FOSECO

SIVEX FC - a ‘Filter’ with a ceramic foam structure especially for aluminium repetition castings

General:

The use of ceramic foam filters for the purification of metal melts in the aluminium foundry industry has been the state of the art for some time. In addition to their high filtration efficiency foam filters also have a calming effect on the metal flow. Many authors (1,2) now consider the latter effect to be the most important for obtaining optimum casting quality. Extruded filters, pressed strainer cores, glass cloth or small steel mesh sieves have been or are also being used in some cases in the casting mould.

Misgivings have been expressed in the past with regard to the re-melting behaviour of these ‘foreign constituents’ in the casting system. This has taken place with regard to the typical material properties of these filters for example:

- **Chemical composition of the filter recipes:** The frequently used phosphate bond has been a cause for concern. It has been shown in numerous trials that under certain conditions phosphorus is picked up by the aluminium melt (concentrations of 100ppm were not unusual) with the known consequences for melts modified with Sodium

- **‘Ceramic Hardness’ of the filter:** The refractory constituents which make up the structure of the ceramic filter are normally silicon carbide (grey to black coloured filters) or alumina (white coloured filters). Both materials are characterised by a relatively high hardness, which lies close to that of diamonds. Errors in the application of ceramic filters such as the wrong filter print dimensions, inappropriate transport of the packed units which cause filter breakages, or the use of filters having insufficient thermal stability or a high degree of friability are often doubly ‘punished’. On the one hand the casting becomes ‘scrap’ due to filter inclusions, and on the other hand appreciable problems are observed during the mechanical machining of the castings. Especially when machining repetition castings in transfer lines appreciable costs can be created by the failure of tools and/or machine down time.

- **Specific (intrinsic) density of the filter material:** Because of their relatively high Al_2O_3 and/or SiC content, the known recipes of standard filters have a relatively high density (about 3.0 g/cm3), which is greater than the density of liquid aluminium (about 2.5 g/cm3). Filter particles remain suspended in the metal bath or sink down and in the course of time collect on the bottom of the molten metal container. A reduction in furnace capacity is one consequence, another may have more disagreeable results because the reactions which are described previously, apart from being dependent on metal temperature are clearly also dependent on time.

In order to prevent problems arising from re-melted returns containing filter particles, aluminium foundries generally ensure that ceramic filters are cut out of the runners and re-melted separately or sold to a secondary refiner. One would recognise very quickly how very expensive such a procedure is when the cost of two saw cuts and the metal content of the return are considered.

All the aspects noted up to now frequently cause the aluminium founder to regard the use of ceramic filters with a certain amount of scepticism (even the relatively widely used application of small iron mesh sieves can cause problems with regard to the pick up of iron by the metal melt during the re-melting operation).

As a response to the difficulties associated with ceramic filters a more suitable filter formulation for the aluminium sector is frequently demanded by customers. For some time now, SIVEX FC filters having a foamed structure have been approved in aluminium foundries. Apart from their filtration efficiency and the calming of the metal stream due to an especially effective foamed structure, they are distinguished by some specific material advantages which permits their use for aluminium application without the disadvantages outlined above.

The problem associated with the higher specific gravity of the ceramic filter when compared with liquid aluminium has been solved by a fundamentally new type of filter formulation: SIVEX FC filters exhibit a lower density in comparison to liquid aluminium so that even small filter particles float upwards to the surface of the bath and can be skimmed off together with the dross. It has been confirmed in many foundries that SIVEX FC filters collect in the dross during re-melting either as complete filter bodies or as fragments. Furthermore, the filter composition does not contain any critical elements for the metallurgy of aluminium such as phosphorus or iron.

The ability of SIVEX FC to resist thermal shock is very good; a regular check with molten aluminium for this property is a component of quality control testing so that no problems occur in normal foundry operations.

In addition, the composition of SIVEX FC is adjusted so that relatively good machinability is possible when using standard machine tools. In technological applications such a filter permits several positive degrees of freedom in the casting system, for example the application of the filter as a breaker core in the KALPUR Al direct pouring system. Apart from this, problems resulting from filter damage during the casting process which lead to 'filter inclusions', for whatever reason the damage might have been caused, are a considerably lesser problem for any subsequent casting machining process in terms of damage to machine tools.

