trials of molds after pouring with the results of conducted trials.

a) b)

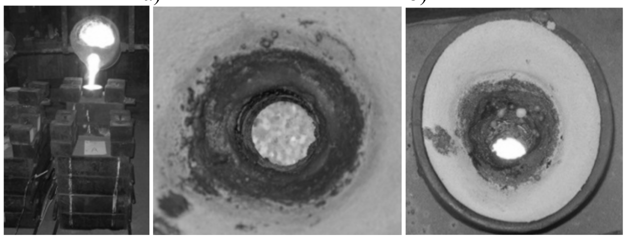

Fig. 3. Pouring trials, a) mold with filter, b) damaged filter

2.1. Computer tomography and measurements

During the manufacturing process of ceramic-carbon bonded filters polyurethane foam is used as a base structure and covered with suspensions such as SiO_2, SiC, Carbore resins etc., which is later drained from excess of ceramic material and subjected to pyrolysis [6]. During the process ceramic material is heated, hardened and polyurethane skeleton is burned out leaving a void in the filters structure branches. Analysis performed by CT scan [7,8,9] allows the assessment of the thickness of the layer which was formed in the process of covering with ceramic slurry and size of the void left by the skeleton of polyurethane foam. The CT reconstruction of two filters named A and Z made from new ceramic-carbon material was compared to commercially available filter. Processing of STL file with the measurements of a thickness of selected branches is shown in Figure 4.

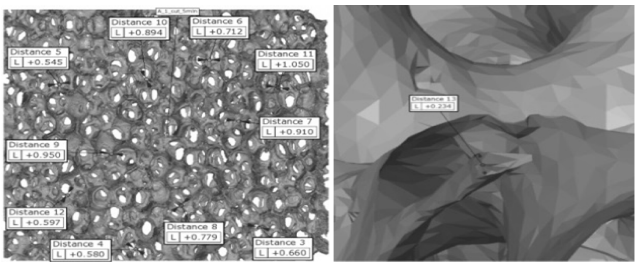

Fig. 4. The specified thickness of selected branch of foam filter A and the remains of the polyurethane skeleton

These measurements were made for filters A, Z and commercial filter. The Table 1 and 2 summarizes the results of thickness measurements. Summary of the results should be considered as approximate estimation of the repeatability of branch thickness of the filter. Due to the lack of symmetry the direct measurements of filters branches are not possible. This assessment allows you to compare their thickness in relation to the quality of coverage.

Table 1.
Summary of branches thickness

No	Filter A [mm]	Filter Z [mm]	Commercial filter [mm]
1.	0.545	1.622	0.957
2.	0.894	1.128	0.751
3.	0.712	1.536	0.804
4.	1.050	0.829	1.019
5.	0.910	0.975	1.006
6.	0.950	0.950	0.937
7.	0.597	0.952	0.825
8.	0.580	1.256	0.886
9.	0.779	0.672	0.640
10	0.660	0.939	0.961

Table 2.
Thickness of the void, residue from polyurethane skeleton

No	Filter A [mmm]	Filter Z [mm]	Commercial filter [mm]
1.	0.234	0.324	0.210
2.	0.284	0.312	0.204
3.	0.304	0.298	0.198
4.	0.259	0.288	0.245
5.	0.248	0.322	0.238

It can be observed that the technology of manufacturing of ceramic-carbon filters allows for achieving similar size of net to those in the commercial filter. In Figure 5 are shown cross-sectional views of 1mm of each filter.

a) b) c)

