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Application of SEDEX Ceramic Foam Filters on vertically parted moulds such as Disamatics

Synopsis

The paper seeks to describe the principles of applying filters to vertically parted moulds such as Disamatics. Key differences between horizontally and vertically parted moulds are outlined. A simple system to categorise Disamatic mould types into 3 categories is described and the effect of differing ingate position on filtration application practice are outlined. The calculation technique for determining the minimum or controlling gating system cross-sectional area for vertically parted moulds is described. The optimum location of the SEDEX filter in the mould is explained. Filter print designs for Disamatics are given, their role in securing the filter in the mould along with filter handling techniques are described.

Introduction

The use of Disamatic moulding machines has grown rapidly during the past three decades to such an extent that there are currently many hundreds of machines in daily operation world-wide. With their extremely high productivity, hard mould and vertical parting line the successful operation of Disamatics requires considerable specialised knowledge and technical skill. Gating, feeding, core insertion and metal pouring technologies have all been specifically adapted to obtain the maximum benefit from Disamatic operation.

This also applies to filtration, a foundry technology, which has also been adapted, ensuring that its application is able to support the production of quality cast components at the high levels of productivity associated with the use of Disamatics.

1. Differences between horizontally and vertically parted moulds:

There are a number of practical differences between horizontally and vertically parted moulds; these exert an influence on basic SEDEX application principles and the runner system design:

- ❑ Moulds are more often bottom-filled, so more of the iron to be poured is likely to be ABOVE the ingates. This increases back pressure and results in LOWER effective pouring heights.
- ❑ Disamatic moulds generally have SHORTER pouring times, often in the range of 5 to 10 seconds, than horizontal moulds.
- ❑ Larger filter areas may have to be applied to enable the quantity of iron to be poured in the short TIME available.
- ❑ The mould cavities to be poured may often be at 2 OR MORE levels:
- ❑ To ensure simultaneous filling of the mould cavities the gating system has to be carefully CALCULATED and DESIGNED to ensure even, rapid, non-turbulent filling of each mould level.
- ❑ Very limited time is available for insertion of the filter into the mould print, so there is a special need to devise rapid, accurate methods for handling the filter; holding it, inserting and securing it in the Disamatic mould.
- ❑ Access to the open mould is restricted

The design of good conventional gating systems for Disamatic applications is a specialised subject in its own right, it is therefore not surprising that the design of running systems employing filters has been slow to evolve.

2. Mould category, its effect on ingate position and filtration practice:

There are THREE main categories of vertically parted moulds which influence how filtration can be applied, namely

Bottom gated mould cavities, these fall into one of 3 sub-categories:

a) Single casting
b) Two or more castings at the **same level**
c) Two or **more levels** of castings

Categories 1a) and 1b): Moulds in these two categories can be poured using much the same filtration principles as those applied to horizontal moulds, with the gating system control or choke located at the beginning of the horizontal runner bar(s), after this point the cross-section(s) can be increased to minimise turbulence.

Category 1c): Moulds in this category are similar to 1a and 1b but in order to keep the gating system full during pouring it is necessary to locate the controlling cross-sections (there may be more than one) of the gating system at the junction of the downsprue and horizontal runner bars. After this point the cross-section of the runner bars and ingates can be increased in an effort to slow the flow of metal and minimise turbulent flow into the mould cavity.

Side gated mould cavities, these fall into one of 3 sub-categories:
a) Single casting
b) Two or more castings at the **same level**
c) Two or **more levels** of castings

Categories 2a) b) and c): Moulds gated in this way require that the choke in the gating system is located at the downsprue junction, otherwise the pouring system cannot fill completely with liquid iron and the filter will not be correctly primed, this may permit slag and reaction products to pass through it.

Top gated mould cavities, these fall into one of 3 sub-categories:
a) Single casting
b) Two or more castings at the **same level**
c) Two or **more levels** of castings

Categories 3a) b) and c): Moulds gated in this way require that the choke in the gating system is located at the ingates, otherwise the pouring system cannot fill completely with liquid iron, the filter may not prime properly causing slag defects or defects associated with gas and/or steam aspiration. This design is essentially a traditional, ingate controlled or 'pressurised' gating system.

