Reply Paper

Reply to Discussion of "Characterization of Ceramic Foam Filters Used for Liquid Metal Filtration" and "Electromagnetically Modified Filtration of Aluminum Melts: Part I. Electromagnetic Theory and 30 PPI Ceramic Foam Filter Experimental Results"

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The focus of the current study has been on the filtration of particulates in aluminum cast house operations and not in foundry casting. The Remelting and Inclusion Refining of Aluminum project (RIRA) was conducted in coordination with industrial partners (Alcoa, Norsk Hydro, and Sapa) and addressed their desire to remove very fine particulates (down to 10 μm) for high performance applications.

The filter sizes used in aluminum cast houses are of the order of 20 to 50 pores per inch (PPI) and the typical "free space" casting velocities are in the range of 0.2 to 1.5 cm/s, as recommended by one filter manufacturer.[1] Filtration efficiency is known to be inversely related to velocity and positively correlated with higher filter PPIs. Lower velocities and tighter filters are typically applied to the higher quality grades. Low velocities (<1 cm/s) and "tight" filters (30 to 80 PPI) were, therefore, selected by the current authors as being consistent with the goal of improving filtration efficiencies for particles as fine as 10 μm.

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In the paper, "Characterization of Ceramic Foam Filters Used for Liquid Metal Filtration," much higher than typical cast house filtration velocities were considered in order to derive Forchheimer coefficients[2] suitable for use with the 2D axial symmetric finite element modeling of "Electromagnetically Modified Filtration of Aluminum Melts." The Lorentz forces present during electromagnetic filtration were known to induce powerful and rapid magneto-hydro-dynamic (MHD) mixing. The range of velocities was therefore *increased* by more than one order of magnitude, in order to insure the validity of the derived coefficients in the subsequent modeling work. Higher velocities than those reported could not be achieved with the apparatus constructed for this experimental work due to the high-volume/low-head pump used. Slightly higher velocities were achieved for the lower PPI filters due to their lower pressure drop at any given velocity.

The authors have made no assumptions as to the correct role of filters, filter pore sizes, or the relative importance of bifilms and particulates in foundry applications. Any potential application of the current research to foundry castings is fortuitous, as the current work was focused solely on high tonnage aluminum cast house operations.

Bifilms[3] are very large as noted by Prof. Campbell, and are therefore relatively easy to filter (unless rolled tightly) in comparison to the target particulates in the current study (down to 10 μm). Bifilms were therefore not a primary consideration. This in no way reflects the current authors' opinions of their relative potential for harm, should they be present in quantity, in any given casting application. The authors do not wish to debate the relative roles of bifilms and particles in foundry applications; however, the current research has shown that at high particle loading, individual particles tend to form clusters and *interact strongly with bifilms when present*. Bifilms have been observed to form scaffolds within the filter media and appear to positively influence the net filtration efficiency of lower PPI filters. Random variation in the concentration of bifilms may be responsible for some of the variability in filtration efficiency experienced when using low PPI ceramic foam filters (CFFs). Low PPI CFFs exhibit a large standard deviation in filtration efficiency.[4]

A new paper is in review by *Metallurgical and Materials Transactions B*: "Electromagnetically Modified Filtration of Aluminum Melts Part II: Filtration Theory and Experimental Filtration Efficiency with and without Electromagnetic Priming for 30, 50 and 80 PPI Ceramic Foam Filters." This paper includes some representative high resolution SEM micrographs showing the interaction of bifilms and particles during low velocity gravity filtration. The alumina bifilms are observed anchoring themselves to the alumina of the CFF and obstructing the opening of pores. The melt downstream of many bifilms is very clean. The relative wetting characteristics of the filter media and the material to be filtered, *i.e.*, SiC and bifilms, are discussed in relation to the observed filtration efficiencies.

In the Part II paper, the role of the effective electrical conductivity of the filter media and its influence on the magnitude of the Lorentz forces within the filter and the resulting *Leenov–Kolin effect*[5] are discussed. It is postulated that 10 or 20 PPI filters would be more optimal for Electromagnetically Enhanced Filtration due to their higher effective electrical conductivity. Lower PPI filters have higher effective electrical conductivity due to their higher porosity and lower tortuosity (lower fraction of closed windows), which results in more conducting area and a more direct conducting path. The higher effective electrical conductivity results in higher induced currents for any given applied magnetic field intensity and more powerful Lorentz forces near the outer surface of the filters. The authors are therefore positively disposed to extend the current research to lower PPI filters and to as high a velocity as can be accommodated within the capabilities of the current test equipment. Collaborative efforts would be welcomed.

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