In-house Investigations

The last named filter property - machinability - of SIVEX FC has undergone a qualitative and quantitative examination during the course of a comprehensive project which was carried out in 1998 jointly with the Fraunhofer IPT, Institute for Production Technology at Aachen. Some of the results from this investigation will be presented and discussed in the following.

The objective of the project was to show to what extent 'broken off' filter particles in a machined casting surface would lead to lasting damage to standard repetition machine tools. Figure 1 shows an overview of typical tool wear. The width of the wear marks serves as a quantitative measure for the damage to the tool.

By machining aluminium test samples containing small cast in plates of various 'Filter Materials' (for the construction of the trial see figure 2) it was intended to determine to what degree different filter materials would damage the test

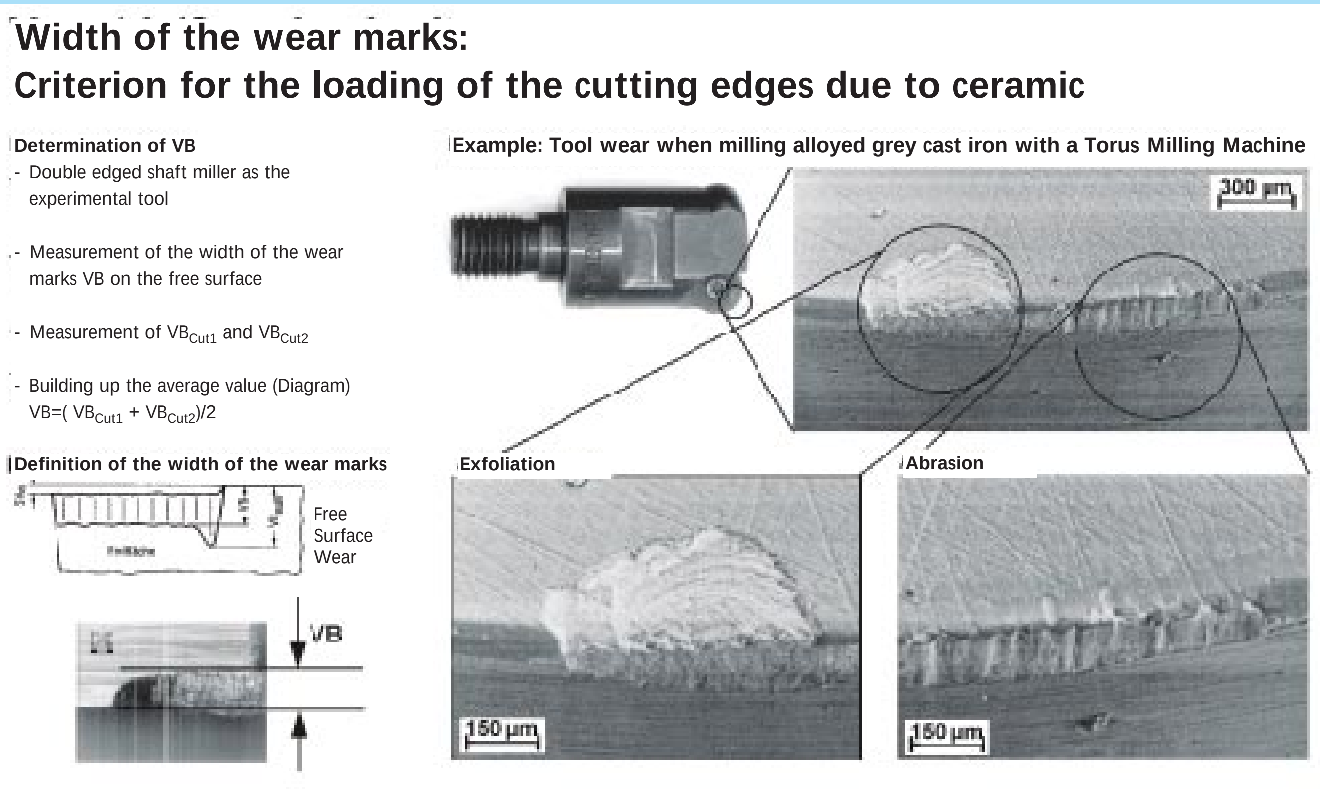
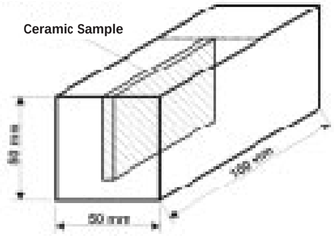


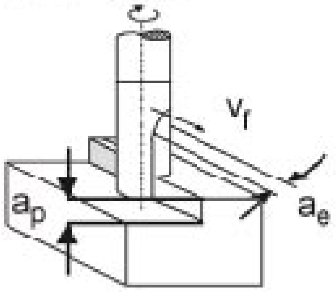
Figure 1: Types of tool wear and the width of the wear marks.