Ideally foundries should try to plan their production methods in such a way as to place the majority of castings in the **categories 1a, b, and c** for the best filtration results, the second best option is categories 2a, b, and c. Use of these systems offer the founder the possibility of designing gating systems to minimise mould filling turbulence.

3. Calculation of the controlling or minimum gating system cross-sectional area for vertically parted moulds:

During pouring, as a stream of liquid metal falls it accelerates; at any given point in the stream the quantity of metal flowing must remain the same, therefore the cross-sectional area of the stream progressively decreases. In contrast with gating systems designed for horizontally poured moulds, systems for vertically poured moulds can be designed to take advantage of natural fluid flow dynamics, resulting in a downsprue which is gradually tapered from its top to the bottom.

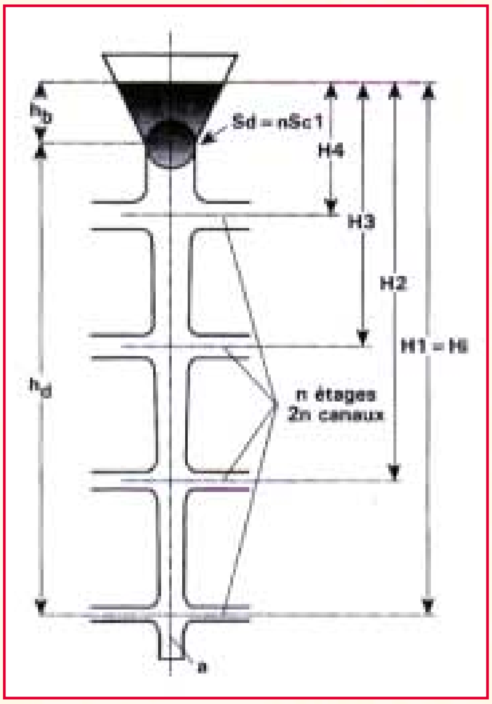

Figure 1: Effect of different mould cavity heights on gating system dimensions

Figure 1 is taken from a French paper, and shows the effect of the dimensional change of the falling metal stream and influence of height on the calculation of the ideal gating system dimensions (1). The use of a natural tapered downsprue means that a vertical gating system can be kept completely full of metal; this reduces turbulence and the risk of gas or steam aspiration.

Tapered downsprue of 1-3 degrees results in:

- rapid filling
- minimum turbulence
- elimination of aspiration
- lower scrap.

Progressive ingate size reduction:

- controls and regulates the metal velocity
- compensates for differences in pouring height.

Clearly there is no single Disamatic casting example which completely summarises how to calculate the gating system for use with a ceramic foam filter. There are however a number of general principles which can be applied to most Disamatic gating systems.

For a pattern plate with castings located at different heights, it is necessary to calculate the effective pouring height for EACH level of castings and then to calculate the controlling cross-section for that level using the standard gating equation:

$$A = \frac{22,6 \times W}{e \times \xi \times t \times \sqrt{H}}$$

A = Controlling cross-sectional area or choke (cm^2)
22,6 = Physical constant
W = Mould or spray weight (kg)
e = Density of iron – (g/cm^3)
ξ = Friction factor
t = Pouring time (s)
H = Effective pouring height **(cm)** **not mm**

The effective pouring height 'H' can be calculated using one of the three simplified formulae:

1) bottom gating $H = h - \frac{c}{2}$

2) centre line gating $H = h - \frac{a^2}{2c}$

3) top gating $H{-}h$

h = parting line to top of mould (mm)
a = parting line to top of mould cavity, including any feeder (mm)
c = overall depth of mould cavity (mm)

The controlling cross-sectional area:
The smallest effective cross-sectional area in any gating system is termed **the choke**, or the section which 'controls' or regulates the pouring time of the mould cavity.

In the case of a conventional system this controlling cross-section is usually located at the ingates **(pressurised or ingate controlled system)** but where circumstances permit, in the case of bottom filling the controlling section may also be located in the downsprue **(depressurised or downsprue controlled system)**. In the case of a downsprue controlled system it is possible to increase the cross-sectional runner area behind the choke section by 10% and the ingate area by a further 10%, this reduces velocity and turbulence.

