SIVEX FC foam filters ---
more than just a filter

The quality requirements of aluminium castings continue to grow more demanding. As there is an increased focus on automotive components and aluminium is used in more safety critical applications, then it is clear that foundry processes have to be more controllable. Major efforts have been undertaken to improve metal treatment practices to produce an aluminium melt to an optimum cleanliness and integrity. The correct use of fluxes and the implementation of FDU rotary degassing technology has significantly increased metallurgical control in every type of foundry.

Now that a ladle of high integrity aluminium is available at the pouring station the difficult stage of the production cycle begins - pouring.

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In the introduction of his book titled "CASTINGS" John Campbell wrote the following:

> "The surging and tumbling flow of the melt through the running system can introduce a cloud of bubbles and Saragossa seas of oxide films."

In the following work the primary aim has been to give a greater understanding of flow characteristics of liquid aluminium in the mould.

Figure 1a

Figure 1a shows a real time X- ray picture of a simple sand mould during the early stages of filling. Within the runner bar it can clearly seen, that there is turbulent flow directly below the downsprue giving the opportunity for oxide to be formed and carried into the mould cavity. The runner bar at this stage contains a mixture of aluminium and air, some of which can be carried through into the mould cavity.

Figure 1b

Figure 1b shows that even later in the process the turbulent condition remains and the runner bar, being still partly unfilled continues to introduce air into the moving aluminium stream.

The early stages of the pouring and the initial downsprue and runner bar are all key factors in controlling the final casting quality. Considerable attention has been given in recent years to downsprue design. Metal velocity in a parallel downsprue increases with distance and so the metal stream must contract leading to aspiration and entrainment of air but even when carefully calculated and tapered sprues are used the metal velocity will increase according to the following formula:

$$v = \sqrt{2gh}$$

g: acceleration due to gravity [9.81 m/s2]
h: falling height of the metal
v: resulting melt velocity

The simple mould shown in Figure 1a and 1b has a downsprue of 220 mm. This means that a metal velocity of 2.1 m/s is achieved at base prior to impact and a 90 deg change of direction.

The foundry industry now accepts that a metal velocity in excess of 0.5 m/s is liable to result in a turbulent condition, hence the effects seen in figures 1a and 1b.

The pouring system comprises of:

- Ladle or Launder: designed to introduce a smooth stream of the correct size and shape into the pouring system at the required rate.

- Pouring Basin: ideally these should be designed to steady the flow, be fast to fill and to control the rate of introduction of liquid metal into the downsprue. However because of limitations of mould or die design, robotics and yield considerations, these often have to be simple conical shapes allowing everything poured to enter the downsprue. Existing oxides can be held back by the basin and correct design can avert temperature loss and further formation of oxide.

- Downsprue: ideally tapered, but because of the moulding process may need to be parallel or reverse tapered. Must be of the correct size and shape. If the downsprue cannot be filled and maintained air and oxide are taken down with the metal and can be taken through into the mould cavity. Even when ideally designed, metal velocities will be excessively high. In particular round cross sections can have an adverse effect on casting results. To overcome this Fredrich Nielson, in his book, made fundamental proposals on the design of running systems to overcome oxide problems.

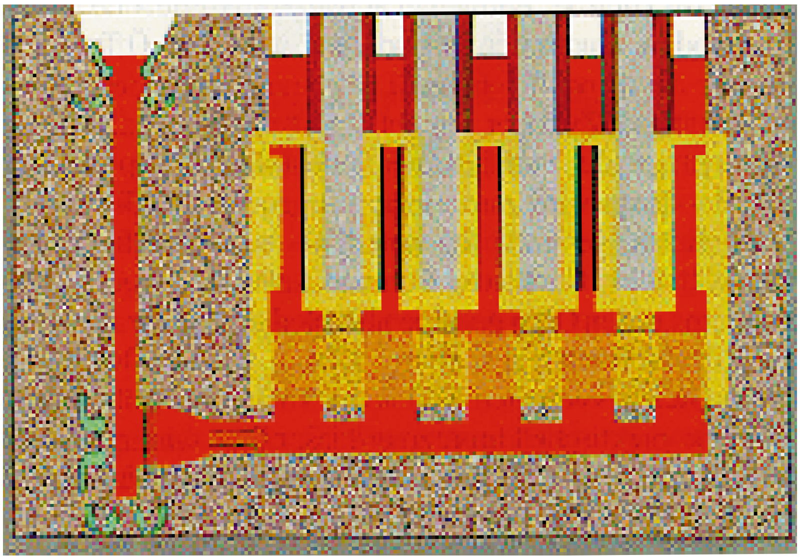

Figure 2: Schematic view of part of a pouring system (2). The green arrow indicates likely areas for turbulent flow.

