Available online at www.sciencedirect.com
ScienceDirect
Journal of the European Ceramic Society 27 (2007) 637–640
www.elsevier.com/locate/jeurceramsoc

Production of ceramic foam filters for molten metal filtration using expanded polystyrene

Z. Taslicukur *, C. Balaban, N. Kuskonmaz

Yildiz Technical University, Metallurgy and Materials Engineering, Davutpasa Campus, Davutpasa-Esenler, 34210 Istanbul, Turkey

Available online 7 July 2006

Abstract

Filtration of molten metals with ceramic foam filters is a proven method in order to remove the inclusions. This paper develops a new approach for the production of ceramic foam filters. In the conventional method of ceramic foam filter production, polyurethane sponges are used.

In this work, ceramic foam filter was produced by using expanded polystyrene. Polystyrene is expanded in a specially designed mold by steam to form polystyrene patterns. Various ceramic slurries are then poured into the polystyrene cell and allowed to air dry. After the shaping operation, filters are subjected to sintering process under various conditions. By this new method, filter channel sizes can be controlled and traps with desired configurations can be formed. Some tests were applied to the produced filters. Thermal shock tests ensured that the filters could withstand temperatures of 1450 °C. Water absorption test showed that bauxide based material absorbed water more than the others.

Keywords: Ceramic filter; Inclusion; Thermal shock resistance; Refractories; SiC

1. Introduction

The presence of nonmetallic inclusions is considered to be one of the most widespread causes of defects encountered in the casting process.[1] Nonmetallic inclusions are particles that are present in virtually all metals and depending on their shape, size, number and distribution, can influence the deformation properties of that metal and subsequent quality of the finished product.[2] The use of conventional gating systems even with generously dimensioned runner bars is not sufficient to retain enough slag and suspended reaction to meet the high quality standards of today's castings. These demands can be achieved with the help of filters.[3]

Liquid metal filtration during the casting process is now a very common technology in both ferrous and nonferrous alloy casting. Exogenous and indigeneous inclusions in the melts can be removed using filtration.[4]

Filtration is the process of seperating solid particles from the melt, with the solid particles being captured on the filter and the liquid phase passing through the filter.[5] Filtration improves the surface finish and pressure tightness of castings and improves mechanical properties of the castings. It reduces the rework on castings, increases machinability and improves casting yield.[4]

There are several established filter technologies presently on the market. These include strainer cores, woven cloth or mesh, and ceramic tile filters. Ceramic tile filters are generally considered to be the most effective. Pressed cellular, extruded cellular and foam filters are ceramic tile filters. Pressed cellular are characterized by round cells, extruded filters have square cells, foam filters have a random dodecahedron type structure.[6]

Metal filtration using foam ceramic filter media has been found to be an effective means of controlling the level and particle size of inclusions.[7] Reticulated ceramic foam filters have been used commercially in the foundry industry since 1977. The first application was in the United States in the production of premium quality aluminium castings for aerospace applications.[8]

The foam filter was recognised to have a unique, tortuous path through its body,which trapped inclusions and allowed clean, smooth-flowing metal to exit into the mold cavity.[9] Their main advantages are: the best filtration effectiveness and turbulence reduction, also their refractoriness and erosion reduction for the most demanded casting.[10]

Ceramic foam filters have open pore reticulated structure with a very high volume of porosity and very high surface area to trap inclusions.[11] They are open foam structures composed of

* Corresponding author. Tel.: +90 212 449 16 28; fax: +90 212 449 15 54.
E-mail address: ztasli@yildiz.edu.tr (Z. Taslicukur).

