# The filtration of large grey and ductile iron castings

## Introduction

In order to produce sound inclusion free castings of good quality it has been extensively proven that filtration in the mould is of prime importance.

Dross stringers, especially magnesium-sulphides, oxides and silicates (figure 1) are the main sources of non-metallic inclusions and a big problem for all ductile iron casters. They can impair mechanical performance and lead to an unacceptable cast surface. It is therefore, of primary importance to reduce, or better, prevent inclusion related defects, which result in unacceptable castings either before or after machining. Efficient removal of slag, dross and other non-metallic inclusions can be achieved by the use of a ceramic foam filter, along with a correctly designed runner system.

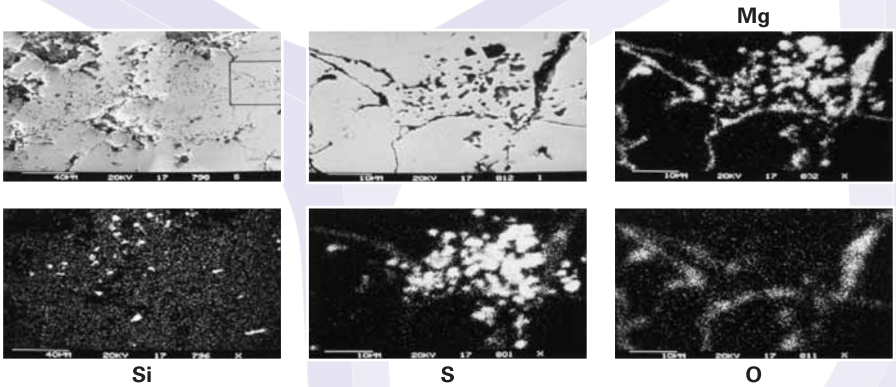



**Figure 1** Dross, the main inclusion in ductile iron

## Filters

To reduce inclusion defects and ultimately scrap castings, silicon carbide ceramic foam filters (figure 2) have been incorporated in gating systems of mass production grey and ductile iron castings for many years.

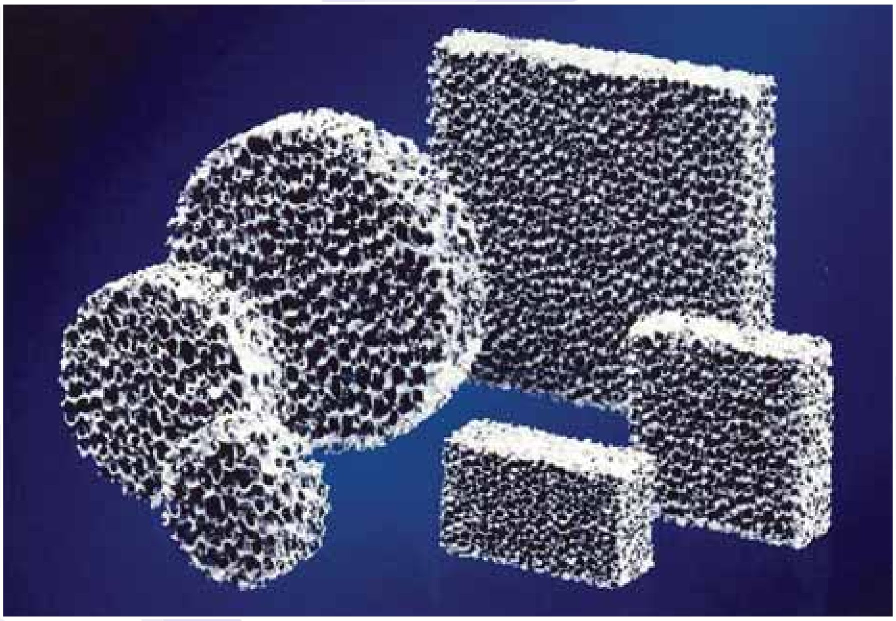
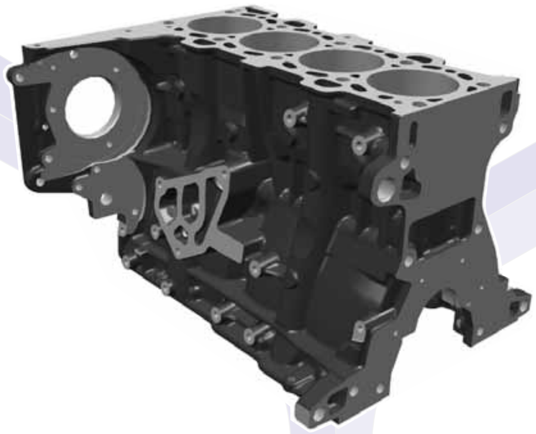


