THE INCORPORATION OF ADDITIVE MANUFACTURING TECHNOLOGY (3D) IN CASTING FILTRATION, PROVIDING OPTIMISED EFFICIENCY AND CUSTOMIZATION

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Ceramic foam filters have become the leading choice for metal filtration in casting since the 1980s. They are extensively used across various alloys and casting technologies, providing cleaner castings with improved properties. Over the years, our understanding of filter application has advanced significantly, and guidelines have been developed to ensure their durability. Despite their limitations in pore size and design flexibility, ceramic foam filters outperform other filter types in terms of filtration efficiency and turbulence control. The emergence of additive manufacturing, particularly 3D printing, offers new opportunities for customised filter designs with precise pore sizes and structures, further optimising casting filtration.

INTRODUCTION

Ceramic foam filters (Figure 1) became extensively used in the filtration of castings in the 1980's and are now the leading type of metal filtration system used to produce castings in most alloys and casting technologies.

Over the last 40 years our knowledge and understanding of all aspects of filter application has advanced considerably; filter application is now established in the production of castings of less than 100 g to more than 25 tons. A variety of materials are used as the ceramic base, the selection is based on the alloy to be cast and the required temperature performance. Filters are also commonly applied in "Direct Pour Units" removing the need for a separate running system providing enhanced yield and directional solidification. Application requirements are understood, and guidelines developed, to ensure filters do not break in the very demanding application conditions. Filter limitations are also recognised, including the mechanisms and materials that block filters, so that flow rates and capacities in specific applications can be predicted.

Casting simulation, and flow modelling through computer simulation packages, now provides greater insight into the molten metal flow enhancement generated by filters. The reduction in turbulence decreases the potential for mould erosion and miss run defects, together with reducing exposure to air and the generation of oxide films and inclusions.

Ceramic Foam Filters have restrictions including, pore sizes and limitations in the flexibility in design. Other filter types are commercially available but not extensively used as they in general provide a lower level of filtration efficiency and turbulence control.

ADDITIVE MANUFACTURING TECHNOLOGIES DELIVERING NEW STRUCTURES

Using additive manufacturing technologies (3D Printing) in casting filtration technology, allows for the creation of objects which are built up layer by layer. The term Additive Manufacturing covers a number of different techniques including stereolithography, sheet lamination, and binder jetting. Foseco used a binder jetting technique as the base for launching its first 3D printed filter - STELEX* Optiflow3D (Figure 3).