This early stage of the pouring cycle is the most fraught with danger. During a discussion with John Campbell, Professor of Casting Technology at Birmingham University, it was stated that the likelihood of casting defects being created at this stage were 10 times higher than that by poor ingate design.

The critical elements of an ideal running system are:

- Scale: Yield is becoming more important to the foundry man and so a system must be affordable without compromising casting quality.

- Filling Rate: Metal speed must be controlled while filling time is correct to give a complete casting, absence of inclusions and good thermal balance to encourage directional solidification. The ability to segregate exogenous and indigenous inclusions from the liquid is a vital property of the system.

Flow Control: To avoid surface turbulence and subsequent tearing of the existing surface oxide layer which protects the internal metal stream. The mould can be filled both quickly and quietly if optimum conditions are achieved.

It is becoming common practice to position a foam filter across the runner bar prior to the first ingate. To avoid inconsistency in flow and filling rate the choke is positioned at the base of the downsprue prior to the filter, and the filter size is selected to give an area in excess of the runner bar itself. (5)

Now it has been seen how important running system design and flow control can be. It was decided to investigate how different filter- media, which are commonly used in aluminium foundries can impact on flow characteristics. The aim of this investigation is to simply compare different filter-types in the same running system in terms of their different flow control.

The method used was Real Time X- Ray taken through a sand mould. For trial details see Table 1.

Investigation method	**Real Time X-Ray**
Alloy	AlSi7Mg
Casting temperature	730°C
Gross weight	5.5kg
Net weight	3.5kg
Sprue height	220mm

Table 1: Trial details

The different filters investigated are listed in Table 2.

Filter type	**Porosity**
Glass cloth	2mm
Metal screen	1mm
Double metal screen	
Extruded ceramic filter	200csi
SIVEX FC foam filter	10ppi
SIVEX FC	20ppi
SIVEX FC	30ppi

Table 2: Filter material investigated

Figure 3a

Figure 3a: This shows early stages of the pouring via glass cloth. There is no back pressure from the filter visible and the downsprue remains only partly filled. Metal is sprayed in individual streams through the cloth, an amalgam of air and aluminium jetting into the cavity.

Figure 3b

Figure 3b: Later in the pour large bubbles are still escaping into the cavity. The system can not be filled.

Figure 4

Figure 4: Incorporates a mesh steel filter in the system and gives similar results to those seen with the glass cloth. Again there is a mixture of air and aluminium leaving the filter, the most damaging situation possible.

Figure 5a

Figure 5a: Flow through the cellular filter is also unrestricted.The downsprue remains only partially filled, with the risk that the surface oxide layer tears away and inclusions result.

Figure 5b

Figure 5b: Later in the filling process we can see the stream is still very turbulent. Oxide will be produced in the runner and the mould cavity.
The remaining work was carried out using SIVEX FC non- ceramic foam filters in different porosities, these filters act totally differently from all the other types. They have the ability to remove inclusions, if metal treatment problems occur in addition to stream lining the flow.

Figure 6a

Figure 6a: shows the early moments of filling through a SIVEX FC 10 ppi- filter. Compared to all the earlier results with alternative filter media described above there is an immediate difference in the flow characteristics. The metal clearly holds still when it hits the surface of the foam material. No flow occurs until sufficient back pressure builds up, this gives a good chance to overcome problems which very often occur during the first instances of the pouring process, because it's now quite easy for the downsprue to fill.

After "priming" the filter there is another important difference clearly visible: The liquid aluminium alloy fills the runner bar behind the filter very quickly and -importantly -, quite smoothly. This gives the foundryman a good chance to fill the cavity without the danger of air bubbles or entrapped oxides from various sources. Once completely filled the system will readily remain full.

Figure 6b

Figure 6b: shows that a few moments later, the metal has already entered the mould, there is a smooth uninterrupted flow of the metal in the cavity.

Since all the systems investigated had identical dimensions, this study clearly indicates that SIVEX FC has reduced the energy of flow and avoided the danger of turbulence. Further investigation with finer pore sizes, 20 and 30 ppi, were carried out. As expected finer filters further reduce metal velocity leading to smoother mould filling.

Figure 7: Runner bar is filled and metal rises into the cavity without any significant fountain.

Figure 7

In practice finer filters are particularly appropriate for running systems with relatively high downsprues or, if quality of casting is particularly high. e.g. x - ray, crack detection or pressure tested. It is important to remember that finer porosity grades are more sensitive to changes in melt quality and temperature. The open pore area for SIVEX FC is around 80% but may reduce during pouring due to retention of inclusions. In extreme cases this leads to cold lapping or partly filled castings. This illustrates the importance of controlling all aspects of the production cycle and that consistent results will only be achieved with thorough control, SIVEX FC filters alone are not the complete answer.

Case Studies

In the next section the previously introduced thoughts will be further explained with the aid of practical examples. The case studies were chosen to illustrate a few of the most significant properties of SIVEX FC filters.

