# Optimisation of grain refinement in a melting operation based on primary metal

John Courtenay of MQP Limited recently presented a paper at the TMS Conference in San Antonio, Texas, USA dealing with optimisation of the industrial aluminium alloy grain refining process.

It is now possible to study and quantify the various factors affecting grain refinement including melt nucleation level, growth restriction factors, grain refiner recovery, in line treatments and potency and variation in grain refiners with the use of Opticast technology.

The Opticast system (1) is proving to be an invaluable tool in carrying out assessment and control of grain refinement practice in industrial casthouses by using data generated from sampling the melt in real time. The system allows rapid and reliable results to be generated so that accurate conclusions can be quickly made regarding implementation of optimised grain refining practice.

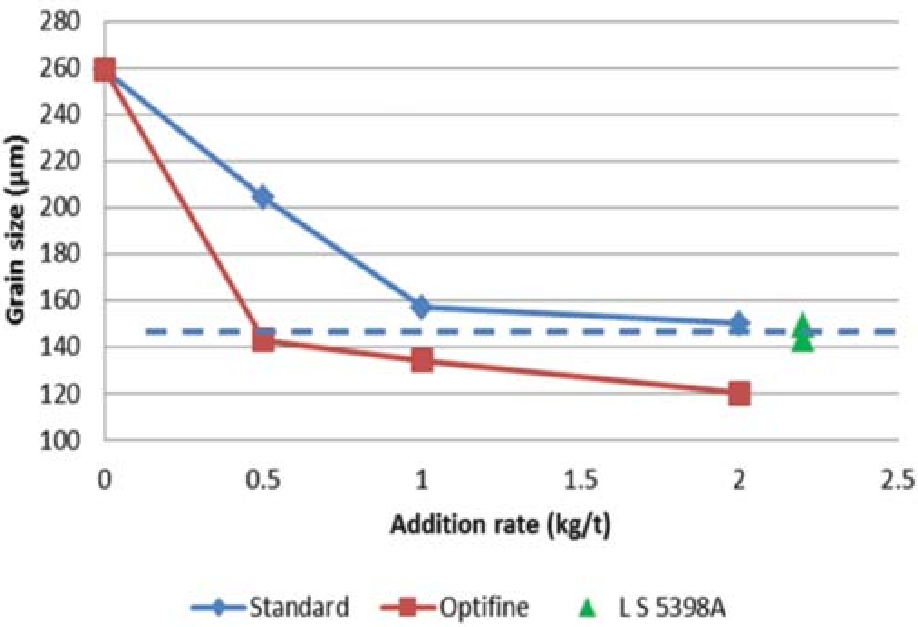
Grain refiner variability has been found to be an important consideration factor in achieving a fully optimised practice and this has led to development of a consistently potent grain refiner, Optifine. In the TMS paper the results from two casthouses where optimisation was carried out and Optifine introduced were described. In this short article one of these, the Eti Alüminyum operation at Seydisehir, Turkey, is the focus of attention.

### Eti Aluminyum

Production at the Eti plant is around 65,000 tpy of 6063 billet. Casting equipment comprises two 45 MT holders, an Alpur inline degasser, a filter box with 40ppi ceramic foam filters and a Wagstaff billet casting table. The majority of the furnace charges contain a large proportion of primary metal, supplied by the nearby smelter, and the current grain refinement is with 2.2 kg/t of standard commercial 5/1 TiBAl. The first objective of the optimisation work was to demonstrate the ability to achieve a minimum of a 50 per cent reduction in grain refiner addition with Optifine. A second target was to reduce consumption by 70 per cent. This would mean initially reducing addition rates from 2.2 kg/t down to 1.1 kg/t and then to 0.65 kg/t.