Experimental design

Test Geometry



Process Conditions



Test Geometry

- three different filter materials A, B and C were made as 3 mm wide samples.
- In each case one material was bedded in one aluminium block

Build up of the Experiment

- Machining the aluminium blocks including the test materials with a shaft miller (Diameter D = 10 mm, 2 cutting edges)
- Standard machining parameters for machining cast aluminium

Rate of Feed	V_f =2 m/min
Rate of Cut	V_c = 377 m/min
Depth of Cut	a_p = 2 mm
Width of Contact	a_e = 0.2+0.5+1 mm
Feed per Cutting Edge	f_2 = 0.1 mm

- The use of reversible cutting plates
  Cutting Material:- Hard Metal Type K10 uncoated

Figure 2: Construction of the trial and test geometry employed.

machine tools. In order to ensure that the test results were interpreted as objectively as possible, the various samples were characterised only with the letters A, B and C; the meaning of the characterisation was only disclosed at the end of the project (see the last page). Together with those responsible for carrying out the project, the most suitable sample geometry was discussed and defined. The small pure aluminium blocks with their various 'filter inclusions' were produced in the laboratory of Foseco in Borken. The aluminium samples with their cast-in 'small filter material plates' are shown in figure 3.

The samples produced in this manner were then machined on a high speed milling machine (see figure 4) by a shaft miller with a reversible cutting plate coated with hard metal. In order to avoid the formation of cutting build up, machining was carried out using a minimum quantity of lubricant.

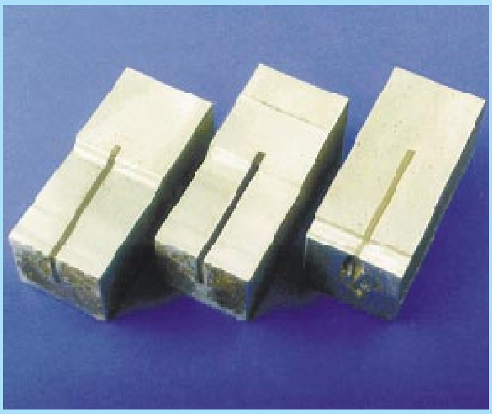


Figure 3: Test bodies.

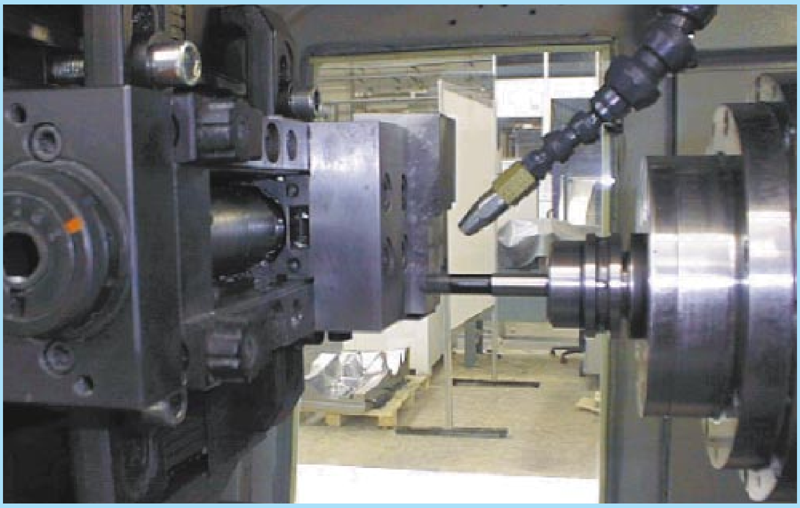


Figure 4: A view of the milling machine.

The wear on the cutting tool was quantified by a determination of the width of the wear marks VB. A scanning microscope examination of each of the samples to determine the micro structure after machining, completed the test procedure.

The width of the wear marks after several machining passes - I -

Rate of Feed: v_f = 2 m/min. Rate of Cut: v_c = 377 m/min. Depth of Cut: a_p = 2 mm. Width of Contact: a_e = 0.2 mm. Feed per Cutting Edge: f_z = 0.1 mm.