0955-2219/$ – see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jeurceramsoc.2006.04.129

ceramic material, such as alumina, mullite or silica. Ceramic foam filters operate in a mode of deep bed filtration where inclusions smaller than the pore openings are retained throughout the cross-section of the filter.[12]

Inclusion capture in deep bed filtration is considered to be a result of two sequential events: transport of an inclusion to capture sites on the filter media. Attachment of the particles to these sites.[13]

Ceramic foam filters are produced by impregnating reticulated polyurethane foam with a ceramic slip, removing the excess slip by squeezing the foam, then drying and firing the body.[14]

Correct choice of refractory material is essential for clean foundry practice. Poor quality refractories tend to be eroded very quickly causing particulate to be washed into the mold cavity.[15]

Refractory filter material must be able to withstand the initial metallostatic priming head and thermal shock without of spalling of filter fragments or breaking down.[16] Filter material properties necessary to attain temperature capability, chemical inertness, mechanical, physical properties and thermal properties.[17]

Proper pore size also is important, and size selection often involves a trade-off between product quality and size of the filter.[12] Finer pore size filters offer higher filtration efficiency and improved casting cleanliness,but larger areas are required to offset their higher flow resistance.[16]

In this work; it is aimed to produce a new filter that has larger surface area for deep bed filtration than the conventional one. The dimension of the molds can be changed so the size and amount of the filter porosity can be easily controlled.

2. Experimental procedures and results

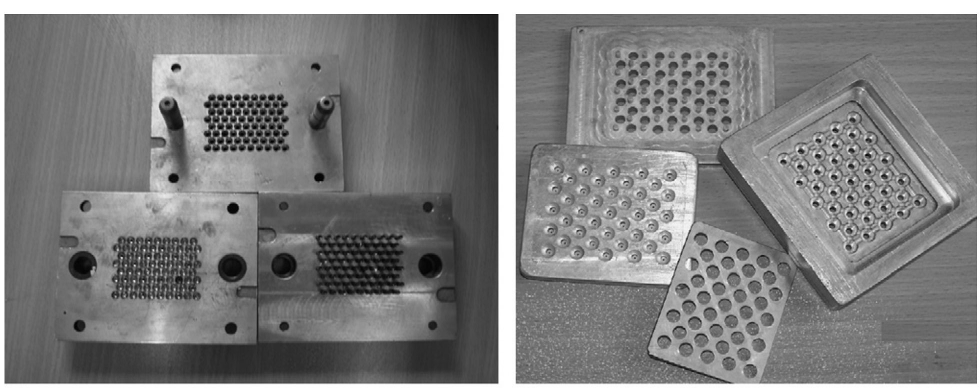
Conventional ceramic foam filters are produced from reticulated polyurethane foam. In this study, a new method is used in the production of ceramic foam filter. Expandable polystyrene is used instead of polyurethane sponge. Expendable polystyrene hard foam is a thermoplastic insulating material produced from petroleum. It is a hydrocarbon polymer made from crude oil and natural gas. It has a long chain-like structure consisting of 92% carbon and 8% hydrogen.[18]

2.1. Polystyrene pattern making

Two different molds are used to produce the filters. These two molds have different dimensions. The main objective is to use different molds where the sizes of filtration channels can easily be controlled and the filter can be produced with desired traps. One of the molds is made from stainless steel. The mold is made of three parts. It has 5 mm diameter spherical voids and connecting transitions with 0.1 mm diameter which connects the voids. In Fig. 1a, stainless steel mold is shown.

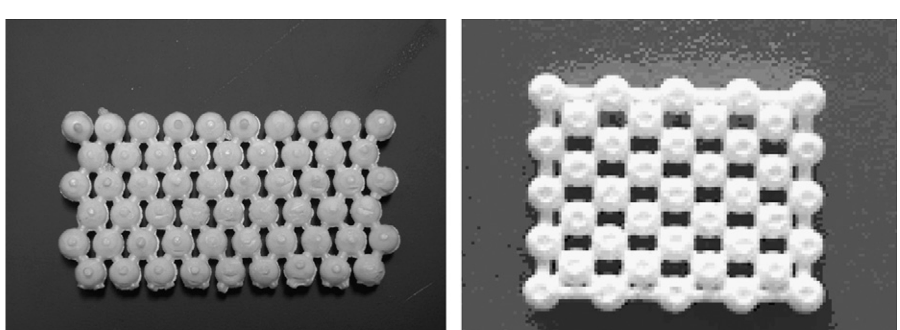
0.80 g of expandable polystyrene was weighed and put in the stainless steel mold uniformly to form polystyrene pattern. The mold was put in a furnace at 180 °C for 30 min. Then it was taken out and cooled in a water bath. Polystyrene pattern, formed in stainless steel mold, is given in Fig. 2a.