The calculation of the section to achieve the required pouring time has to be performed for **each level of castings**. The areas are inversely proportional; as the effective pouring height (H) INCREASES, the cross-section of the 'ingates' and/or downsprue (A) DECREASES.

Once the total area to achieve the pouring time has been calculated then it is possible to calculate the downsprue cross-section, runner bar cross-sections and the operational casting ingate areas to be applied to the specific casting(s) to be poured.

The Disamatic Nomogram
The Disamatic gating Nomogram can be very helpful as a rapid means of determining the cross-sectional area of the ingate or runner, its use is described in detail in the Disamatic handbook (2).

Friction Factor selection:
The value of the friction loss factor for SEDEX filtered Disamatic gating systems can vary from 0.25 to 0.65, but is most commonly in the range 0.2 to 0.45. Selection of the factor depends on the much the same variables which are applied to horizontally parted moulds, mainly:

- ❑ casting complexity,

- ❑ casting geometry.

The extra friction arising from the insertion of a foam filter should be compensated for by a reduction of 0,1 in the friction factor value used to perform the calculation of the gating system dimensions.

4. Design of the gating system:
Calculating the gating system ratios is only the beginning of the process; once that is done the system has to be designed to do the job intended. A Disamatic gating system has to be calculated in steps from the bottom upwards; as it takes shape it is 'assembled' section by section beginning from the bottom of the mould, progressing upwards, to give the final result.

Figure 2 indicates the required pattern layout to make maximum use of a plate 650 x 850 mm in size to produce 5 unventilated brake disks. The first judgement to be made, bottom gating is not going to be possible, the 5 castings will have to be side gated; the spray can be classified as falling into category 2 and with two or more levels of castings sub-category 'c'. It is proposed that castings in category '2c' should have the controlling gating system cross-section positioned just above and in front of the ingates, their section can be increased by approx. 10% to reduce metal velocity and turbulence as the stream enters the mould cavity, which is how this system was designed. The second judgement is the friction factor to be applied, with no filter a relatively simple casting of this type would have a friction loss factor of about 0,5, however because the use of a foam filter will introduce extra friction losses, therefore a value of 0,35 was selected.

The calculation is carried out in steps for each level of casting; this will result in gating system dimensions which are suitable for each level of casting. The downsprue dimensions for each lower level are added to those of the next level up to ensure there is sufficient cross-sectional area to supply metal to each level of mould cavities.

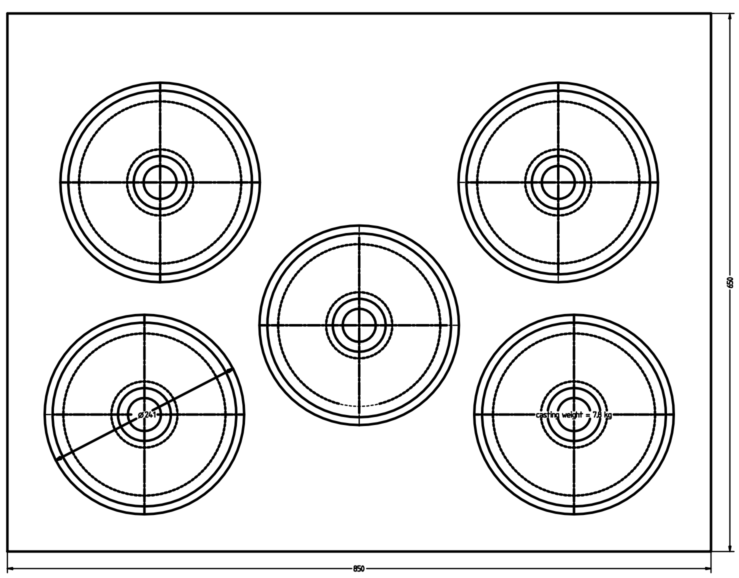

Figure 2: Basic plate layout for gating system calculation and design

The data for the lower pair of castings:

- ❑ pouring time 6 sec
- ❑ casting weight 7,8 kg
- ❑ allocation of runner weight 1,2 kg
- ❑ pouring height 485 mm
- ❑ effective pouring height 454 mm
- ❑ friction factor 0,35

Using the Disamatic Nomogram indicates that the ingate area required to pour the casting in 6 seconds is 199 mm², this was confirmed by manual calculation and also by the use of an ingate computer calculation program. However in this case the control area can be taken as the downsprue and the ingate area can be increased by 10% of the controlling section to give 219 mm²; these areas are valid for both lower castings.