### Optimisation trials

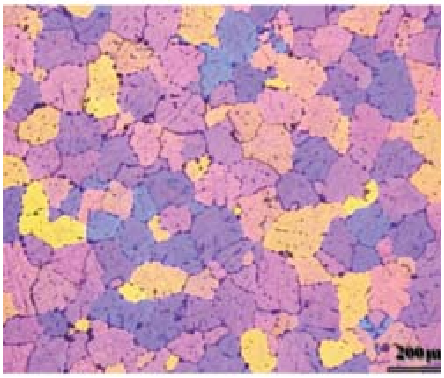
In an initial trial, samples of un-grain refined metal were taken from the furnace spout and Opticast crucible tests carried out with standard 5/1 grain refiner and Optifine added at 0.5 kg/t,1.0 kg/t and 2 kg/t. The aim was to establish the current an acceptable launder grain size and confirm that it was safe to reduce current grain refiner addition rate to 1.1 kg/t with Optifine. The resultant Opticast curves in figure 1 revealed a large difference in efficiency between the standard commercial grain refiner mounted at the casting line (blue line) and Optifine (red line). The horizontal hatched line indicates the grain




*1 Opticast grain refinement curves from an initial trial*

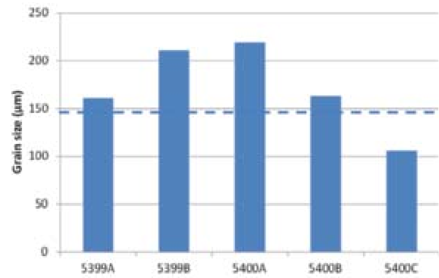
size obtained in samples taken in the launder when the standard Ti BAl grain refiner was used at an addition rate of 2.2 kg/t. The average grain size was 146 $\mu$m. The red curve for Optifine additions indicates that the same grain size can be achieved with an addition of only 0.5 kg/t of Optifine.

Based on these results it was decided to carry out a second trial with Optifine at an addition rate of 1.1 kg/t. The results from this showed an average grain size measured at 135 $\mu$m in the Opticast samples which confirmed the prediction made in the first trial. After homogenisation, a billet slice from this trial was examined and the grain structure is shown in figure 2.




*2 Micrograph of billet cast from second trial with Optifine added at 1.1 kg/t. Grain size after homogenisation was 65 $\mu$m compared to the 135 $\mu$m measured in the Opticast samples.*

It was then decided to produce five production casts with a 50 per cent reduction in the addition rate down to 1.1 kg/t. The normal practice at Eti is to assure a titanium level of 50 ppm in the furnace before casting in order to assure a high enough growth restriction. The base level of titanium in charges may vary from as low as 5 ppm to 100 ppm in the furnace, depending on the ratio between pure metal and scrap. This means that if the analysis shows less than 50 ppm, Ti waffles are added to increase the concentration to 50 ppm. In two of the production casts, the titanium content was increased by Ti addition, but in the other three casts no titanium additions were made as a means of evaluating if Optifine could perform acceptably even if the growth restriction conditions were not optimised. The results from the tests are shown in figure 3.




*3 Grain sizes in Opticast samples for five production casts with an Optifine addition rate of 1.1 kg/t*

The Opticast results indicate clearly that having an adequate Ti level is essential in order to provide conditions to ensure a small grain size. The two casts without Ti addition had extraordinary low Ti levels, about 2 ppm, which resulted in grain sizes around 210 $\mu$m.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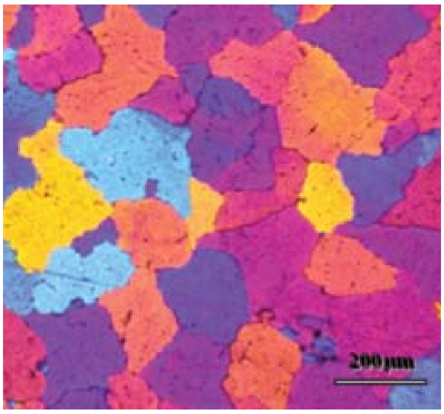
Two other casts to which Ti had been added to around 20-30 ppm produced grain sizes just above 160 $\mu$m. The other cast without a Ti addition, but with a base Ti concentration well above 50 ppm due to a large proportion of scrap in the charge, showed a very small grain size of 110 $\mu$m.

