More than just a filter

Introduction

The last 20 years has seen significant improvements in foundry practice and process control. Improvements in melting technology; inoculation/nucleation and alloying processes; temperature control and moulding and coremaking practices have fundamentally improved the quality and consistency of liquid metal in the foundry.

During the same period, the application of filtration technology has continued to rise. How can it be that despite advances in metal quality, the growth in the number of filter applications shows no sign of slowing down?

There are a number of reasons to explain these seemingly contradictory statements:

- the ongoing development of filtration technology to produce more effective and efficient inclusion removal;
- the realisation by foundrymen that filters add as much to casting production in the form of process control and productivity enhancements as they take away in the form of unwanted non-metallic by-products of the casting process;
- rising casting quality standards;
- increasing casting performance requirements;
- the pressure to reduce costs by reducing scrap and/or improving yield;
- the drive to reduce casting weights, resulting in thinner wall sections which are more sensitive to inclusions and reoxidation defects;
- the rise in popularity of automatic pouring leading to higher metal velocities and the increased potential for turbulence and erosion defects;
- the increased use of simulation and other predictive techniques has shown the positive benefits of filtration on mould-filling much more clearly.

In short,the use of foam filters continues to grow because the value added is greater than the cost of their application and purchase.

It is not simply the elimination of scrap but the improvement in the quality of casting production as a whole. Whereas 20 years ago filters were used only in an emergency, today they are fundamental to the production of high quality automotive and engineering components at optimum cost (1).

Sources of Inclusions

"Dirty" metal is the most obvious source of inclusion material. Unwanted materials may enter the melt through any number of ways including the addition of unshotblasted returns to the charge, oxidation problems during metal transfer, the generation of reaction products of alloying elements and other melt treatment products and the erosion of refractory materials and slag build-up due to poor ladle maintenance.

However, often overlooked sources of problems occur in the mould such as reoxidation due to excessive turbulence; mould erosion due to high metal velocity, poor mould strengths; and steam or gas problems in the mould due to insufficient venting and/or metal mould reactions.

One of the benefits of using foam filters is in assisting the foundryman in diagnosing the source of scrap by separating the problems of dirty metal from problems occurring behind the filter in the gating system and mould cavity.

How Filters Work

Uni-dimensional products such as extruded (figure 1) and pressed ceramics (figure 2) and steel or cloth mesh only remove inclusions at the surface and inclusions smaller than the minimum cell or hole size are not retained and flow into the mould cavity (figure 3).

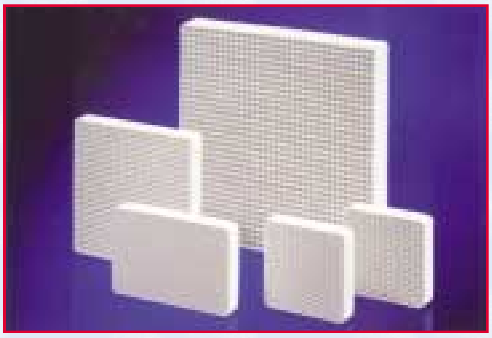

Figure 1: Extruded filters

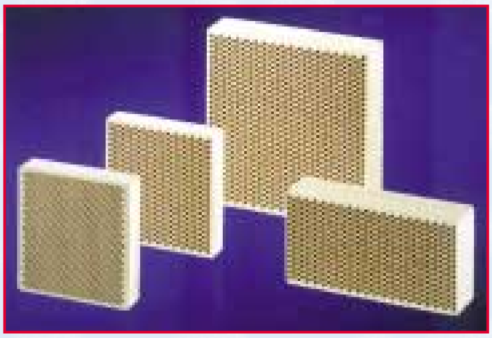

Figure 2: Pressed filters

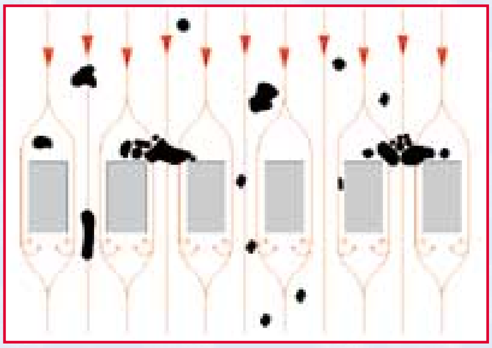

Figure 3: Mechanism of uni-dimensional filter types

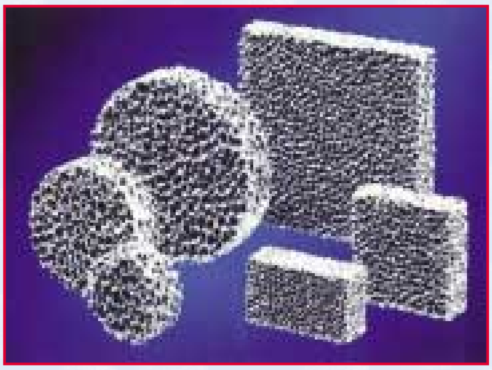

Figure 4: Foam filters

In contrast, foam filters (figure 4) are multi-dimensional filters. The metal must flow through a tortuous path before it enters the casting cavity

First, coarse inclusions, too large to enter the passageways are trapped on the surface of the filter (figure 5).

