

Progress update on Optifilter trials

Casthouse trials of the Optifilter three chamber filtration system are continuing with an unexpected result. This article is based on a TMS 2017 paper authored by John Courtenay of MQP together with Marcel Rosefort and Phil Jankowski of Trimet Aluminium, Essen

The development of a three - stage filter, Optifilter, comprising a ceramic foam filter applied in a first chamber operating in cake mode, a grain refiner added in a second chamber and a cyclone deployed in a final chamber, has been described in detail in previous papers.

Casthouse evaluation of the prototype Optifilter is an essential feature of this programme. Tests with the first industrial prototype, installed at Trimet Aluminium at Essen in Germany, demonstrated that liquid metal could pass through the cyclone successfully without excessive turbulence or splashing. Initial difficulties in achieving the desired flow rate through the cyclone were overcome by increasing the head height difference to 150 mm and a flow rate of more than 20 t/hr was achieved in testing on a sow casting station.

In this 2017 TMS paper the authors describe further trials carried out using the Research Casting Pit at Trimet. Podfa measurements of metal cleanliness before and after passing through the Optifilter were made together with analysis of the spent filter sections. Interestingly, cleanliness results were not at all as predicted. The explanation was to be found in the subsequent metallographic examinations, as will be revealed here.

Background

Firstly a reminder that the reason the Optifilter is being developed is to provide an efficient, low hold up volume filtration process capable of treating high metal flow rates.⁽¹⁾ In other words, a filter that can deliver the high efficiency performance of a deep bed filter, but with a low hold up volume, a low floor space requirement, and the ability to be used economically in conjunction with frequent alloy changes.

The starting point for the development was a finding^(2,3) that a TiBAI grain refiner addition, via a suspected agglomeration behaviour and alteration of filtration mechanism, prevented bridge formation in fine pore ceramic foam filters. Enhanced filtration efficiency from ceramic foam filters could be achieved by adding the grain refiner to the metal stream after the filter, rather than before, which was the normal practice in most casthouses.

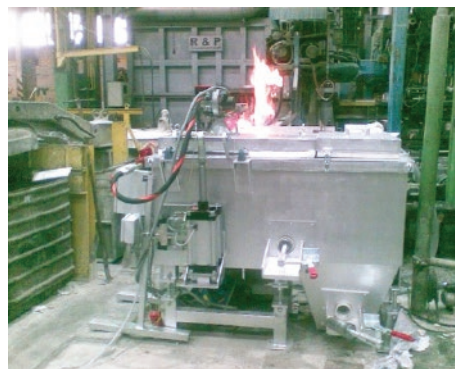
A more recent confirmation⁽⁴⁾ showed that when standard TiBAI 5/1 grain refiner was added to AA 5182 at a casting speed of 1.8 cm/s, the post filter LiMCA count increased from 9 k/kg up to 20 k/kg and the filtration efficiency decreased from 71% to 31%. It was concluded that this was due to the interference of grain refiner particles with the bridge formation mechanism observed in non-grain refined melts, a process needed to produce high filtration efficiency.

The XC filter

The first filtration system to take advantage of the benefits of post-CFF grain refinement was the XC Filter. In 2005 Instone et al^{(5),(6)} described a new design of filter unit named the XC filter which gave superior filtration efficiency compared to a CFF used alone, and was achieved by the combination of ceramic foam filtration and deep bed filtration. Importantly this design comprised a three chamber unit with a ceramic foam filter in the first chamber, grain refiner addition in the second chamber and a small bed filter in the third chamber.

Several prototypes of this filter were built and tested over the period 2000-2005 at the pilot DC casting centre at the Rheinwerk smelter in Neuss Germany. More than 80 evaluation casts using this technology were conducted and LiMCA and PoDFA measurement techniques showed that excellent filtration efficiency could be achieved.

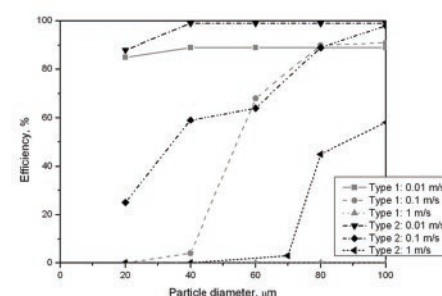
Designing the Optifilter



1 The prototype Optifilter filtration unit under pre-heat.

A new three chamber filter system (Figure 1), known as the Optifine filter, was designed based on the XC experience. In this a cyclone replaces the mini bed filter to further minimise footprint and importantly to provide a low maintenance solution for frequent alloy changes. The Optifilter has:

- A first chamber containing a ceramic foam filter
- A second chamber for the addition of grain refiner
- A third chamber containing a cyclone.