The data for the middle casting same pour time, friction factor and casting weight as given above.

- ❑ pouring height 377 mm
- ❑ effective pouring height 347 mm

The required control section is 228 mm², this area is divided into two, half for each side of the casting, to keep the gating system symmetrical. This 114 mm² section must be added to the 199 mm² for the lower casting (because the downsprue at this point has to supply 1,5 mould cavities), the ingate cross-section for each half casting, 114 mm², is increased by 10% to give 125,5 mm² per side.

The data for the UPPER two castings same pour time, friction factor and casting weight, as given above;

- ❑ pouring height 216 mm
- ❑ effective pouring height 176 mm

The calculated control section is 321 mm², this area is added to the previous two areas to give a total downsprue cross-section of 634 mm², which is large enough to supply 2,5 mould cavities, the ingate cross-section is 10% larger than the 321 mm² or 353 mm².

Figure 3 shows the finished layout with a cross-section of 634 + 634 mm² or 1268 mm² at the top of the gating system, this is the section which is able to supply all 5 mould cavities with liquid iron in the required time of 6 seconds.

This progressive reduction in the cross-sectional area of the gating system from top to bottom of the

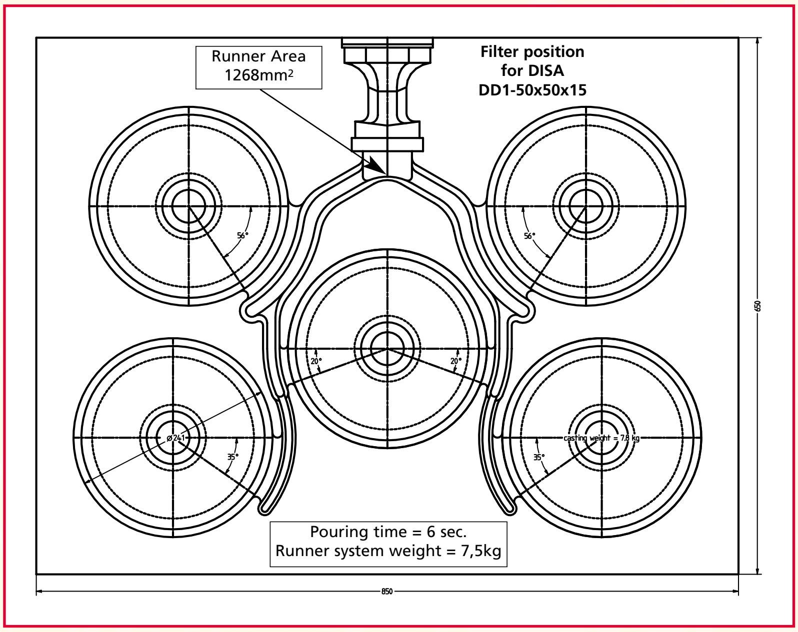

Figure 3: Finished layout

mould helps to ensure that the upper and lower cavities fill simultaneously and that the gating system itself is completely filled with liquid metal during pouring. If the flow rate in the bottom half of the mould is too high this will introduce turbulence and increase the tendency to produce casting defects such as metal penetration, erosion, pinholes and gas porosity.

One of the most important features of the design of a SEDEX gating system for Disamatic application is that it should encourage rapid, even, smooth and non-turbulent mould filling. The key dimensions of the gating system should be adjusted according to the distance of the mould cavities from the top of the mould.

i.e. Use SMALLER cross-sections as the ferro-static pressure INCREASES and LARGER cross-sections as the ferro-static pressure REDUCES.

Some recent simulation work appears to indicate that the introduction of a sloping downsprue with sharp angular changes in direction may be beneficial in slowing the flow of metal into the lower cavities. At the time of writing practical foundry evaluation of this phenomena is still ongoing.