Figure 8

Figure 9

- The first case study stresses the importance of non - turbulent flow. The casting concerned is a sand cast racing motorbike wheel produced in a magnesium alloy. Details are kindly provided by Ruote Marchesini, an Italian foundry. As a result of the highly reactive and sensitive alloy it is vital to have smooth and quiet filling of the mould cavity. In addition it is a necessary requirement to achieve particular mechanical properties while retaining the aesthetic appearance of the casting. The application of a SIVEX FC100x100x2210 ppi in the running system ensures acceptable quality while maintaining the required pouring time.

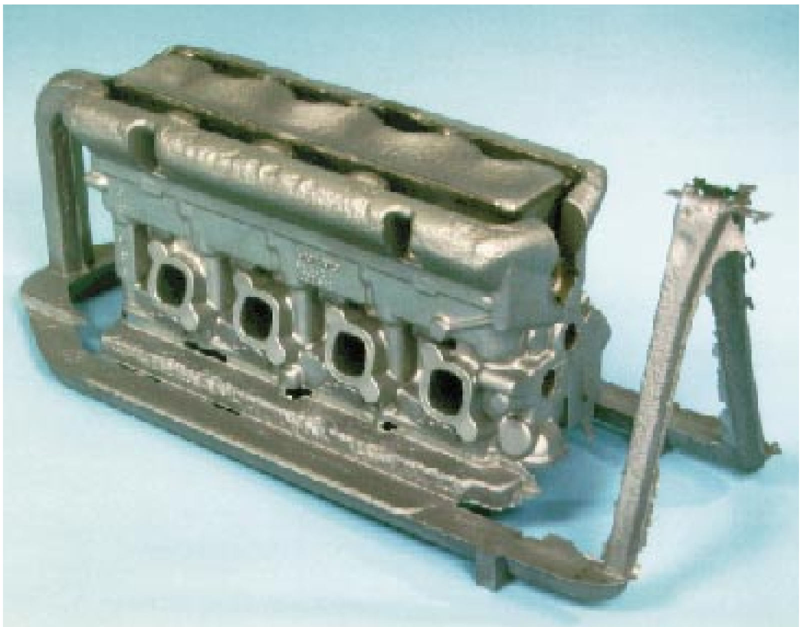

Figure 10

- The second example is a Volvo cylinder head. The running system has a downsprue of 400mm and after several minor modifications it was decided to carry out a fundamental change to the die tooling. The initial problems were rejects due to pressure test leakers and internal rework and more importantly external scrap at the customer following machining.

Two SIVEX FC non - ceramic foam filters are now applied to the running system and the filter prints in the die are shown below.

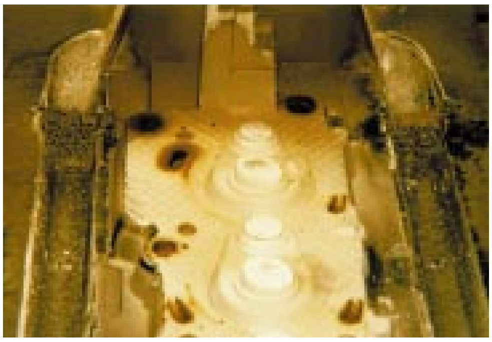

Figure 11

- The third case study is a thin wall aluminium cylinder block which is a casting made in gravity die. The block is used in a straight 4 engine. During the development and the early stages of volume production rejects were being found both in the foundry and at the customers and a number of process improvements were made to raise the quality standard. However, one particular problem was linked to turbulence which was only evident after the final machining of certain critical faces. A 63% improvement was achieved by greater process stability, reliability and increased production team knowledge. However, to significantly improve the oxide and turbulence problems, a step change in technique was required. The downsprue being 250 mm again made non turbulent filling difficult and because certain thin sections existed there was always the compromise of fast filling and smooth flow. Modifications to tooling were made to apply two 50x50x22 10 ppi SIVEX FC filters, to replace the existing steel mesh filters, and a reduction in reject rate of 65% was achieved. Figure 12 shows a section through the SIVEX FC filter. On the entrance face the oxide folds are held, without the filter these would be entering the casting cavity. Development work continues to explore the fine tuning of the technique with the aim to further improve the performance of the Sivex filter.

Figure 12

Conclusions

The use of real time X-ray now offers the foundry a better understanding of mould filling and ideally illustrates the value of the priming characteristics of the foam filter.

This property can be used to overcome the problem of flow control where tall downsprues lead to high metal velocities and oxide formation. SIVEX FC foam filters offer a combination of not just an extremely effective filter but also the opportunity to control the flow of the liquid metal through the running system. As part of a carefully controlled melting and pouring technique SIVEX FC further controls some of the critical variables in fluid flow.