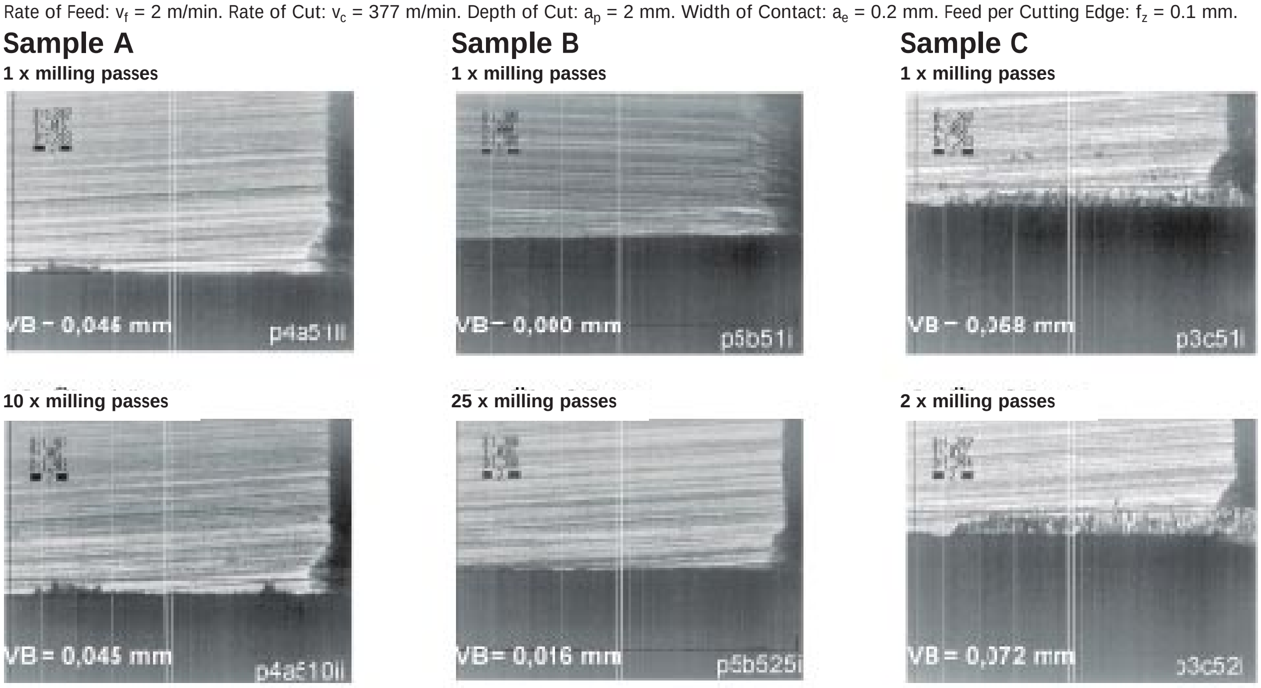


Figure 5: Results of the measurement of the width of the wear marks.

The width of the wear marks after several machining passes - II -

Rate of Feed: v_f = 2 m/min. Rate of Cut: v_c = 377 m/min. Depth of Cut: a_p = 2 mm. Width of Contact: a_e = 0.2 mm. Feed per Cutting Edge: f_z = 0.1 mm.