5. Optimum location of the SEDEX filter in the mould:
The choice of filter location in a Disamatic mould is often limited, in the case of a multiple spray of castings for example, the filter will have to be positioned in the UPPER half or quarter of the mould. However given the freedom to choose a location, the upper half of the mould is the preferred option, the advantages are:

- ❑ reduction in the high initial iron velocity
- ❑ minimised risk of breakage
- ❑ reduction of ferrostatic pressure on the filter which reduces the risk of fluid slag being pressed through the filter

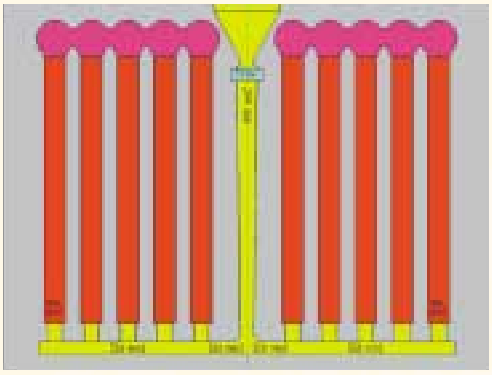

Figure 4: Filter positioned in the UPPER part of the mould

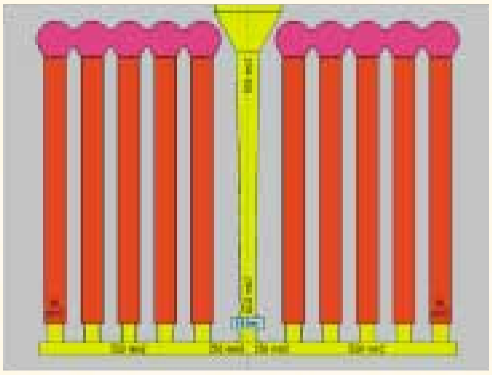

Figure 5: Filter positioned in the LOWER part of the mould

This last point is illustrated by the results obtained from a large scale foundry trial in which the effect of filter type and position in the mould on both foundry and machined casting scrap levels were evaluated. Figures 4 and 5 illustrate the layouts investigated and give the details of the gating systems employed for the trials, whilst Tables 1 and 2 summarise the results obtained from the two series.

Locating the SEDEX filter at the bottom of the downsprue caused the casting defects to become finer and more numerous as the filter structure became finer (Table 1). From these results it was concluded that it would be better to locate the filter higher in the mould. This was evaluated in the second test series (Table 2), the actual number of casting defects both in the foundry and after machining were significantly reduced.

Filter type	No. of castings produced	% Foundry scrap	No. of castings machined	% Machined scrap
SEDEX 10ppi	160	0,60	100	9,0
SEDEX 20ppi	170	2,85	100	2,0
SEDEX 30ppi	200	4,0	100	3,0
EXTRUDED	220	1,85	100	9,0
PRESSED	200	2,52	100	20,0

TABLE 1 Filter positioned at the BASE of the downsprue.

Filter type	No. of castings produced	% Foundry scrap	No. of castings machined	% Machined scrap
SEDEX 10ppi	90	4,7	80	2,5
SEDEX 15ppi	140	3,5	137	0
SEDEX 20ppi	100	1,0	97	0
EXTRUDED	120	13,6	102	2,9
PRESSED	140	9,6	122	1,7

TABLE 2 Filter positioned at the TOP of the downsprue.

Locating the controlling runner system cross-section just behind the filter allows the runner system to fill completely and the filter to remain fully primed during the pouring sequence.
Cross-sectional areas behind the controlling cross-section can be increased in 10% steps from runner(s) to ingate(s).

Increasing the area of the runner system section behind the controlling section helps to reduce turbulence and erosion during mould filling. This aspect of filter use can often be as important to foundries as the filtration effect itself.

The filter should NOT be inserted standing on its edge but placed horizontally in the mould;

- ❑ this provides maximum exit face support,
- ❑ the filter is much less sensitive to dimensional variation either of mould or filter,
- ❑ it is easier to apply thinner filtration products, provided these give an acceptable filtration result,
- ❑ there is less risk of the filter falling out of the mould cavity during blowing, movement and closing.

6. Filter print types and their role in securing the filter in the mould:
It is absolutely essential that a carefully designed and correctly dimensioned sand print is available into which the filter can be accurately and securely positioned. A suitable print has to be designed in such a way that the filter:

- ❑ cannot move as the moulding line moves,
- ❑ cannot fall out as the mould is blown clean.