**Figure 2** Silicon carbide ceramic foam filters

However, up until recent times, the filtration of iron castings in excess of 1 tonne has been difficult. Product performance issues, application difficulties and relatively low economic benefits, when compared to the automotive sector, such as shown in Figure 3, have all made the use of filters unattractive.



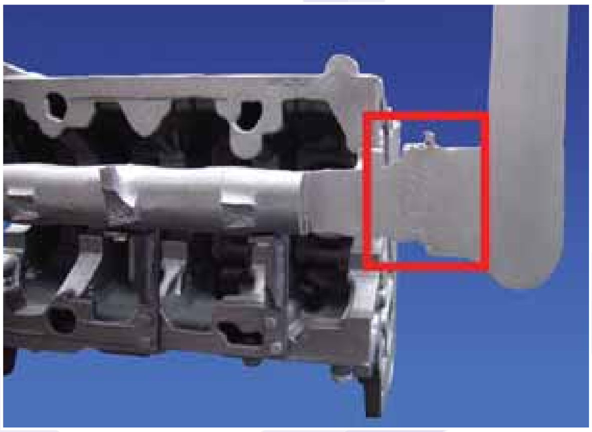


**Figure 3** BMW engine block filtered with one SiC SEDEX foam filter of size 75x75x22/20ppi

## Filter materials

The use of foam filters made of standard silicon carbide ceramic is usually limited to sizes up to 100x100mm. High ferro static pressures, high flow rates and extended pouring times increases the risk of breakage with larger than 100x100mm filters during the filtration of (very) heavy castings, and there is often not enough space available to place the required number of filters in the gating system/mould.

The need for high-strength filters in large sizes has seen an increasing use of carbon bonded foam filters (figure 4) or partially stabilized zirconia filters (figure 5) over the last two years, the users of these filters obtaining a number of technical and economic benefits.

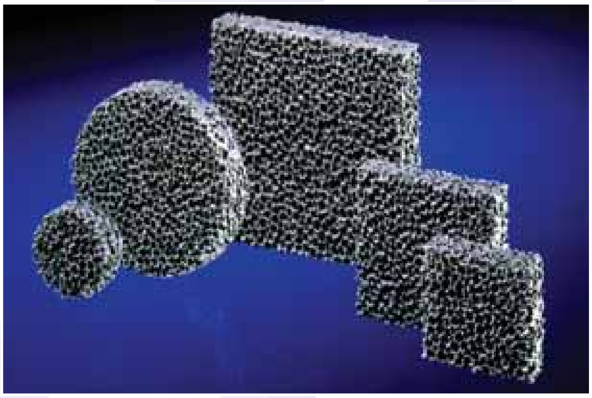


**Figure 4** STELEX* PrO Carbon bond ceramic foam filter

**Figure 5** STELEX ZR Zirconia ceramic foam filter

The selection of the most suitable ceramic composition $Al_2O_3$/carbon or $ZrO_2$ is driven by several factors such as: thermal shock resistance, cold compression strength, pouring times, priming performance, cooling rates and chemical compatibility.

## Filter performance

The size and number of filters used should be adequate to maintain normal flow during mould filling. The quantity of ductile iron that will pass through a given size filter depends on a number of factors including:

- Increasing manganese and/or sulphur levels, decreases the quantity of iron that will pass through a filter.
- The cleaner the nodularising alloy used, the higher the degree of iron cleanliness, and consequently a higher quantity of iron passing through the filter.
- Inoculant types and practices influence the capacity of a given filter.

Therefore to avoid filter blockage and provide sufficient filter area for consistent mould filling these factors need to be carefully considered when designing a filling system.

## Foam structure

The ceramic foam structure consists of a network of "Dodecahedra" (figure 6), these pores are defined by more or less triangular ceramic strands which intersect to form pentagonal openings of different sizes (figure7).