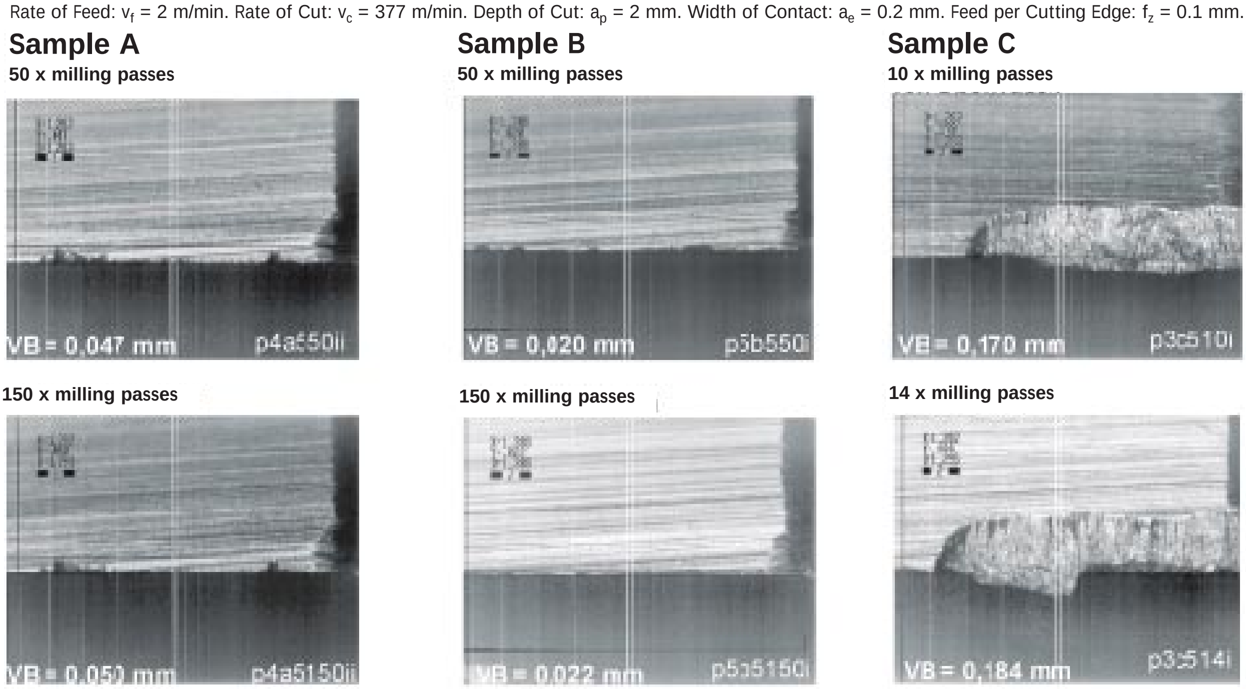


Figure 6: Progressive tool wear under standard conditions.

Results

The whole investigation was carried out under various experimental parameters. The results will be explained in greater detail for those examples which were obtained by the observance of the standard parameters determined for the machining of cast aluminium (see figure 2). In the overview shown in figure 5, the wear patterns on the reversible cutting plates are shown after milling over the various 'small filter plates'. The situation is shown after only a few 'machining passes'. A really clear difference may already be seen in the wear behaviour of the various materials. For sample B it should be noted that after 25 passes almost no wear is shown, whereas for sample C after only two passes a value for VB has been determined which is almost five times as great.

Apart from the strikingly reduced damage to the cutting edges of the tool by samples A and B the different wear picture is also notable (compare with figure 1). After only one milling pass over sample C the reversible cutting plate is already quite markedly worn by 'abrasion'. No clear picture showing the wear is yet to be seen for samples A and B. After 10 passes over inclusion type C clear signs of exfoliation on the tool can be distinguished, fine machining with such a milling head may now be no longer possible.

No significant enlargement in VB can be distinguished for samples A and B. Even after 150 milling passes over the filter material no increase in wear worth mentioning has taken place (see figure 6). If one evaluates this examination graphically and shows the width of the wear marks VB as a function of the number of milling passes, then one obtains the plot shown (see figure 7).

Summary and Result

Diverse filter materials, with distinct differences in structure and properties are employed today in the aluminium foundry industry. Materials with a foamed structure are very frequently employed mainly to control the rate of mould filling in the production of high quality castings with the most demanding mechanical properties. In discussions, standard filters based on Al_2O_3 - or SiC have created a certain amount of scepticism with regard to their suitability for re-melting and ceramic composition. SIVEX FC filters, developed specially for aluminium castings combine the advantages of the foamed structure with those of a machinable and relatively light filter material. The machinability of these filters was compared with standard filters in a comprehensive project with Fraunhofer IPT Aachen. The result from Fraunhofer IPT are reproduced in figure 8.