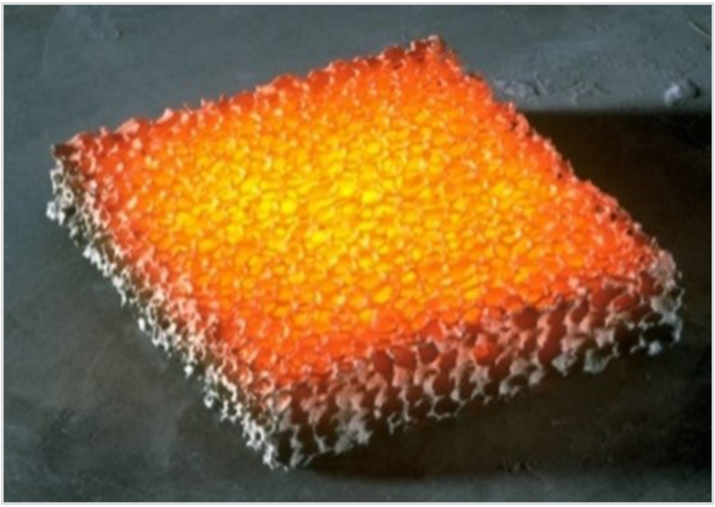

Figure 1. Ceramic Foam Filters

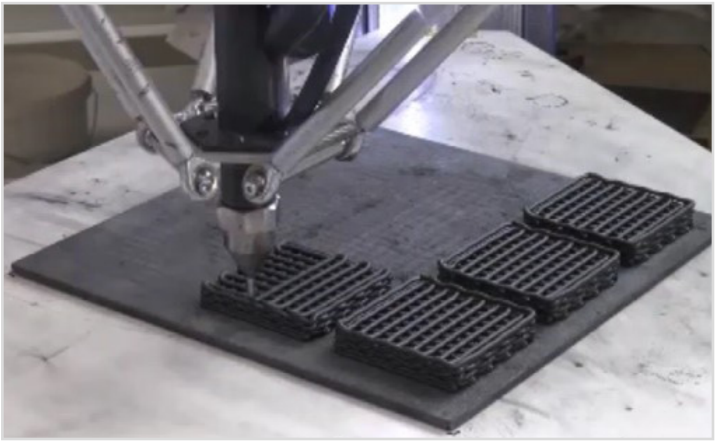

Figure 2. Research into the production of extruded 3D printed filters

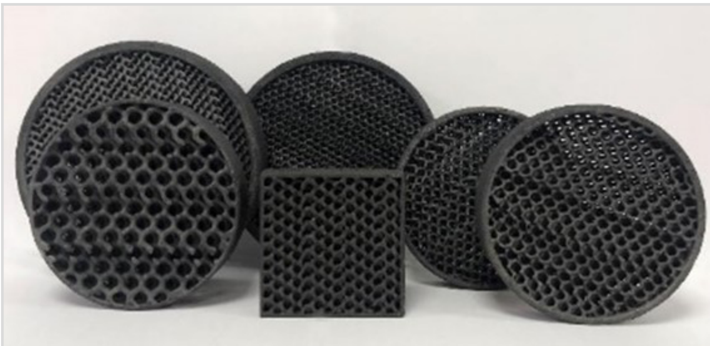

Figure 3. Additive manufactured filters - STELEX Optiflow3D

Ceramic Foam Filters have served the industry very well, but as previously mentioned different alloys and casting types have varying filter performance needs. The first structures to be offered in the STELEX Optiflow3D product range are based on Gyroid and Voronoi structures, the filters are available in an increasing range of product sizes and porosities (Figure 4). STELEX Optiflow3D filters are based on a carbon bonded alumina ceramic and therefore have a low density and thermal heat capacity. The filters are suitable for application to both iron and all steel alloys. Foseco have their own inhouse foundries and have developed tests to replicate some of the most demanding conditions the filters will experience in customers applications. These tests are used both during the development of new products, and for production batch quality control during manufacturing, to ensure confidence that the required performance standards have been met for application by our customers (Figure 5).

Additive manufactured filters extend the range of castings that are filterable. Very large castings are commonly not filtered due to the complexity of applying the large number of filter units required. With the advent of alternative structures to foam, the capacities of filters will be extended so a more manageable number of filters will be required, particularly for heavier castings (Figure 6). For example, a 22 tonnes ductile iron windmill rotor hub may require 18 ceramic foam filters to be applied, this can lead to a complex gating system for the filter application and in some cases bypassing of safe filter application (Figure 7). The new STELEX Optiflow3D filters will facilitate the need for fewer filters, and the possibility to filter even larger castings.

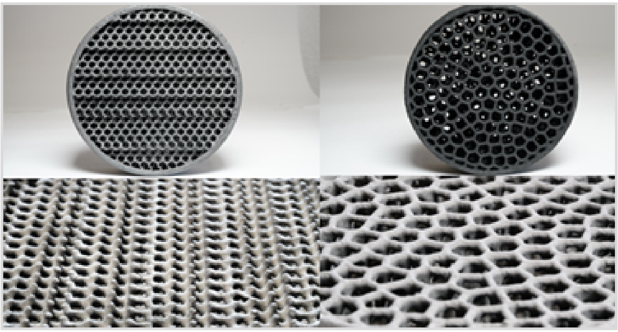

Figure 4. STELEX Optiflow3D available in a range of structures and sizes

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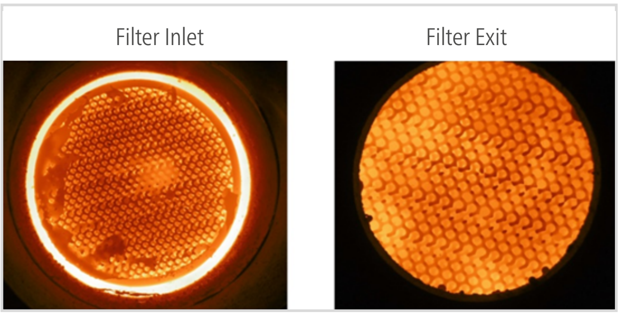