2 Predicted efficiency for particle removal by cyclone.



3 Prototype Optifilter installed at the Trimet Aluminium R&D casting pit.

The predicted efficiency of the cyclone is shown in Figure 2. There is an expected removal efficiency of approximately 50% for particles greater than 60 micron with a flow velocity of 0.5 m/s, rising to 80% for particles greater than 100 microns.

Casting trials

Three sets of casting trials have now been carried out at Trimet Aluminium:-

1. In the first trial the conditions were as follows:

Alloy:	1000 series 790
Number of billets:	32
Billet length:	2,000 mm
Cast size:	13,000 kg
Casting speed:	200 kg/min
Casting temperature:	790 °C

Some difficulties were experienced with preheating the first chamber, however a heat was successfully started and metal flowed through the filter for some 20 minutes before freezing off on the casting table.

2. In the second trial the prototype was modified to improve insulation and pre-heating and a second casting trial was attempted. Liquid metal passed successfully through the cyclone but the flow rate was very low and the exit tube only filled to approximately 10% of the exit cross section. It was estimated that the flow rate being achieved was of the order of 3t/h instead of the 15 t/h target.

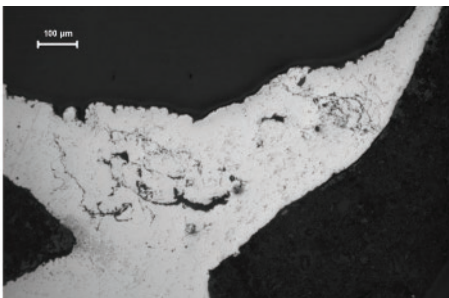
It was concluded that:

- The measures to improve insulation and increase preheat temperature had been successful but that restriction to the outlet flow must be due to either insufficient head height to overcome the resistance to flow of the cyclone and/or an insufficient cross sectional area at the cyclone inlet slot to allow adequate flow through the cyclone.
- Further water modelling was required, which was carried out at Delft University, to re-validate the flow modelling data and incorporate a design modification to the prototype Optifilter. This resulted in satisfactory metal flow through the prototype.

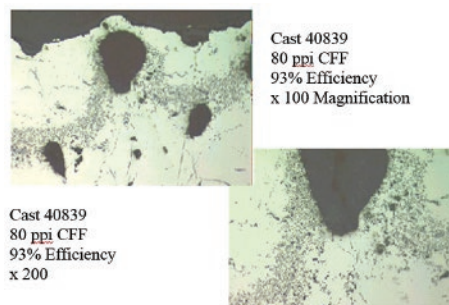
3. The third and recent trial involved using the Research and Development casting pit at Trimet Aluminium, where the outlet from the Optifilter discharged into a sow mould. As a consequence of this the trial was run without the addition of grain refiner. The R&D furnace contained approximately 4 t of Al 99.85 to which Mikro 100 was added as a contaminant.

Al 99.85 material was melted and degassed and then deliberately contaminated with a rod coil of Mikro 100 at an addition of 4-5 wt. %. The melt was cast through the Optifilter filter and solidified in an open mould. During the cast PoDFA samples were taken before and after the cyclone filter. The PoDFA values were compared with results of internal Trimet filtration CFF trials with similar conditions.

The Podfa results obtained in the trials were very disappointing. The best values obtained, for samples taken at the middle of the cast, showed a 51.5% removal efficiency. This compares poorly to the efficiencies that had earlier been reported for the XC Filter, also based on the principle of using a three chamber configuration where the first chamber contained a CFF operating in cake filtration mode. Efficiencies in the range of > 80% would have been expected in the Optifilter trial, so the reasons for this unexpected poor performance were investigated.



4 Photomicrograph of spent filter section from Optifilter.



5 Bridges formed in an 80 ppi CFF during casting trials with the XC filter at Hydro Neuss.

Investigations of spent filters

The purpose of this examination was to determine whether a filter cake had been formed on the surface of the CFF. Four sections were cut with a high pressure water jet cutting technique from the spent filter and prepared metallographically. The immediate sub surface was examined at 200 times magnification and the solidified aluminium contained in the filter pores studied for evidence of the formation of bridges. Figure 4 is typical of the many fields examined but no evidence of the formation of bridges comprising discreet particles could be found in any section. A characteristic of bridge formation is the accretion of fine discreet particles, mainly oxides, which grow at the neck of the filter pores, and there is no evidence of

this occurring. For comparison the process of the formation of bridges can clearly be seen in Figure 5, taken from the earlier work with the XC filter at Hydro Neuss.