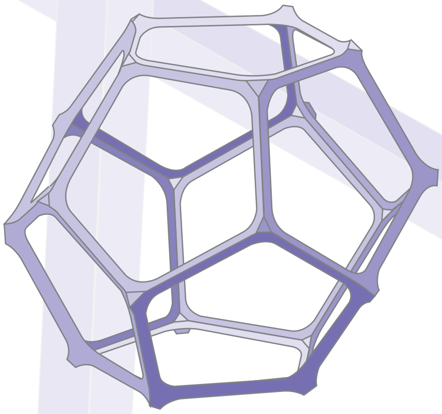


**Figure 6** Ideal foam cell, Dodecahedra

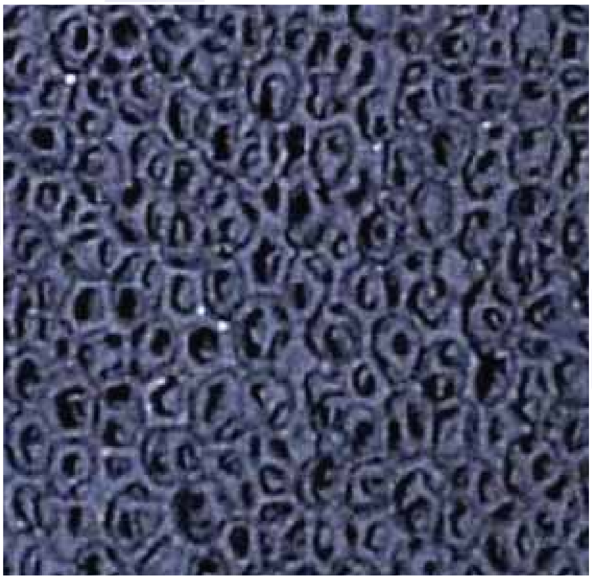


**Figure 7** Intersects forms pentagonal openings of different sizes

Some of these openings are blocked with ceramic (windowing), however this can increase the tortuous path through the filter. This foam structure provides diminished turbulence and better flow control and prevents non-metallic inclusions reaching the mould cavity. (figures 8a – 8d).

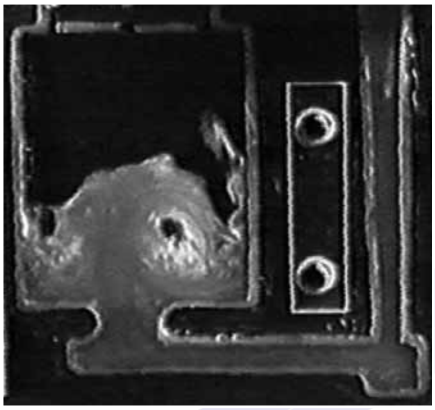


**Figure 8a** Water flow model without filter

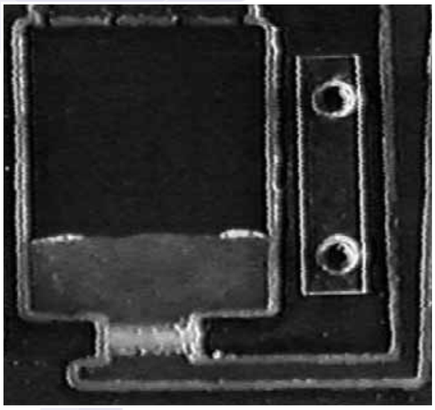


**Figure 8b** Water flow model with foam filter

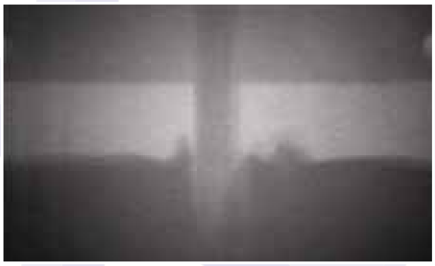


**Figure 8c** Direct pour without filter

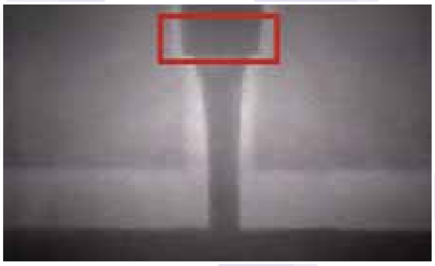


**Figure 8d** Direct top pour with foam filter

Ceramic foam filters offer an ideal combination of properties, they are capable of trapping both large inclusions at the entrance (figure 9) and much finer particles than the actual pore opening. They act also as deep bed filtration because of the tortuous flow path through the filter (figure 10).