Figure 5. STELEX Optiflow3D after R&D testing with molten stainless steel

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Figure 6. 22 pieces of STELEX ZR applied to a large SG Iron casting requiring Holloware for each filter

Figure 7. 18 pieces STELEX PrO 150x150x30/10 ppi applied to an iron windmill rotor hub

CASE STUDY 1: METALLWERK FRANZ KLEINKEN GMBH, WULFEN (GERMANY)

Metallwerk Franz Kleinken GmbH, Wulfen (Germany) is a foundry with more than 100 years of experience for castings up to 30 tonnes in weight. Kleinken is a contact partner, specialist and problem solver for all challenges in the production and processing of individual castings and small series made of cast iron and non-ferrous metal castings.

Kleinken produces ductile iron "Cross Head" castings for application in die casting machines. Like most foundries facing rising energy and labour costs they are looking to optimise workflows through improved application technology. Conventionally the castings are produced with a running system; in this example a STELEX Optiflow3D Ø125 mm filter was applied in a Direct Pour application providing enhanced casting feeding, and yield improvement. Energy costs and labour costs are reduced by the application of the Direct Pour system increasing the casting yield and reducing the fettling area. In addition, the filter application assisted in the production or a casting with excellent integrity and surface finish.

The enhanced application of the high capacity STELEX Optiflow3D filter in the FEEDEX SCK Direct Pour System eliminated the need for a running system and eased subsequent removal since the small feeder neck had a minimal contact area (Figures 9, 10 and 11). The casting was sound with very good finished surface quality achieved. The returns were reduced by 94 kg (10 %) and the fettling area by 75 % (116 cm²). This not only results in cost advantages for the foundry but also represents a relief for the environment through lower CO_2 emissions. The filter delivered a molten iron capacity of 7.0 kg/cm², which is almost double of what is normally considered as safe for a 10 ppi ceramic foam filter. If a ceramic foam filter had been applied, it would have needed to be a Ø175 mm filter.

CASTING DETAILS:

Alloy:	Ductile Iron (EN GJS 400-18)
Casting weight:	800 kg
Pouring temp.:	1350 °C
Pouring weight:	Conventional gating system - 959 kg
	STELEX Optiflow3D SCK Direct Pour - 865 kg
Pouring time:	Conventional gating - 50 s
	STELEX Optiflow3D SCK Direct Pour - 40 s
Moulding Process:	Hand moulding / Furane

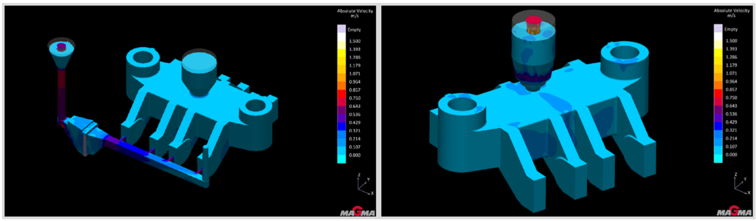

Figure 8. Magma representation comparing the conventional gating system (left) with the Direct Pour solution (right)

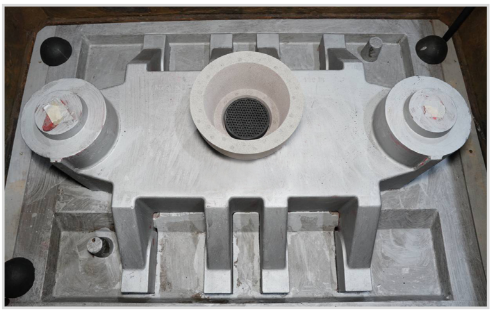

Figure 9. The STELEX Optiflow3D filter on the pattern plate

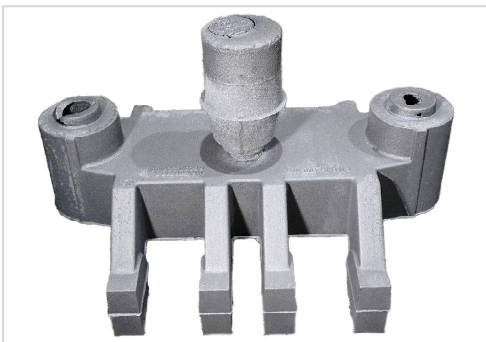

Figure 10. The casting

CASE STUDY 2: EICKHOFF GIESSEREI GMBH, BOCHUM (GERMANY)

Eickhoff Gießerei GmbH is part of the Eickhoff Group, a globally active family business which has been based in Bochum, Germany since its foundation in 1864. In addition to the foundry, the Eickhoff Group's portfolio includes mining machines as well as industrial and wind power gearboxes.