The second mold is made from aluminum material. The mold has four parts and diameter of 8 mm spherical voids, connecting



(a) (b)

Fig. 1. (a) Stainless steel mold. (b) Aluminum mold.



(a) (b)

Fig. 2. (a) Polystyrene pattern formed in stainless steel mold. (b) Polystyrene pattern formed in aluminum mold.

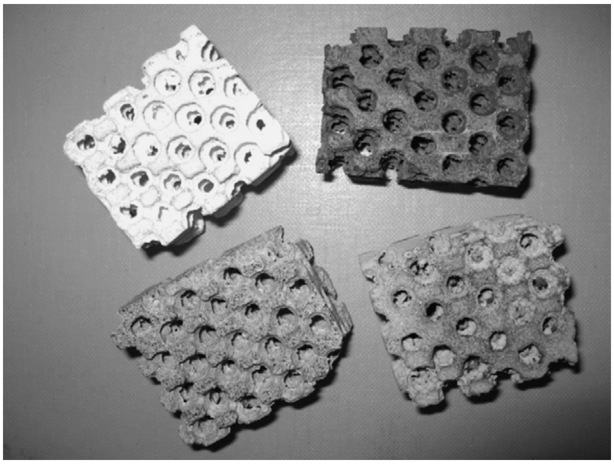


Fig. 3. Ceramic filters produced with different material.

transitions with 2.5 mm diameter which connects the voids. In Fig. 1b, aluminum mold is shown.

Polystyrene was pre-expanded to produce a foam in the steam production machine. Steam pressure is 6 bar in the machine. Polystyrene was pre-expanded at 100 °C for 40 s in pre-expansion machine. Pre-expanded polystyrene was dried at 50 °C for 2 h. 0.25 g expendable polystyrene was weighed and put in the aluminum mold. The aluminum mold was heated under 1 bar pressure for 75 s. Polystyrene pattern, formed in aluminum mold, is given in Fig. 2b.

2.2. Production of polystyrene cell and ceramic foam filter

Polystyrene cell was produced by sticking of the polystyrene patterns onto each other with a thermoplastic adhesive. Several ceramic materials such as lime bound corundum, spinel, silicone carbide and bauxide based materials were used to prepare the slurry. They were mixed with water and poured into the polystyrene cell in the silicone mold under vibration. Ceramic foam filter was dried at 600 °C for 3 h and sintered at 1250 °C for 3 h. Fig. 3 shows filters produced with different materials.

2.3. Properties of ceramic filters

Lime bound ceramic mixtures are used because the samples have a wet strength, they can be moved from the mold in a short time and have no cracks during drying and sintering processes.

Water absorption test was applied to the ceramic materials according to DÖKTAS A.S. Qualification Handbook Ceramic Filter Specification.[19] Filters were immersed in water for 24 h. Filters were weighed before and after this process. Max 9.5–11% is a normal value for weight difference. Silicone carbide, korundum, bauxide and spinel based materials have the weight difference of 5.4%, 2.9%, 9.2% and 7.5%, respectively. These results show that bauxide based material absorbs water more than the others.

Thermal shock resistance to flowing metal is the most important filter property. The literature has lack of consistency in the techniques employed to evaluate the thermal shock resistance. For determining thermal shock resistance of filters, the filter samples were heated to 1150 °C and held there for 5 s., and then were swung away from the flame in order to air cool. The weight loss of the sample due to spalling was then used as a measure of its thermal shock resistance. A zero weight loss would indicate that no damage occured during the test.[20] The test was applied to the filters and there was zero weight loss in each sample.