**Figure 9** Trapping of large inclusions at the entrance

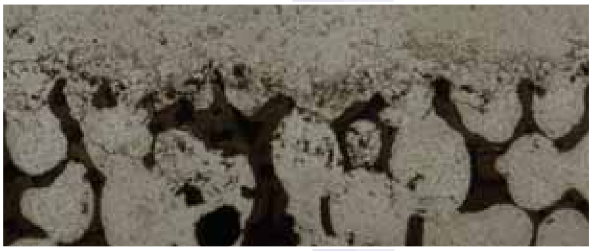


**Figure 10** Deep bed filtration

## Filter location

The pattern layout of a particular casting must be carefully considered when filters are applied. In many cases, little room is available for the gating system on the pattern plate and filter placement is restricted. The correct insertion of the filters into the gating system offers the optimum means of providing effective filtration.

Guidelines for incorporating filters have been determined over many years from actual field experience, and three different kinds of techniques for positioning the filters are shown below.

### In-line pouring system – STELEX FP

Horizontal placement (figure 11) in the drag mould is the preferred orientation for large filters. However, especially for the carbon bonded filters, vertical positioning is a common application. Foseco STELEX filter-position 6 wherein filters are placed vertically (figure 12), allows large inclusion to flow up before the filter, thus increasing the quantity of metal that will pass.

**Figure 11** Pattern horizontal placement

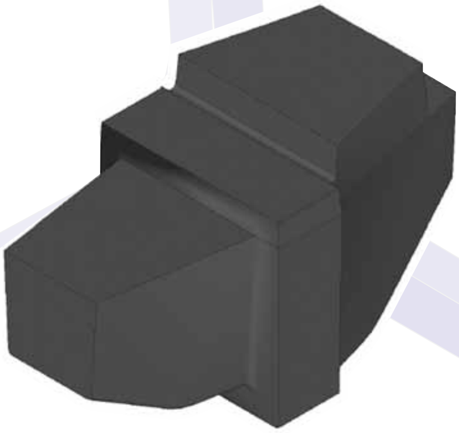


**Figure 12** Pattern vertical placement

### In-line pouring system – Hollow Ware

For filter placement external of the parting line, ceramic hollow ware prints (figures 13 and 14) in different types and different sizes are available. Their entrance and exit diameter are designed to be fitted into hollow ware tubes forming part of the running system.

**Figure 13** Ceramic print for horizontal filter placement

**Figure 14** Ceramic print for vertical filter placement

**Direct pouring system – KALPUR* ST**
Using filter-feeder direct pour systems (figures 15 – 17) is a most economic method for producing quality filtered castings.

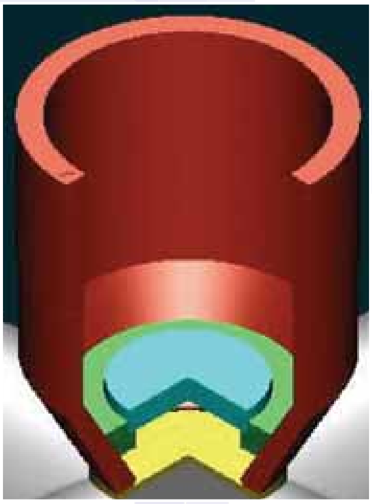


**Figure 15** Neck down feeder with insert filter carrier core

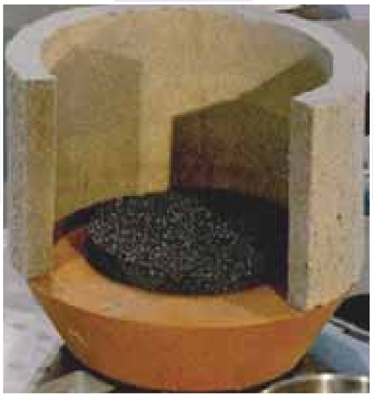


**Figure 16** Cylindrical feeder with filter carrier core

**Figure 17** KALPUR filter feeder

## Gating systems

Not only the choice of filter, and its introduction into the gating system are of importance, it is essential that a correctly designed gating system is in place for maximum benefit.

