The Next Generation of Carbon Bonded Filters

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Abstract: Filtration of molten metal is established practice for many foundries around the world. Filters are used to reduce the risk of non-metallic inclusions being present in the casting and to modify the metal flow – essentially to reduce metal turbulence in the casting cavity.

Traditional filters are generally either foam, pressed, or extruded refractory ceramic products. Each of these filter types offer some advantages and disadvantages. This paper describes a next generation filter that Capital Refractories has recently introduced that offers most of the advantages with less of the disadvantages of traditional filters.

Key Words: Metal Filtration; High Capacity Filters; Steel Filtration; Heavy Iron Filtration; Next Generation Foundry Filters

1 Introduction

There are several types of molten metal filter available to foundries. The most popular "traditional" filters include foam, pressed and extruded. More recently, "Next Generation" filters have emerged thanks to new manufacturing technologies: such as additive manufacture.

2 Different Types of Molten Metal Filters

Foam Filters

Foam filters are manufactured using a ceramic slurry. The slurry is usually an aqueous mixture of the main refractory powders This slurry is then used to coat reticulated polyurethane foam. After coating, the filter is dried and fired. During firing, the polyurethane foam pre-curser will burn out and the strands of the foam filter will be hollow. This process lends itself to utilising a wide range of materials for different alloys types: such as zirconia/alumina or carbon-bonded alumina for steel, silicon carbide for iron and non-ferrous metals.

Foam filters are characterised by their sponge like reticulated structure; this makes for a tortuous path through the filter. Their porosity is expressed as "ppi" (pores per inch) and will range from about 10ppi for coarse filters to about 30ppi for fine filters. Finer porosities are available for more specialised applications.

3 Pressed Filters

Pressed filters are manufactured by pressing refractory powders into a complex mould. This mould contains many pins that form the holes in the filter. The powders are formed around the pins, and these are then extracted to form the filter. The pressed filters are then dried and fired. They are usually made using mullite or alumina with a clay bond.

Pressed filters are characterised by a honeycomb design with circular holes. Their porosity is usually expressed as a cell diameter: e.g., 2.5 mm cell diameter. Unlike foam filters, pressed filters do not create a tortuous path but a simple linear one.

They are generally not as refractory as foam filters and are rarely used for steel but do find considerable use for grey and ductile iron.

4 Extruded Filters

Extruded filters are manufactured by extruding a refractory dough through a die. The dough is usually an alumina-based composition with rheological additives. The extrudate emerges from the die as a continuous "log". This log is then sliced into individual pieces after which they are dried and fired.

Extruded filters are again characterised by a honeycomb design with square holes. They are commonly made from alumina and their porosity is conventionally expressed in CSI (cells per square inch).

Like pressed filters, they are not normally as refractory as foam filters and are mainly used for melting iron and rarely used for steel. The lack of refractoriness also gives a limit to the time of exposure to hot metal.

5 Next Generation Filters

New manufacturing techniques have made new filter structures possible. An example of a new manufacturing technique is additive manufacturing which uses a process in which layers of material are laid down upon the previous layer in such a manner as to create an engineered structure that can be designed to form a tortuous path of differing complexities. They are then dried and fired as per other filter types.

A next generation filter can generally be characterised as having a consistent and repeatable structure (like pressed and extruded filters) but combined with a tortuous flow network (like foam). They are made from various materials such as zirconia, alumina and can be carbon bonded.

6 Desirable Properties in a Molten Metal Filter

There are many desirable traits that an ideal molten metal filter should have. Some of these properties are in conflict with each other. For example, a filter with a very large capacity may not have a very high filtration efficiency. Filters with a very consistent structure (e.g. pressed cellular filters), may not have very good flow modification properties. Ideally a filter should have the following attributes:

Good filtration efficiency
High pour rate
High capacity
Consistent structure
Good flow modification abilities
High strength (hot and cold)
Be cost effective.

7 Filtration Mechanisms

Filters prevent inclusions from occurring in the finished casting by a variety of mechanisms. These include screening, deep bed filtration and flow modification.

Screening is simply the prevention of large pieces of slag or dross passing through the filter due to their physical size compared to the size of the filter cells/pores.

Particles that are smaller than the lattice gap that are able to pass through the initial layers may eventually stopped due to the tortuosity of the internal structure. This is deep bed filtration

This sort of filtration process is realistically only offered by filters that force the metal to take a tortuous path through them such as foam filters and next generation filters.