The other thermal shock test was applied to silicon carbide and bauxide based filter material according to DÖKTAS A.S. Qualification Handbook Ceramic Filter Specification.[19] Filters were dipped in a crucible with liquid metal at 1450 °C temperature for 30 s. There were no cracks or fracture in the filters.

3. Conclusions

Filters produced using polystyrene cell have desired and predetermined surface versus transition areas. The filters can be used in two positions. In the first case, it has straight transitions and in the second case, it has crosswise path.

The result of the water absorption test shows that the average value of the difference between filter weights is 6.25%. The filters can withstand temperatures of 1450 °C.

One disadvantage of this new method is the usage of excessive ceramic material which increases the cost and the weight.

Acknowledgements

The authors wish to acknowledge The State Planning Organization Prime Ministry of T.R., Yildiz Technical University Research Fund and BCACT—Balkan Center for Advanced Casting Technologies for their financial support and providing research facilities.

References

1. Hack, J. A., Clark, H. and Child, C., *The filtration of steel castings*. The Foundryman, April 1990, pp. 183–188.
2. Riedel, U. T., Morgan, J. E., McMahon, C. A., Guild, F. J. and Bleck, W., The detrimental effect of non-metallic inclusions during metal forming processes. *Proc. Instn. Mech. Eng.*, 1999, **213**, 427–430.
3. Foseco Foundry International, SEDEX, The Ceramic Foundry Filter With Foam Structure. Staffordshire, England, 1999.
4. Wang, V. W., Mako, G. J. and Matthews, A. L., Pressed cellular filter application in an aluminum foundry. *AFS Transact.*, 1996, 1045–1052.
5. Jaromir, R., Casting alloy filtration. Czech foundry society technological commission. *Brno*, 2000, 15–16.
6. Andrews, I. A. and Matthews, A. L., *Molten metal filtration*. Ductile Iron News, Hamilton Porcelains Limited, Canada, 1996, pp. 1–10.
7. Chen, F., Huang, X., Wang, Y., Zhang, Y. and Hu, Z., Investigation on foam ceramic filter to remove inclusions in revert alloy. *Mater. Lett.*, 1998, 372–376.
8. Aubrey, L. S. and Schmahl, R., Application of reticulated silicon carbide foam filters for iron casting applications. *Foundry Trade J.*, September 1991, 769–773.
9. Sandford, P. and Sibley, S. R., Optimization of Al casting productivity using foam filter technology and application. *AFS Transact.*, 1996, 1063–1068.
10. www.lanik.cz.

11. Brown, J. R., *Filtration of castings. The Foseco Foundryman's handbook* (*10th ed.*). Nechells, Birmingham, 1994, pp. 339–363.
12. Adams, K., Williams, E. J. and Kannah S, *Filtering basics: who, what, where, why & how. Modern Casting*, March 2002, pp. 1–6.
13. Hübschen, B., Krüger, J. G., Keegan, J. N. and Schneider W. A new approach for the investigation of the fluid flow in ceramic foam filters. *Light Metals*, 2000, pp. 1–7.
14. Ray, S. F., Recent improvements in the measurement and control of ceramic foam filter quality. *Aluminium World*, 2001, **1**(2), 1–4.
15. MIBF Corns DB, Metal filtration—a positive means to clean castings. The Foundryman, October 1991, pp. 370–372.
16. Aubrey, L. S., Schmahl, J. R. and Cummings, M. A., Application of advanced reticulated ceramic foam filter technology to produce clean steel castings. *AFS Transact.*, 1993, 58–66.
17. Morris, J., Sahu, S. and Sievers, U. S., Advanced reticulated ceramic metal filters and performance results from select steel foundries. *AFS Transact.*, 1990, 671–675.
18. Monroe, R. W., *Expendable pattern casting*. American Foundrymen's Society, Georgia, 1992, pp. 21–37.
19. Doktas, A. S, *Qualification handbook ceramic filter specification*.
20. Sutton, W. H., Palmer, J. C. and Morris, J. R., Development of ceramic foam materials for filtering high temperature alloys. *AFS Transact.*, 1985, 339–346.