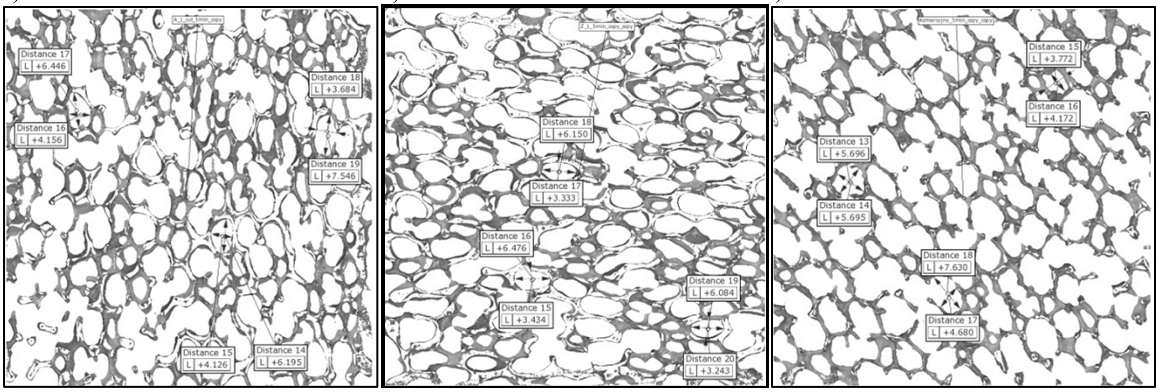

Fig. 5. A cross-section of 1mm filters a) A; b) Z and c) commercial

In the figures of cross-section it can be seen that the thickness of the commercial filter branches are more uniform. In the areas of nodes there are significant thickenings compared to ceramic filters A and Z. This may be due to different foam coating method and the process of removing excess saturant. The use of CT gives a view of internal shape of the filter. In Figure 6 the images of are air as spherical objects are shown, which could be enclosed in a ceramic slurry. The CT imaging shows that in the filters A, and Z the air bubbles are smaller and more dispersed. In the commercial filter the air bubbles are more accumulated in several areas and occupy larger volume. There should be taken an amendment to possible residues or artifacts present during the CT scan. In this analysis was used a software algorithm for reduction of such artifacts. The presence of voids in the form of air bubbles may negatively affect the strength of the filter surface. The local clustering of such voids can cause weakness in the filter branch, which can consequently cause damage of the filter.

a) b) c)

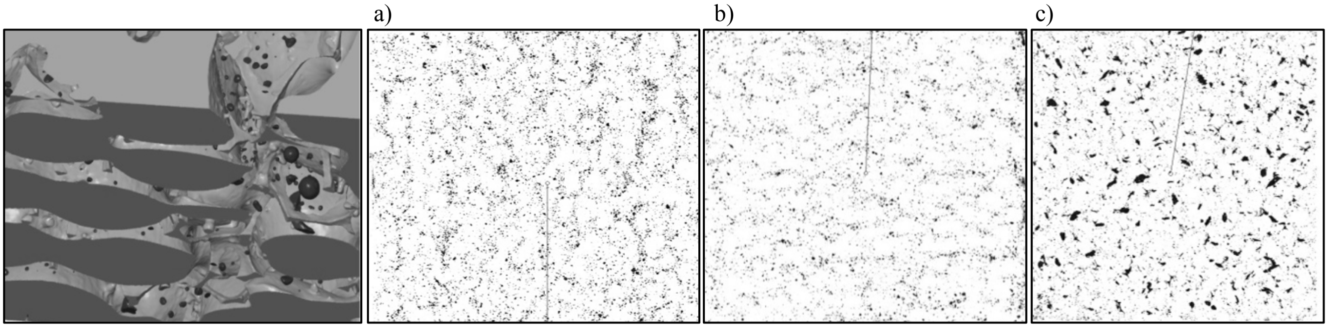

Fig. 6. CT visualization of air trapped in the ceramic coating a) A; b) Z and c) commercial

2.2. Computer simulations

Computer simulations were run in Flow3D program in order to verify the effect of the use of the filter in the gating system of commercially produced casting. It focuses mainly on the impact of the filter on the way how the liquid metal flows through the gating system [10]. The boundary conditions were set with regard to the parameters accompanying real process of casting. Figure 7 presents CAD model of casting with gating and risering system, view of modeled workspace in simulation software and casting.

a) b) c)

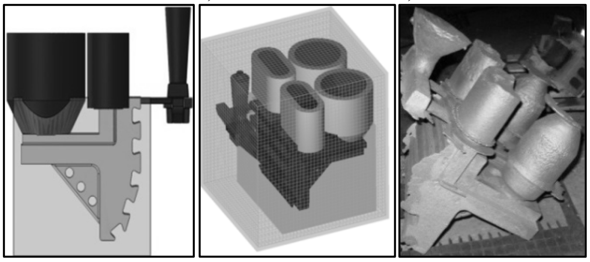

Fig. 7. a) CAD model with gating and risering system; b) workspace of simulation software; c) casting

In Figure 8 there are presented results from simulation of air entrainment in the flowing liquid metal. The amount of air that could be entrapped in the liquid metal is connected with turbulent flow. If the flow is turbulent the surface defects are grater and the risk of oxidization of the front of liquid metal is higher.