During pouring the filter print must also provide adequate support for the filter to ensure that during pouring:

- ❑ no breakage occurs,
- ❑ no unfiltered metal can bypass the filter.

FOSECO Disamatic filter prints are of three basic types, each with features to suit specific operational circumstances.

Parallel side wall prints:
The filter is positioned with its side walls at right angles to the mould joint face, the complete filter is inserted into the newly moulded exposed back-face of the Disamatic mould. The filter is held in position on the Disamatic Coresetter carrier plate by means of air suction, which MUST be automatically de-activated when the mould and carrier plate come together, releasing the filter which then remains secure in the mould.

Filter print type D1
As illustrated in Figure 6 this type of print is split in two parts, the main print and a smaller section. This arrangement gives support on all FOUR edges of the exit face of the filter. A profile of the smaller print portion MUST be accurately located on the Disamatic Coresetter carrier plate to enable correct positioning of the filter on the plate for insertion in the mould.
D1 Sizes currently available:

- ❑ 50 x 50 x 15, and 22 mm thick filters
- ❑ 40 x 40 x 15 mm

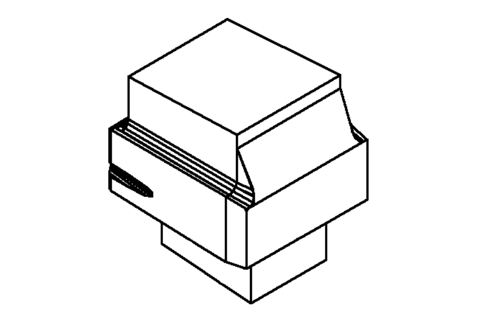

Figure 6: Filter print D1

The D1 filter print produces two small tapered fingers of sand on the rear sides of the print cavity which hold the filter in its final position in the mould, in a sort of finger and thumb grip, when the Coresetter carrier plate is withdrawn. Because these gripping fingers are under the centreline of the print cavity, this also permits the use of filters which are thinner than 22 mm.

Any sand grains which might be dislodged by the filter as it is pressed into position fall safely into the small profiled ridge created by the print, behind the filter.

The D3 filter print illustrated in Figure 7 is basically the same but it has TWO exits, for those cases when a double downsprue is required.

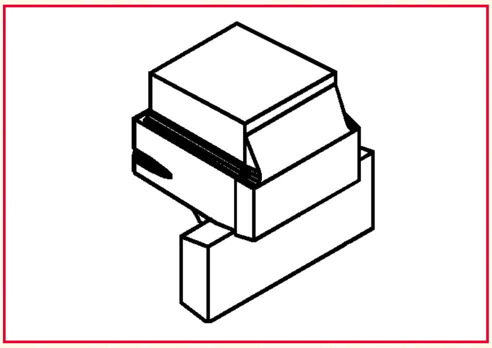

Figure 7: Filter print D3

Diagonal Insertion:
Filter print DD1
With this type of print shown in Figure 8 the filter is positioned in the mould diagonally, once in position, slightly less than half of the filter is exposed until the other mould half closes over it, this locks it in position in the mould. For this operation to be successfully performed it requires an accurately dimensioned print, if this condition cannot be met there is a potential risk of the filter being crushed upon mould closure and filter pieces finding their way into the castings.

Use of this print requires that a corresponding half diamond or triangular shaped recess is also produced in the Disamatic Coresetter carrier plate, the filter is placed in this recess. The filter is treated just like a small core, held in position on the carrier

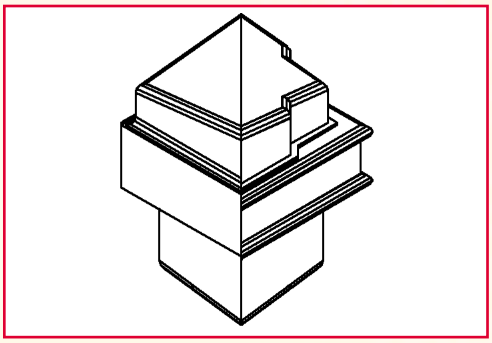

Figure 8: Filter print DD1

plate by means of air suction which is de-activated when the carrier plate and the mould come together, releasing the filter which then remains in the mould.