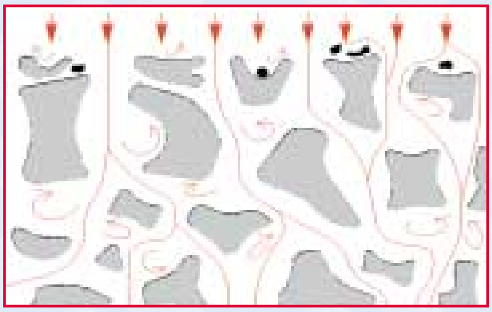

Figure 5: Surface filtration

As inclusions begin to accumulate on the filter face, a "cake" of material is formed which only then permits retention of some finer particles (figure 6).

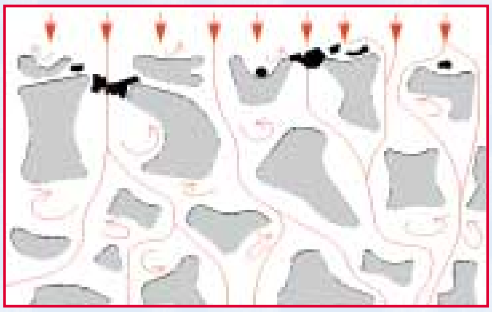

Figure 6: Cake filtration

Molten metal that flows past the filter cake and into the passageways follows a tortuous path through the body of the filter. The foam filtration mechanism is based on multiple changes in metal flow direction and reduction of flow speed, causing smaller particles to be trapped in the internal filter structure (figure 7).

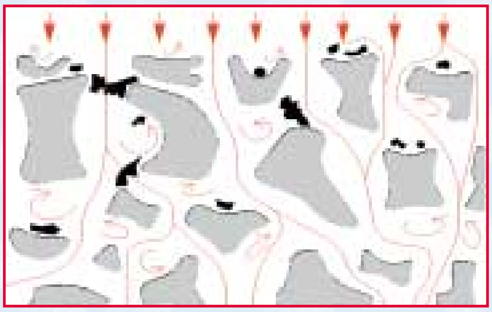

Figure 7: Deep bed filtration

The efficiency of foam filters in removing typical non-metallic inclusions arising from the melting, alloying and moulding processes can be seen in Figure 8. In the first picture, sand grains plug the filter pores. In the second image, slag accumulates in the top of the filter. In the final image, a thin zone of magnesium sulphide can be seen across the entire entrance face.

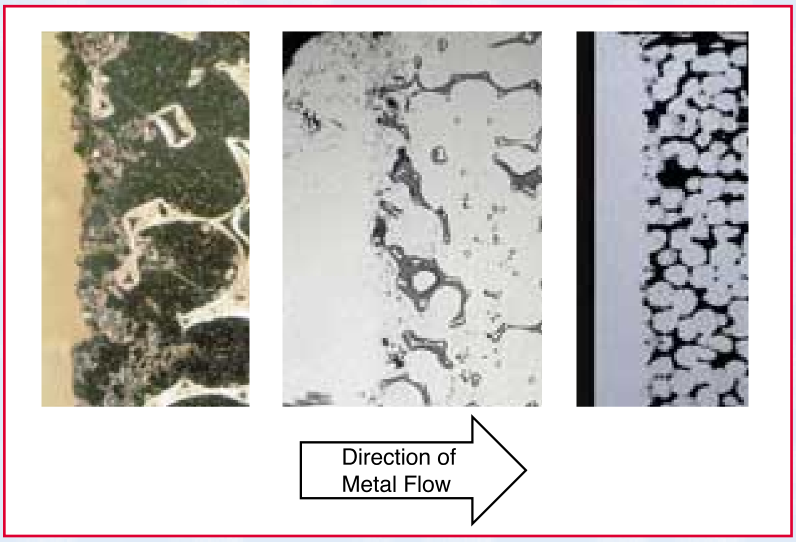

Figure 8: Removal of non-metallic inclusions

Finally, foam filters help to prevent the formation of reoxidation inclusion by promoting reduced-turbulent flow as the molten metal enters the casting cavity (figure 9).