a) b)

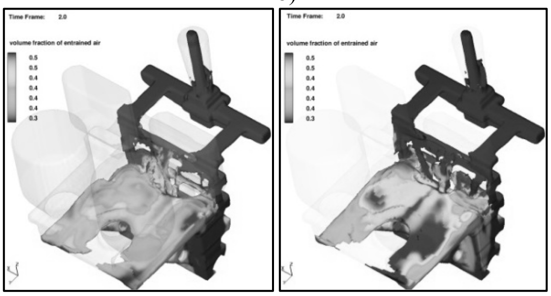

Fig. 8. Visualization of air closed by flowing liquid alloy a) gating system with applied filter; b) gating system without filter

Simulation allowed for visualization of the flow effects during mold filling. In the above figure it can be seen that application of filter can reduce the amount of air enclosed in the liquid metal. Filter used in gating system as has already been pointed out besides filtration slows down the velocity of the liquid metal in the filter and in addition makes laminar flow of metal. In Figure 9 there is a visualization of the results of the flow of liquid metal with regard the free surface defects. The scale shown in the figures has been narrowed in order to better present the phenomena.

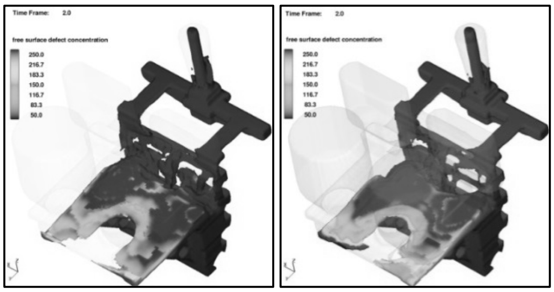

Fig. 9. Visualization of surface defect concentration a) gating system with applied filter; b) gating system without filter

Similarly to the results of the air closed in the melt, the flow of the stream is more disturbed in the system without an applied filter.

3. Conclusions

Implementation of CT allows determining coating thickness, the repeatability of the manufacturing process which results in the filters being transferred into their life in the foundry. Experiments have casting molten overflow allowed for testing filters in foundry conditions. These studies are used to select of the optimal configurations of ceramic-carbon composition.

Acknowledgements

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References

[1] Emmel, M. & Aneziris, C.G. (2012). Development of novel carbon bonded filter compositions for steel melt filtration. *Ceramics International*. 38(6). 5165-5173.

[2] Gwiżdż, A., Pirowski, Z., Pysz, S., Żuczek, R., Dworak, P., (2009). *Analysis of the pouring and solidification process of alloyed steel castings for low - temperature performance*. Papers of Foundry Research Institute. XLIX(1), 43-52.

[3] Piech, K., Siwecki, K. (1993). *Characteristics and application of ceramic filters. Quality and Technology*, Kraków: Foundry Research Institute.

[4] Trytek, A. (1996). Improving of the quality of heat resistant alloys by the use of foam filters. *Solidification of Metals and Alloys*. 26.

[5] Eds. Foundry Research Institute, Technology Department (2003). *The filtration of metals*. Wisła: Foundry Research Institute.

[6] Muzyka, R., Robak, Z. & Lipowska B. (2013). Determination of criteria for the selection of a carbon carrier in ceramic-carbon suspensions for liquid metal filters. *Ceramic Materials*. 65(4), 406-411.

[7] Tchórz, A., Boroń, Ł. (2013). Quantitative characteristics of morphology 3d graphite ductile iron with x-ray CT scan. In Pacyna J. (Ed.), *Papers of Materials Engineering* (p. 392). Krynica: PAN.

[8] Uniwersał, A., Wróbel, M., Wroński, S., Bonarski, J., Tchórz, A. & Kania, B. (2013). Comparison of selected methods of the porosity testing in pressure die-castings of the AZ91 alloy. *Metallurgist. Metallurgical news*. LXXX(4).

[9] Karwiński, A., Małysza, M., Tchórz, A., Gil, A. & Lipowska, B. (2013). Integration of Computed Tomography and Simulation Analysis in Evaluation of Quality of Ceramic-Carbon Bonded Foam Filters. *Archives of Foundry Engineering*. 13(4), 67-72.

[10] User Manual, 2010.