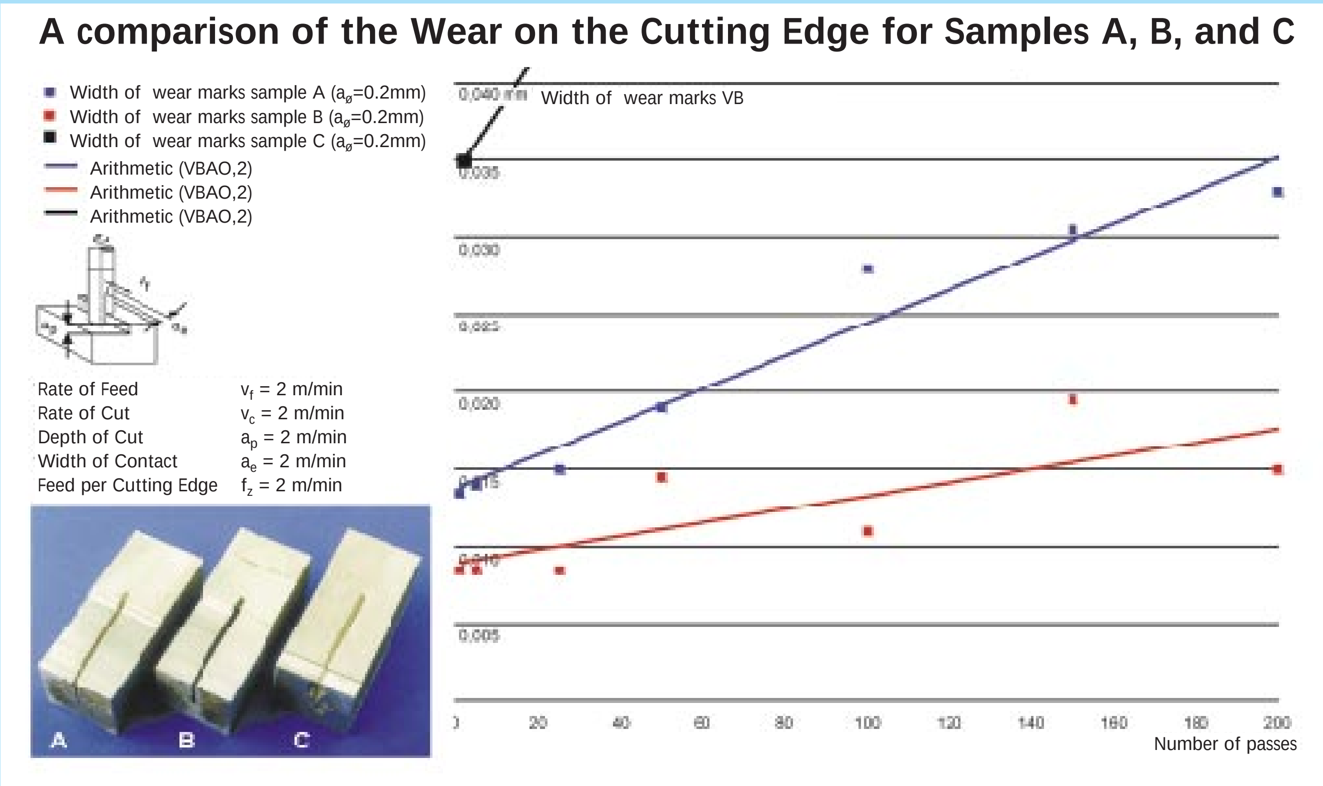


Figure 7: Tool wear as a function of the number of machining operations.

Result I - Cutting Edge Wear

- 1. Milling cycle

  - Sample A: Cutting edge shows small areas having exfoliations
  - Sample B: Cutting edge shows no damage
  - Sample C: Cutting edge is damaged over a large surface by exfoliation and abrasive wear

- X Milling Cycles

  - Sample A: The areas damaged by the first milling cycle are responsible for the additional wear, additional further damage has been caused
  - Sample B: Insignificant exfoliation on the cutting edge, even after 150 cycles less than after one cycle for sample as A and C
  - Sample C: Large surface areas are continuously being damaged further

- Sample C creates the greatest wear

- Sample B has the smallest effects after one milling pass

- Sample A produces a relatively high starting wear yet nevertheless the progressive wear is favourable

Figure 8: Result for the machinability trials.

Tailpiece:

Samples A and B represent two different, machinable, light SIVEX FC recipe variants. Sample C represents a filter based on silicon carbide.

Bibliography

(1) Woijtas H.- J:, Kurutas O.: Contribution to the operating mechanism of the filtration of metal melts - the use of ceramic foam filters for steel castings. Giesserei 85 (1998) No. 7, page 74.

(2) Sirrell, B.; Campbell J.: The Mechanism of Filtration in the Reduction of Casting Defects due to Surface Turbulence during Mould Filling. American Foundrymen's Society. Reprint No.: 97-011