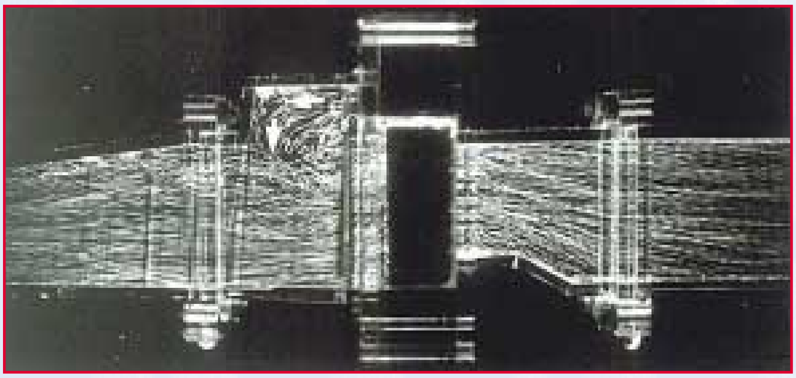

Figure 9: Water model – demonstrating function of slag chamber and filter

Turbulence should be minimised for all alloys and especially those that oxidise readily. Turbulence leads to the entrapment of gas inclusions, folding in of oxides and the creation of new oxides from the exposure of clean metal to the atmosphere (3).

Filter selection, placement and running system design are all fundamental to the minimisation of reoxidation. Extensive water flow testing, x-ray studies and fluid-flow analysis have proved conclusively that foam filters, correctly applied, have the greatest effect on preventing reoxidation.

Pressed filters have larger "dead zones" on the exit face of the filter which reintroduce air bubbles into the metal stream after the filter. The exit area of the water stream from a foam filter is much broader, indicating a slower, less turbulent flow and there are almost no air bubbles behind the filter (figure 10).

Repeating the same test with an aerated water flow shows that both pressed and extruded products have no effect on entrained air bubbles. In contrast, the foam filter slows the flow of water so that the entrained air can escape. This is the same mechanism that reduces turbulence and gives a foam filter its higher filtration efficiency (figure 11).