A gating system designed for ceramic foam foundry filters should take into consideration the technical benefits provided by a filter and the method of application in which the filter will function most effectively. The location in a gating system plays an important part in the level of filtration effectiveness obtained. Location and positioning are influenced by casting shape and weight and also by moulding practice and process.

Turbulence and aspiration of air in the gating system after the filter must be minimised to obtain maximum filtration benefits, and filter gating systems should fill as quickly as possible. The best results are obtained when gating systems are designed to completely fill before metal enters the mould cavity.

A correctly designed gating system for ceramic foam filters should provide the following:

- ❑ Minimum gating system size
- ❑ Consistent mould filling time
- ❑ Minimum erosion and turbulence
- ❑ Simple filter placement

## Practical case studies

The following case studies help to illustrate the differences in behaviour and performance of the two ceramic compositions. The studies are also chosen to illustrate different methods of positioning of foam filters in gating systems.

The advent of high-value, high technology ductile iron castings e.g. such as wind energy components, has seen an increased interest in filtration because of economic and technical benefits achievable. Ductile iron had been selected by the producer of wind energy for many mechanical components because of its lower density and excellent quality and reliability, even at low temperatures (-20 °C). Maintenance of this quality level could confirm the dominant position of ductile iron in the future in this sector of the market.

A windmill contains about 40 t of different ductile iron castings e.g. rotor hub - blade adapter - gear (box) - machine (bed) frame - shaft - planet carrier - nacelle - beam - front section - front bearing.

## Cylinder head

About 70 castings of this cylinder head type are produced continuously per month. Alloy is ductile iron GJS 400-15 with a pouring weight of 980 kg and a casting weight of 930 kg. Figure 18 shows the cope and drag site of the pattern plate.

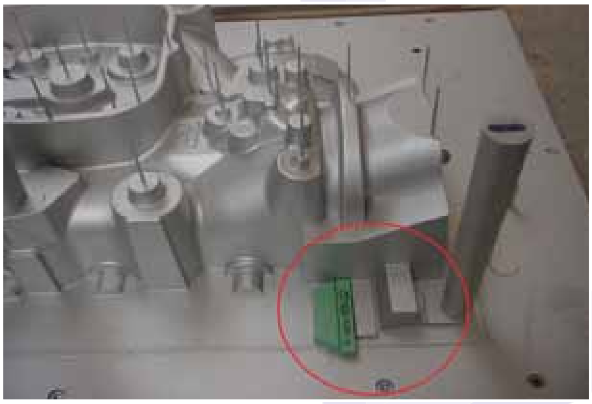


**Figure 18** Drag and cope site of the pattern plate

One 150x200x30mm STELEX PrO ceramic foam filter is used, vertically located directly after downsprue. Filter capacity 3,27 kg/cm$^2$; pouring temperature 1360-1380 °C; pouring time 35-40 sec; downsprue diameter 50 mm; the 30% enlarged ingate cross section is 2514 mm$^2$.

## Ring housing

This casting is produced in GJS with a pouring weight of 9500 kg and a casting weight of 5800 kg. Figures 19 a/b show the cope and drag site of the casting just after shot blasting. Figures 20 a/b show two different views of casting ready for machining.

Filters used are 8 pieces STELEX PrO ceramic foam filter size 200mm diameter, horizontally located on parting line in the inner ring. Filter capacity 3,87 kg/cm$^2$; pouring temperature 1340 °C; pouring time 68 sec.

**Figure 19a** Cope of ring housing

**Figure 19b** Drag of ring housing

**Figure 20a** View of the ring housing

**Figure 20b** View of the ring housing

Downsprue 2 times diameter 80mm; the runner in front of the filters consists of resin sand while the runners beyond the filters are made of ceramic hollow ware. All eight ceramic runners are directed into the six feeders which are placed beneath the inner ring to provide smooth filling of the casting.

## Windmill rotor hub

Figure 21a shows the sketch of a hub and its gating system with filters. This casting is produced in GJS. The pouring weight is 9000 kg. Six zirconia filters of diameter 200mm are used. More than 90 hubs have been cast in this manner. Pouring temperature 1340 °C; pouring time approximately 50 sec; filter capacity 4,78 kg/cm$^2$.