Flow modification is essentially the reduction of turbulence in the molten metal stream and is arguably the most important attribute of a filter. A reduction in turbulence will reduce the chances of inclusions being generated from re-oxidation, the effects of mould erosion, and other flow related defects such as caused by mould erosion.

8 Attributes of Foam Filters

Foam filters have very good filtration efficiency by virtue of their structure; both screening and deep bed filtration mechanisms will be effective. Additionally, foam filters have a very good flow modification effect due to their tortuous structure. This reduces the kinetic energy of the metal stream and essentially calms the flow.

The capacity of foam filters is limited by the porosity. One of the biggest issues with foam filters is their consistency. Every foam filter will have a unique structure. This results in variation in both capacity and flow rates.

Another issue with foam filters is spalling or friability. This is when small strands of the filter break off; it is possible that these ceramic pieces can end up in the casting.

In terms of hot strength, foam filters are generally good. However, as the filters get larger (200 mm and above) they are more susceptible to breakage.

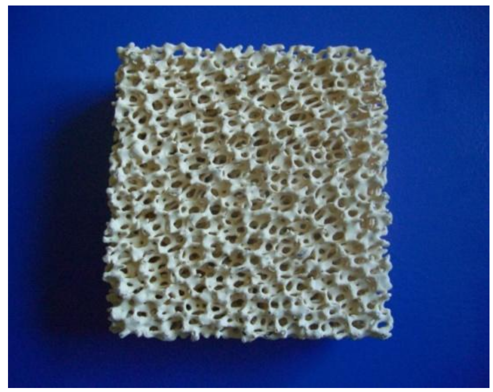

Fig. 1 – A zirconia foam filter

9 Attributes of Pressed Filters

Pressed filters usually have round holes. Unlike foam filters, they have a very repeatable and consistent structure. However, they do not have as good a filtration efficiency or flow modification effects. They are very robust and have good cold strength. Larger sizes can suffer from hot strength and creep issues.

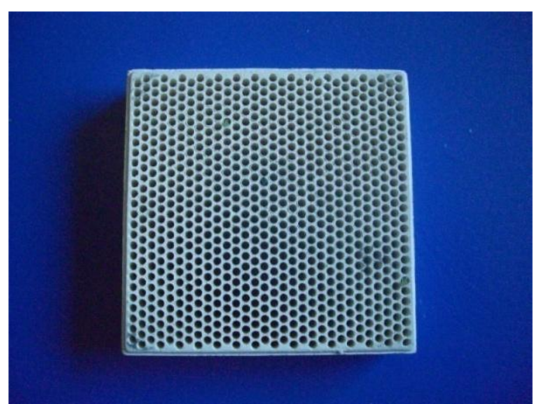

Fig. 2 – A Pressed Ceramic Filter

10 Attributes of Extruded Filters

Extruded filters are similar to pressed filters except they usually have square holes and a higher open area. They also have similar filtration efficiency and flow modification effects to pressed filters. Again, larger filters can suffer from strength issues at high temperatures.

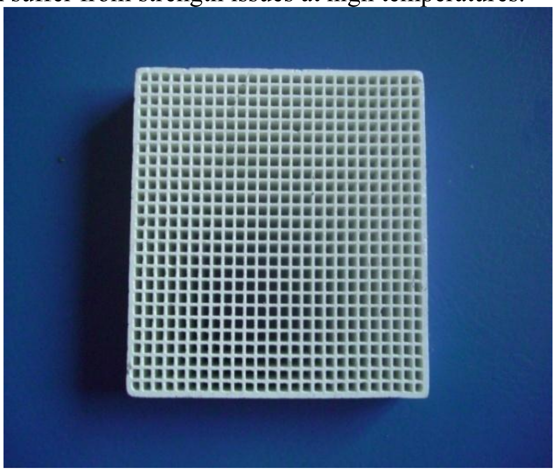

Fig. 3 – An Extruded Ceramic Filter

11 Attributes of MetCon C – Next Generation Filter

There are now several types of "next generation" molten metal filter available. These filters generally use a form of additive manufacture to produce a more consistent, tortuous structure that can be more customisable in terms of pore size etc. Even though these filters offer an "ideal" combination of physical properties, they are generally very expensive and can often be uneconomic to use.

MetCon C filters are manufactured using a unique additive manufacturing type of process with the aim of offering a cost-effective next generation filter. Whilst they may be slightly more expensive than traditional filters, the improvement in physical properties make them cost effective. Like foam filters, they have very good filtration efficiency due to the tortuous path, good screening and deep bed filtration, and good flow modification effects. However, unlike foam filters, their structure is consistent and repeatable. It is also possible to offer very coarse porosities so very high capacity/flow rate filters are possible. The exceptional hot strength of MetCon C filters makes it possible to make larger filters so that very large castings can be poured directly through a single filter.