This application example of the STELEX Optiflow3D involves a planet carrier made of low-alloy steel. This casting is normally made without filters and with ceramic hollowware. In addition to the STELEX Optiflow3D Ø100x25, new HOLLOTEX EG Runner ST tubes suitable for steel casting and a 3D-printed filter holder were used for the revised casting system (Figure 11).

By using STELEX Optiflow3D filter, 3D-printed filter holder and HOLLOTEX EG Runner ST tubes, the casting weight was reduced by 8 kg and the surface quality slightly improved. Process-related non-metallic inclusions from the melting process were retained by the filter (Figure 12). Due to its manufacturing process, the filter provides a very consistent, reproducible structure allowing reliably high metal throughput in steel casting. The specific filter capacity of the STELEX Optiflow3D filter in this application was 3.9 kg/cm².

CASTING DETAILS:

Alloy:	GS 17 CrNiMo 6 V	
Casting weight:	230 kg	
Pouring temp.:	1610 °C	
Pouring weight:	Conventional gating system	317 kg
	STELEX Optiflow3D	309 kg
Pouring time:	Conventional gating	21 s
	STELEX Optiflow3D	24 s
Moulding Process:	Hand moulding / Furane	

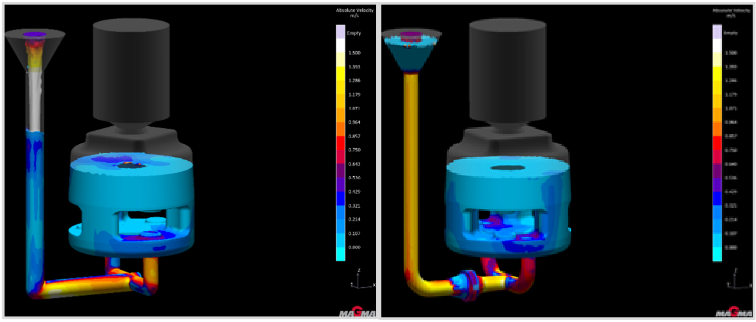

Figure 11. Magma representation comparing the conventional gating system (left) and the revised solution (right) using the STELEX Optiflow3D filter

Figure 12. The planet carrier produced with STELEX Optiflow3D after shake-out

SUMMARY AND CONCLUSIONS

Ceramic foam filters are the state-of-the-art metal filtration system used to produce castings in most alloys and casting technologies. Due to their unique effect in terms of filtration efficiency and flow control they are superior to any other filtration media available up to now. However, they also show structural restrictions with regards to porosity and flexibility in design.

Additive manufacturing technologies (3D Printing) are allowing the next major advance in casting filtration technology providing almost unlimited freedom in terms of structure, porosity and shape of the filtration media. The new STELEX Optiflow3D filters will facilitate the need for fewer filters, and the possibility to filter even larger castings made from iron and steel.

ABOUT THE AUTHOR

Nick has worked for Foseco since 1982. His job includes marketing responsibilities for clean metal systems, including filters, used in the production of castings. This includes ensuring that our products, services and R&D activities are aligned to our customers' requirements and processes. Nick strives to ensure that our technical experts and customers understand optimum filter application to maximise the benefits that can be achieved.

In his spare time Nick is a trustee of a leading UK charity, an active grandfather and enjoys swimming and keep fit.

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ABOUT THE AUTHOR

Stephan originally studied mineralogy and started his career at Foseco as a diploma student in steel filter development 25 years ago. Since then, he has held a variety of technical roles including cast iron metallurgy product management and is now European Product Manager Ferrous Filtration.

Stephan is the father of three daughters and a keen swimmer and cyclist.

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