Filters: The Hows & Whys

Matthew J. Jacobs
Cast Metals Institute (CMI), Des Plaines, Illinois

In these days of increasing quality standards, the need for tighter tolerances, better mechanical properties, more efficient production methods and reduced costs, engineers are constantly searching for every tool they can find. One approach that many metalcasters now utilize is molten metal filtration.

The premise is simple. Through the proper use of a filtration device inserted directly into the mold, castings can be produced with better mechanical properties, machinability, appearance and overall quality. These benefits are possible through lower levels of nonmetallic inclusions such as eroded sand, dross and slag. A slight reduction in metallic inclusions also can be seen, particularly if the casting operation has faced problems with undissolved inclusions or other foreign metallics.

Although it is frequently argued that contaminants can be removed through the use of proper, conventional procedures in the gating system (the channels in which the molten metal travels before entering the casting cavity), filter use is becoming common for several reasons. When a filter is used properly in the mold, a reduction in mold/core complexity can be realized, thus allowing a reduction in the overall size of the gating system. This reduction in gating system size often reflects a decrease in sand usage and an increase in metal yield. These filtration devices also can serve as flow modifiers that aid in the controlled filling of the casting cavity by reducing turbulence and fluid velocity.

To illustrate the benefits of filtering molten metal, Ford Motor Co., in the early 1990s, looked to filtration to reduce its scrap rate on its 5.8 liter crankshaft. With a target of 1% scrap, Ford actually achieved levels of 0.12% through the use of filters and a modified gating system. This production change represented a savings of 9 lb per mold, or 354 tons over the course of the year.

Filter Types

Filtration devices come in a variety of shapes, sizes and materials (Fig. 1) that are designed specifically for each application. Different metals have vastly different pouring temperatures, and therefore exert widely different amounts of thermal shock to the filter. Certain filters will not be able to handle this shock, and will disintegrate or break down before the mold is poured. This leads to inadequate filtering, as well as inclusions from the fractured filter itself.

The high pouring temperatures used in iron and steel casting (up to 2900F and 3050F, respectively) present difficulties for ferrous foundries. Iron and steel operations have resorted to tough materials such as zirconia oxide, or alumina oxide filters compounded with zirconia oxide, calcium oxide, yttrium oxide, mullite, spinels and other ceramics for improved thermal shock capabilities. Preheating filters also has become a well-known practice for trying to control thermal shock. When the filter is preheated, a lower thermal gradient exists between the filter and metal, resulting in a less drastic reaction.

Nonferrous foundries, meanwhile, can utilize less exotic (and usually less expensive) materials since they don’t employ the same levels of thermal stress. Steel wire mesh is used in some applications because its melting point is so much higher than the pouring temperatures of aluminum (1400-1500F) or copper base (2000-2200F) alloys. Fiberglass cloth and mica strainers operate similarly to the metal wire screen, and are used as an inexpensive filter in several applications. Some variations of the screen-type filter have been adapted for the ferrous foundry. Fused silica is a tough refractory fiber that has been formed into a thin-mesh type filtration device. It can withstand even the highest of temperatures in the steel industry. In many cases, wire mesh or cloth-type filters are being replaced by ceramic filters. This is particularly evident with high temperature alloys like iron and steel.

Two major types of ceramic filters—extruded ceramics and ceramic foams—
also are common today. The extruded ceramic filter features pores of the same size and shape in parallel orientation. These are particularly good at creating a laminar fluid stream. The extruded filters are rated by how many pores per inch (ppi) are evident on the face of the filter, and they come with several different variations of pore geometry. The two most common pore shapes for the extruded type are square hole or honeycomb.

Meanwhile, the foam type (also called reticulated foams) has many pores of different size in a random orientation. These filters resemble a foam rubber sponge. There is not a clear passage through the filter, causing the fluid stream to change directions. This change of fluid direction, along with added friction, filters the liquid metal and decreases its velocity.

Filters in Application

Filter size is an important consideration when utilizing this technology. When designing a gating system, the different cross sectional areas of the component must be considered. This variation in section size controls the velocity of the fluid flowing through the system. The “choke” in the gating system is the smallest cross sectional area and the point of highest velocity. If filtration is improperly used, a choke can be created at the filter itself, resulting in problems with the mold filling criteria already established by the gating design. This choke situation occurs when the filter’s pores begin to clog with the contaminants being filtered out, and the total flow area decreases. To avoid this problem, a filter that is much larger than the area it is placed in is commonly used. This way, when the filter is full, a flow area similar to the original cross sectional area remains.

Filter placement is an important aspect of the proper use of this technology. There are many factors that contribute to where the filter is placed. A few common arrangements are shown in Fig. 2. Different placements tend to control different types of contaminants. To use the filter most effectively, placement should be as close to the casting cavity as possible, usually just prior to the gate. This assures that the filter has a chance to remove oxides and eroded sand that may be entrained while the metal flows through the gating system. Ease of filter placement is another concern. Engineers want to make it as easy as possible for operators to properly set the filter in the mold.

In some aerospace applications, filters are used as “insurance” because of the liability that accompanies a field failure. In such cases, expensive materials and even more expensive testing methods make the decision to filter the liquid metal an easy one. Jobbing foundries often use filters with large or complex components. Sometimes these castings will take weeks to mold, pour and solidify. Both of these situations dictate that the part must be made right the first time.

The foundry industry has realized that filters serve an important purpose. When used in an efficient and cost effective manner, filters can help reach the customer’s quality and cost reduction goals. The key lies in analysis of the problem, correct filter selection and proper use of the filter itself.

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Fig. 1. Pictured are six different types of filters commonly used by foundries. These include: A) 3.25 in. extruded ceramic filter (10 ppi); B) 3 in. fused silica screen; C) 2.25 in. extruded ceramic filter (20 ppi); D) 3 in. square ceramic foam filter; E) ceramic foam filter with seal around edge; and F) 2 in. round ceramic foam filter.

Fig. 2. Pictured are gating system locations where filters are commonly placed. Many different placements and orientations are used by foundries, depending on the application.