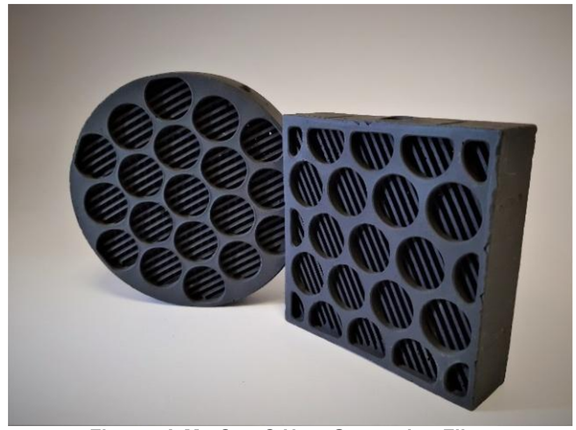

Fig. 4 – A MetCon C Next Generation Filter

High Capacity/High Strength Filters

Foam filters can be limited in their capacity by their porosity. Generally, the coarsest porosity available is 10ppi. There are occasions when a coarser porosity would be desirable such as when pouring manganese steel.

Pressed and extruded filters can have larger hole sizes to increase capacity, but the larger the hole, the more they resemble standard strainer cores – giving very little flow modification and filtration efficiency. Furthermore, large cellular filters can suffer from high temperature creep and lose strength during the pour. This gives limitations on the sizes that can be produced.

MetCon C filters are available in coarse porosities designed for very large castings and/or metals that are difficult to filter such as manganese steel. Because the hot strength is so high, they are available as large filters that can withstand very long pour times and high flow rates. The porosities that are currently available are 3G2S (3 mm gap and 2 mm strand), 4G2S (4 mm gap and 2 mm strand), and 5G2S (5mm gap and 2mm strand).

12 Direct Pour Applications

It is generally advised that direct impingement of the metal onto the filter should be avoided and the filter should be positioned in the runner system so that the metal passes through the filter in a more gentle manner.
However, a pouring/gating method known as direct pour is becoming more and more common. Direct Pour is when a filter/sleeve combination is used to replace a standard gating system. The metal is poured directly on to the filter positioned at the base of a sleeve. This means that the standard runner system can be eliminated. This has the advantage of improving yield and simplifying the gating system. It is not suitable for every type of casting but is good for castings where the sleeve is positioned on a heavy section. Direct pour applications can however be quite limited. For example, it is usual that only one filter is used. If the casting is too large to be filtered with only one filter, then direct pour would likely be unsuitable.

When there is direct impingement, the impact shock on the filter can be very severe. This is especially true when large, bottom pour ladles are used with a large diameter nozzle – or when large lip pour ladles are poured from a great height. The strength of traditional filters is somewhat lacking in applications such as this. Additionally, the capacity of traditional filters can cause issues.

Currently castings of 3.5 tonnes are being poured through a 200 mm 4G2S MetCon filter. Flow rates of 50 kg s^{-1} are being achieved.

New porosities are being produced all the time and it is envisaged that castings over 5 tonnes through a single filter will be achieved in the future with flow rates up to 60-70 kg s^{-1} with the soon to be available 300mm diameter 5G2S porosity.

Fig. 5 shows a MetCon C filter after almost 3 tonnes of molten steel have been poured through it. The filter is a 200 mm tapered 3G2S porosity and the pour rate is 50 kg s-1. In this particular application, zirconia foam filters did not have sufficient strength.

Conclusions

Traditional molten metal filters can be effective but have some limitations on their properties. Foam filters are limited by their pore size and have issues related to consistency. Cellular filters are consistent but have issues related to filtration efficiency and flow modification. Many filters on the market suffer from hot strength issues especially for larger sizes. New "next generation" filters can offer the ideal combination of physical properties but, are often expensive and uneconomical to use.

MetCon C filters have been designed to offer the best combination of properties in a cost effective way. They have a consistent and repeatable structure that is engineered to give the best possible capacity and flow rate whilst retaining a good level of filtration efficiency and flow modification. They have excellent cold strength and superior hot strength so they can withstand long pour times with very high flow rates. They are suitable for a variety of metals including carbon steels, manganese steels, chrome irons, and ductile iron.

MetCon filters are increasing the type of castings that can be produced using the "direct pour" filter/sleeve combination pouring technique. Their high strength and high capacity means that they can be used on larger and larger castings even when bottom pour ladles are used