**Figure 21a** Filters placed at parting line

**Figure 21b** Filters placed in ceramic prints short before the ingates

**Figure 21c** Hub flanges

Figure 21 b shows the sketch of a hub and it's gating system with filters. Figure 21c illustrates one of the three hub flanges from where the casting is filled through two STELEX ZR filters which are placed in Hagenburger ceramic prints. This casting is produced in GJS. The pouring weight is 9000 kg. Six zirconia filters of diameter 200mm are used. More than 90 hubs have been cast in this way. Pouring temperature 1360 °C, pouring time approximately 70 sec; filter capacity 4,78 kg/cm$^2$.

## Windmill planet carrier

This casting is produced in GJS with a pouring weight of 3100 kg and a casting weight of 2500 kg. Figure 22 illustrates the casting and its gating system. Clearly seen is the remaining ceramic hollow ware runners and filter prints. Two STELEX ZR filters of diameter 200mm were used with a pouring temperature 1380 °C and a pouring time of approximately 80 sec. Filter capacity 4,94 kg/cm$^2$.

**Figure 22** Ceramic hollow ware gating system with two Hagenburger filter prints

## Housing

This casting is produced in GJS with a pouring weight of 25500 kg. Figures 23 a/b show the pattern and parts of its ceramic gating system. Twenty-two STELEX PrO filters of diameter 200mm had been used. Pouring temperature 1380 °C and pouring time of approximately 120 sec. Filter capacity 3,58 kg/cm$^2$. A conservative capacity was chosen because of pressure height of almost 3,5 m and because of back pressure during mould filling.

**Figure 23a** 200mm diameter ceramic filter prints

**Figure 23b** Two rows of 200mm diameter ceramic filter prints are needed to cast a 25,5 t GJS casting

**Castor**

This casting is produced in GJS with a pouring weight of 9000 kg and a casting weight of 7500 kg. Figure 24 shows the drawing of the casting and its recommended gating system. The application of eight vertically placed 200mm diameter, alumina-carbon filters were recommended. Pouring temperature of the first casting was 1360 °C; of the second 1340 °C; because of some feeding difficulties with this large casting, temperature for cast three is planned at 1300 °C. Pouring time of approximately 75 sec. was calculated; filter capacity 3,58 kg/cm$^2$.

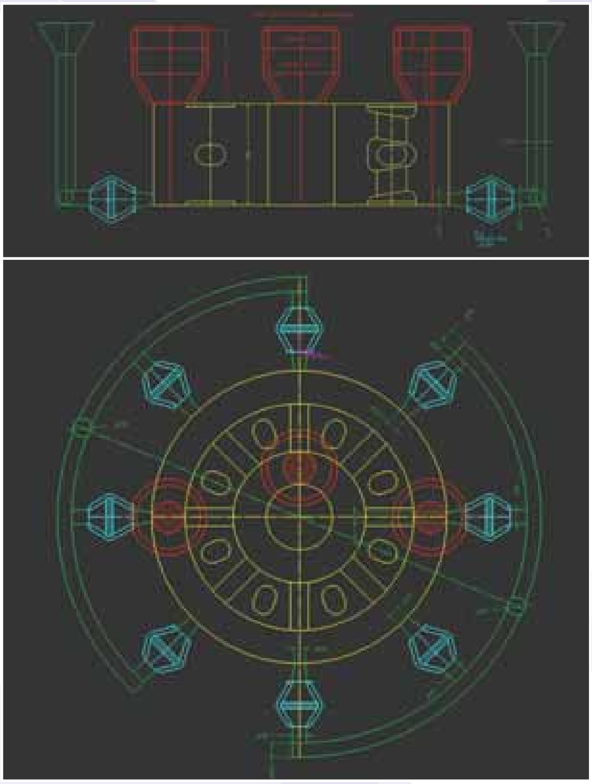


**Figure 24** Drawing of recommended gating system for a heavy wheel

**Crushing body**

Figure 25 illustrates a ceramic gating system where square shaped rather than round filter prints are incorporated. Four filters with size of 150x150mm were used.