### Grain size prediction

Having determined that a satisfactory grain size can be produced with an Optifine addition of 1.1 kg/t, provided that the Ti content is adequate, a further production cast was made with a lower Optifine addition of 0.85 kg/t in conjunction with a Ti level adjusted to 50 ppm. Crucible tests were made with Optifine additions ranging from 0.86 kg/t down to 0.56 kg/t.

Results showed that the grain size prediction works very well, when the Ti level is adjusted to 50 ppm in the furnace, and indicates that it would be possible to cast this alloy with an Optifine addition even as low as 0.56 kg/t, i.e. a decrease of 75 per cent from the original level of 2.2 kg/t. A billet slice from this cast with a 0.65 kg/t Optifine addition showed, after homogenisation, a grain size of 110 $\mu$m as in figure 4.




4 Billet micrograph from cast with Optifine added at 0.65 kg/t

It is worthwhile noting that in these trials none of the 6063 billets cast from metal treated with Optifine experienced cracking even when the measured grain size in the Opticast samples was over 200$\mu$m. A 200$\mu$m grain size in an Opticast sample corresponds to about 100 $\mu$m grain size in a billet. This puts it well within the allowable maximum 176 $\mu$m grain size corresponding to ASTM Grade 2.0, which Eti Aluminium uses as its grain size control standard in production to avoid billet cracking.

The results at Eti Aluminium have confirmed that although in the case of smelter metal the growth restriction factor is substantially less than in a remelt, this can be successfully managed by controlling titanium levels to 0.005 per cent. Optifine was successfully used for casting of 6063 billets on a trial basis with the addition rate being reduced by 70 per cent compared to standard practice.

Here and elsewhere the Opticast methodology is proving to be an invaluable tool in carrying out optimisation and control of grain refinement practice in casthouses regardless of whether furnace charges are based on remelt aluminium or pure aluminium.

**Reader Reply No.110**

### Bibliography

*1 "The Opticast system is truly innovative", Aluminium Times, Vol 15 No 1 (Jan/Feb 2013), p40.*

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# Molten metal treatment

Alkali and alkaline earth metals are generally considered to be undesirable elements in aluminium production. Even in trace quantities these metals degrade the properties of most aluminium alloys, causing cracking and corrosion. The two most troublesome elements, sodium and calcium, are often removed in the casthouse by the direct injection of chlorine gas to molten aluminium in the holding furnace.

Increased emphasis on health, safety and the environment has accelerated efforts to find a subsitute for the extremely hazardous and highly corrosive chlorine gas, and at Rio Tinto Alcan Iceland's ISAL smelter its use was eliminated a number of years ago by implementation of the following process.

### Sodium and calcium removal

In the early 1980s a system of metal treatment in ladles was developed and subsequently commercialised by Alcan. The process uses aluminium fluoride ($AlF_3$) as a flux, added directly into a vortex generated in the molten aluminium by a rotor. This technology has been further developed in a co-operative project between Rio Tinto Alcan and VHE. A test rig was designed and fabricated by VHE, and was then erected at the old metal treatment station at Rio Tinto Alcan Iceland's Straumsvik smelter, ISAL. Experimental work demonstrated that very low sodium levels could be achieved.

Following successful completion of the development work, Rio Tinto Alcan specified a full scale metal cleaning project to be built at ISAL, comprising four stations each equipped with twin rotor vortex generators and injecting aluminium fluoride with argon gas. All stations are fed from an elevated silo using a dense flow system. Gaseous discharges are vented to the existing dry scrubbers. Key figures are (for each station):

VHE Molten Metal Station.

Ladle capacity: 6.7 tonnes
Treatment time: about 10 minutes
Overall cycle time: about 12 minutes
Typical Na removal: 95%
Typical Ca removal: 85%
Rotor speed: 300 rpm
Power consumption: 9 kW maximum

VHE Molten Metal Station during installation.

Fabrication of these stations also created a record. VHE has the largest milling machine in Iceland, which was used to fabricate four 2.8 metre diameter gear wheels, believed to be the largest such pieces ever made in the country.

**Reader Reply No.111**