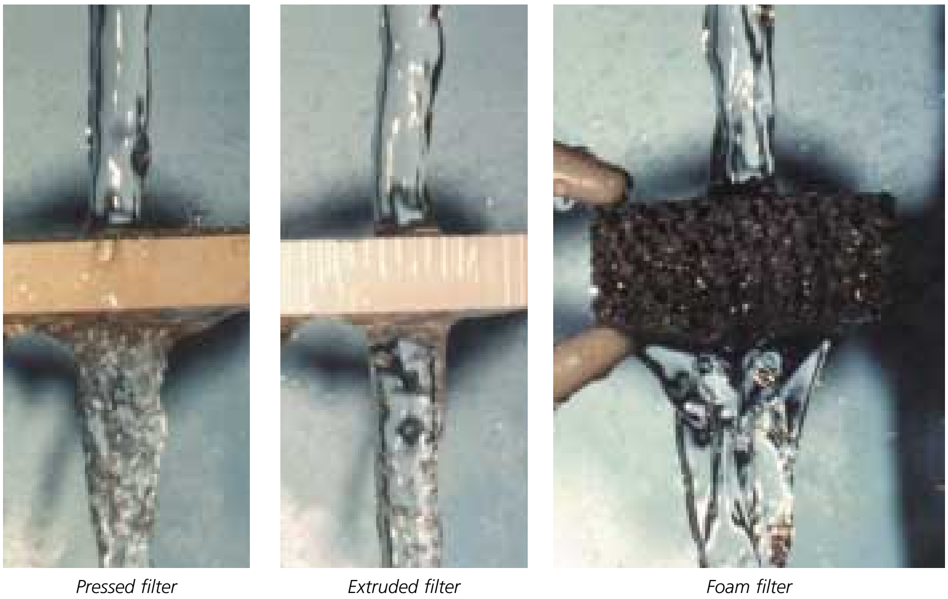

Figure 10: Comparison of water flow through filter types

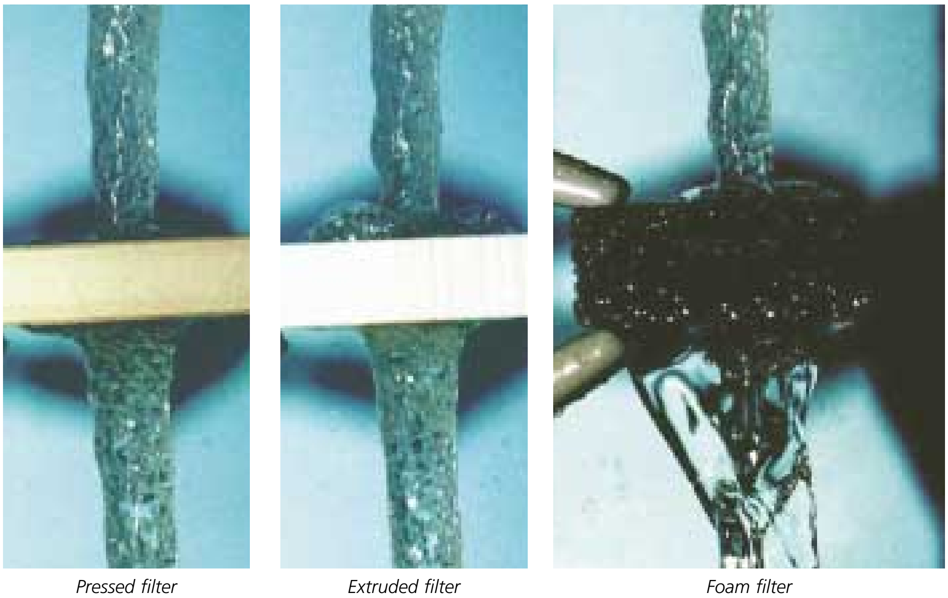

Figure 11: Comparison of aerated water flow through filter types

Figure 12: X-ray analysis shows the ability of filtration to reduce turbulence in molten metal entering the casting cavity

Further confirmation of the flow smoothing properties of foam filters has been provided by real-time x-ray (figure 12).

Attributes of Filters

The attributes of the three basic structures are shown in the table below.

Thus foam filters outperform other types in four key areas:

- smaller, finer particles of inclusion material are removed;
- the reduction in velocity and turbulence reduces sand erosion:
- reduces the risk of reoxidation by entrapped air due to post-filter turbulence;
- greater resistance to thermal breakage in daily use.

Benefits of Foam Filtration

The benefits of foam filtration are not only confined to the reduction in scrap but are seen throughout the foundry. Depending on the alloy and application many of the following benefits are achievable:

Scrap control

- lower levels of scrap produced;
- improved ability to diagnose scrap problems due to a clearer separation of metal and mould factors;
- reduction in expensive machine scrap;
- running systems and downsprues fill smoothly and remain full, reducing the probability of gas bubbles entering the casting cavity;
- in the case of aluminium filtration non ceramic foam filters eliminate the dangers of melt contamination from hard ceramic particles and iron pick up from steel mesh or sieves.

Attribute	Foam	Extruded	Pressed
Dimensional Accuracy	Moderate	High	High
Cold Strength	Moderate	Moderate	High
Filtration Effectiveness	High	Moderate	Moderate
Particle Retention Size	Fine	Medium	Medium/Coarse
Effect on Flow Rate	High	Moderate	Moderate
Turbulence Reduction	High	Minimal	Minimal
Erosion Resistance	High	Moderate	Moderate
Refractoriness	High	Moderate	Good

Productivity Improvements

- lower tonnes shipped to tonnes melted ratio (yield) due to the elimination of long running systems designed to float out inclusion leads to savings throughout the foundry;
- simplified gating systems since the filter itself will reduce velocity and smooth the flow of liquid metal;
- simplified pattern designs can allow a foundry to reduce mould sizes or make more castings per mould;
- higher yields mean that more moulds can be poured per melted tonne;
- frequently possible to reduce pouring temperatures;
- low density, non ceramic foam filters float to the surface of molten aluminium on remelting and can easily be skimmed off with the dross;
- lower levels of cash tied up in work-in-progress.

Casting Quality Improvements

- greater consistency in casting cleanliness;
- a reduction in the variability of metal flow of hand-poured castings leading to increased product consistency (2).
- improved mechanical properties due to greater metallurgical consistency;
- increased fluidity of the metal improves casting finish, appearance and surface details.

After Cast Operations

- improved machinability and reduced tool-wear;
- machining allowances can be reduced with confidence due to a lower level of inclusions;
- reduction in inspection and expensive time-consuming non-destructive testing operations;
- faster cycle times, especially where there are major savings in after-cast operations increases work schedule flexibility and foundry competitiveness;
- non ceramic foam filters can be removed by machining without damaging cutting or machining tools.

References:

(1) SADON, P. HURDEBOURCQ, D. MORISSE, J-C. BESVILLE, J-C. & TAYLOR, K. C. Industrial experience in the filtration of cast iron at the Peugeot Citroen Foundries, Proceedings of Conaf 2001, 10th Foundry Congress, Sao Paulo, Brazil, May 23rd to 25th 2001.

(2) KENDRICK, R. Energy saving using SIVEX FC filters. FOSECO Foundry Practice, Issue 228, September 1996.

(3) SANDFORD, P. & SIBLEY S.R. The application of foam filters to optimize aluminum casting production. FOSECO Foundry Practice, Issue 227, April 1996.