**Figure 25** Ceramic filter prints for square filters 150x150mm

**Roller**

For this casting the same ceramic square prints and four 150x150x30mm carbon bonded filters were used similar to the previous case history. This casting is produced in an alloy with a carbon content of 1,75 % and 16 % of chrome, with a pouring weight of 3900 kg. Figures 26 a/b show the inner of an unfiltered and a filtered casting. Pouring temperature of casting 1460 °C; pouring time was 110 second; filter capacity was 4,3 kg/cm$^2$.

**Figure 26a** Casting unfiltered

**Figure 26b** Casting filtered

The last three case histories are focused on direct pour technology. Because there is no need for an extra sprue and runner system, this technique offers an enormous production cost advantage. Filters can be placed in top or side feeders.

**Clutch disk**

This casting is produced in GJS(GGG60) with a pouring weight of 1700 kg; pouring temperature of casting 1330 °C; pouring time was 30 seconds. Filter used: 1x STELEX ZR Ø200x35mm placed in a filter-feeder ZTAE 23/25; filter capacity was 5,41 kg/cm$^2$. So far 12 castings have been cast successfully. Figure 27 shows a casting with a feeder and the KALPUR direct pour unit remaining.

**Figure 27** Direct pour through a KALPUR unit

**Plaster**

Two of this casting type produced in GJS-400-15 were shown on the GIFA exhibition 2003, one as cast and the other one fully machined. Figure 28 shows the casting with remaining feeder and Figure 29 demonstrates the MAGMA simulation model for temperature distribution after mould filling. One ceramic foam filter STELEX PrO diameter 200mm is used, located in a special collar core underneath a cylindrical feeder sleeve KALMINEX* X11. Pouring temperature of casting 1400 °C; pouring time is around 20 second; filtration capacity 3,39 kg/cm$^2$; yield 86%.

**Figure 28** Casting with remaining feeder

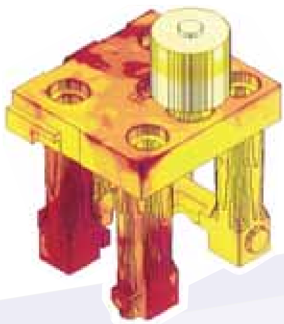


**Figure 29** Temperature distribution after filling

**Valve**

This casting is the only sample where the alloy is GJL. A direct pour solution had been introduced and applied in a Czech foundry where many valve castings have been poured this way. The first poured casting with such a pouring system was displayed during a foundry fair in the Bruin in the Czech Republic and the foundry received an award called "The Golden Ladle" for this work. Two ceramic foam filters STELEX ZR Ø 150x30mm/10ppi were used, located in two feeders topmost of the casting, a pouring basin like a bridge merged the two KALPUR units together to give the required filter cross section. Figure 30 shows the start of mould filling simulation. Poured weight 1280kg.

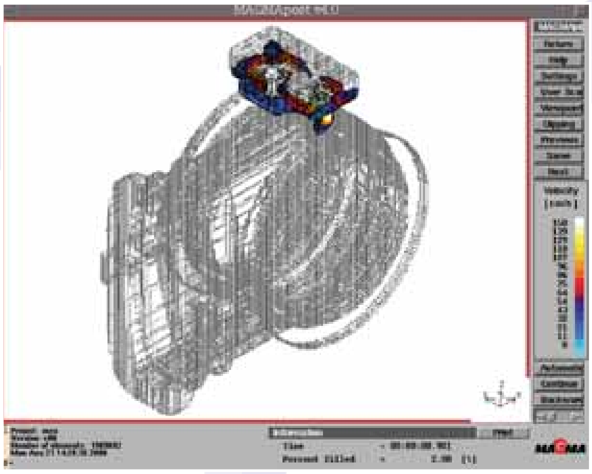


**Figure 30** Mould filling simulation of valve

## Conclusions

Large foam structure filters produced of ceramic $Al_2O_3$/Carbon or $ZrO_2$ give the foundry man a method for filtering castings higher in weight then 1000 kg, along with the ability to reach the quality standards required. Ceramic foam filters like STELEX PrO and STELEX ZR demonstrate that they are highly efficient in removing inclusions from molten metal and minimising turbulent metal flow.

As demonstrated in the paper a number of different methods are available to incorporate filters in sand as well as in hollow ware gating systems. Generally direct pour systems are the most efficient related to improvement of yield. However, they can lead to higher metal velocities which must be taken into account at the design stage.