To prevent the filter from being withdrawn out of the mould print when the carrier plate moves away, sand ridges at the TOP and BOTTOM of the print grip the REAR EDGES of the filter and retain it in the mould half until closure completes the operation of securing the filter in the print cavity.

The print dimensions are such that when the filter is positioned in the mould, it is pressed firmly into the sand edges and, as with filter print D1, any sand grains which might be dislodged by the filter edges fall into the small profiled ridges created by the print, safely behind the filter edge.
DD1 Sizes currently available:

- 40 x 40 x 15 mm thick filters
- 50 x 50 x 15 mm
- 50 x 50 x 22 mm
- 60 x 60 x 15 mm

Pouring Bush Location:
Filter print DPB3
With this type of print shown in Figure 9 the filter can be positioned in the print by hand, in the top surface of the mould.

The filter is basically positioned horizontally but it is inclined at an angle of approximately 15 degrees; this makes it easier to position the filter in the print by hand using a finger and thumb action to insert it and also helps to prevent the filter floating upwards during pouring. This design of print is useful to conduct filtration trials in cases where no Coresetter is available, no cores have to be placed in the mould or the foundry does not wish to use the Coresetter for productivity reasons.
DPB3 Sizes currently available:

- 50 x 50 x 15 and 22 mm thick filters
- 50 x 75 x 22 mm only

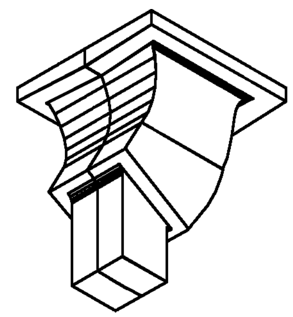

Figure 9: Filter print DPB3

7 Placing the filter in the mould:
The filter can be inserted in the mould in a variety of ways, as follows:

- pouring bush of the closed mould
- exposed mould face before closure.
- specifically designed carrier plate or mask operating in combination with a Disamatic Coresetter which inserts the filter into the open mould half.

The third method is the most widely used insertion technique so the subjects of filter prints and Coresetter coremasks are inseparable from one another. Accurate careful design of the coremask and its correct alignment with the mould is essential whether it is being used to position cores, filters and sleeves or only filters.

Failure to achieve correct coremask and mould alignment can result in broken filters as the Coresetter tries to force the filter into the mould print. Even if only slightly out of alignment the filter may displace small quantities of moulding sand as it is moved into position, this sand may fall into the running system behind the filter and result in casting defects.

8 Filter handling and carrier plate designs:
There are a number of carrier plate or Coremask designs which are influenced by the type of filter print employed, in all cases the mask must line up exactly with both the pattern plate and mould.

A carrier plate for use in conjunction with filterprint D1. This requires a profiled mask with a 5 mm deep rectangular seat 52 x 23 mm, under which there is either a flat steel plate or two support pins under the filter which is held in the correct position by air suction. This design avoids the need for any supplementary location pins L and R of the filter.

For use in conjunction with filterprint D1 a carrier plate equipped with an adjustable spring loaded clip or small compressed air activated ‘fingers’ can be used.

For use in conjunction with filterprint DD1 a carrier plate must be produced with a right-angled triangular pocket (the dimensions and shape of this must correspond with the diagonal profile of the filter); this pocket is cut into the carrier plate. The filter is placed in this pocket and held in place by air suction, ideally two air orifices being used; this arrangement ensures that a closed filter edge is always presented to one of the orifices. The filter is released, just like a small core, once the coremask closes onto the open mould half.

9 Economics of filtration:
Although the use of filtration is now widely practised in the modern industrialised world, unfortunately the economic benefits remain rather poorly documented, foundries perhaps choosing to remain silent concerning the undoubted economic benefits which they obtain from the application of filtration.These are clearly significant given that the correct use of filters can:

- ❑ lower scrap levels,
- ❑ raise quality standards,
- ❑ improve yield levels,
- ❑ simplify methoding input,
- ❑ reduce inspection levels (3),
- ❑ reduce machining scrap levels (4),
- ❑ lower the amount of machine tool wear (5, 6),

In a well documented study of economic benefits prepared by Sadon et al (7) machine shop savings in excess of €281,000 (ca. $260,000) were shown on an annual production of 2,7 million vertically poured ductile iron crankshafts.

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