Bridge formation is the required pre-condition for changing the filtration mode of a CFF from depth filtration to cake filtration. Unless this occurs, no improvement in filtration efficiency can be expected.

The next step was to ascertain why no bridge formation occurred and therefore the nature of the particles added via the Mikro 100 rod was examined. SEM photomicrography showed that the γ -alumina particles found in the Mikro100 are extremely fine, being in the range of 6-8 μm . For bridges to form the pore size to particle size ratio needs to be in the range of times 10 to 12, and therefore given that the pore size in a 40ppi filter would be greater than 1,000 μm , this condition is not met. It follows that bridge formation is unlikely to occur and the filter would not operate in cake mode, with a deleterious effect on filtration efficiency.

Discussion

The Podfa results showed that, at best, the Optifilter only matched the filtration efficiency of a standard CFF tested under the same trial conditions. However, it has to be remembered that the trial procedure at Trimet had been developed specifically to evaluate different CFF filters. Optifilter was inserted into this programme for comparison despite the conditions differing from those under which the three stage filter had been developed.

In the trials at Hydro Neuss the technique used to measure inclusion removal efficiency was Limca and the system was operated to measure inclusion sizes down to N20 or 20 μm . Inclusion removal efficiency increased from 50% at N20 up to 98% at N35-40 where inclusions in the latter size range are considered to be particularly deleterious. What is relevant here is that inclusion sizes in the range 6-8 μm are just at the upper range of grain refiner particles. Particles in the range of 1-3 μm are considered to be ideal for effective grain refinement.

If we consider the expected performance of the cyclone chamber, it can be seen in Figure 2 that in a simple cyclone configuration, without a capture box, calculated inclusion removal efficiency at a flow velocity of 0.1 m/sec is 20% at 20 μm , 60% at 40 μm and 80% at 80 μm , and therefore the removal efficiency for particles of between 6 and 8 μm would be zero.

Undoubtedly Mikro 100 material provides a useful and consistent base for making measured inclusion additions to clean melt to measure the efficiency of CFF filters. However, the particles it releases are too small to help form a filter cake in the first chamber CFF and below the efficient removal range of the cyclone. Therefore the poor Podfa results could have been expected because the CFF in the first chamber would act as a CFF operating in depth mode and the cyclone will have no additional effect because of particle size.

Finally it is worth remembering, from the studies discussed at the beginning of this article, that the addition of grain refiner in front of the filter prevents the formation of bridges and therefore in the three stage Optifilter the grain refiner is added in the second chamber before

the cyclone. The cyclone is more efficient the denser the particle to be removed, the larger the particle and the greater the difference in density between the particle and the medium from which it is to be separated. This means that the cyclone is well suited to remove the unwanted relatively dense titanium diboride (T.B.) particles and agglomerates generated by grain refiner addition.

Latest conclusions

- In the recent tests known amounts of inclusions were deliberately added in the form of Mikro 100 rod to a 99.85% aluminium clean melt.
- Unexpectedly the efficiency of the prototype Optifilter, as measured by Podfa, was only similar to that achieved with a standard CFF tested under the same trial conditions.
- Examination of spent CFF filter from the tests revealed that no bridges had been formed and that the filter had operated in standard depth mode which gives much less efficient filtration than cake mode.
- Investigation of the nature of the Mikro 100 inclusion source showed that particles of γ -alumina in the size range 6 to 8 μm are released into the melt.
- With particles as small as 6 to 8 μm and a filter pore size of greater than 1,000 μm the accepted criteria for the formation of bridges, that is a pore size to particle size ratio of less than 10 to 12 times, was not met and the CFF did not operate in cake mode.
- Furthermore in these tests the cyclone had no effect on particle removal because the effective particle size operating range for the cyclone chamber is from 20 to 80 μm , which is much larger than the 6 to 8 μm particles added with Mikro 100.
- Further casthouse trials of the prototype Optifilter have already been agreed and will be conducted under industrial conditions closer to the design parameters used in the original computer flow modelling.

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