A further step towards total melt quality control

Prefil® Footprinting® in conjunction with inclusion profiling enables thorough identification of the types and level of all inclusions present in molten aluminium alloys. Characterising the inclusion profile of molten metal and benchmarking it against world class production of the alloy or product allows the most appropriate metal cleanliness processes to be introduced, monitored and controlled.

Based in the UK, MQP Ltd is actively involved in a number of projects which focus on the quality of metal in casthouses worldwide. These include: Optimising the grain refining process using the innovative Opticast system in conjunction with a highly effective grain refiner, Optifine; Development and evaluation of novel three chamber filtration systems incorporating the addition of grain refiner to one chamber, and; Casthouse programmes aimed at the audit, characterisation and enhancement of melt quality and cleanliness.

The work on melt quality and cleanliness has been carried out in co-operation with N-Tec Limited, based in the UK. This company specialises in molten metal quality management and has an established reputation for the efficient quantitative measurement and interpretation of molten metal quality data using state of the art equipment and technology. N-Tec currently provides a well-established and proven metal quality benchmarking service known as FootPrinting® which generates profiles of metal quality in terms of dissolved gas and inclusions and compares them with its database of worldwide industrial product profiles collected over the last 15 years. FootPrints are the statistical average of all the individual data in the N-Tec database and provide a very powerful quality management tool.

MQP and N-Tec have pooled their resources and expertise to extend and improve the melt quality audit and benchmarking service into industrial casthouses worldwide. This article outlines the FootPrinting technique and introduces new control charting software called MeltClean® for the determination of a unique metal quality index.

Footprinting

The first essential step in characterising or profiling metal quality is to carry out a Prefil (pressure filtration) FootPrinter test using the equipment shown in figure 1. This provides an on-line measurement of molten metal cleanliness in terms of oxide films and other inclusions. To carry out a Prefil test molten metal is transferred to a preheated crucible and pressurised through a calibrated microfilter at constant temperature and pressure. The flow rate is monitored and used to plot a graph of weight filtered versus time as illustrated in figure 2. Each curve is known as the ‘Prefil Characteristic’.

Inclusions in the metal, such as oxide films build up quickly on the filter surface during a test, reducing the flow rate through the filter. The slope and overall shape of the weight filtered versus time plot then indicates the level, and type, of inclusions present in the metal. Oxide films, and other large inclusions such as MgO, affect the initial slope of the curve, resulting in a straight line with a slope that decreases as the number of inclusions present increases.

The presence of fine particulate inclusions such as TiB2, fine Al2O3 or carbides cause the plot to deviate from a straight line into a curve. The loading of fine particles can be inferred from the area under the curve. Acceptable quality can therefore be defined using upper and lower bound curves as illustrated in figure 3. If a test curve falls between these bounds the metal tested is usually deemed to be acceptable. The industrial FootPrint is the metal quality range defined by the average of all the data for a particular alloy or product in the N-Tec database (+/- one standard deviation). Hence 66% of all industrial data lies within the FootPrint.

Industrial Prefil FootPrints can be determined for an alloy family, a specific alloy type, process stage or a particular product. They are therefore an ideal way to benchmark and characterise a process or product line and the ‘real time’ benefit of Prefil becomes clear when a background FootPrint is used as a reference. Specific FootPrints can be imported into the database on any Prefil machine. Sometimes, additional curves are

![Prefil Footprinter® equipment, consumables and spares are available exclusively from ABB Analytical, Quebec and Canada under licence from N-Tec.](image)

2 Typical Prefil plots for low inclusion metal (high flow rate) and high inclusion metal (low flow rate).

3 Prefil Characteristics and Industrial Prefil FootPrints.

4 Comparison of Prefil Characteristics after CFF filtration.
provided. For example, the fastest and slowest curves in the database may be included to describe the industrial range or a threshold curve for a particular product might be given. Every year the database is updated with the latest industrial data.

**Process quality**

Footprints can be used to monitor how processing steps such as furnace treatment, inline degassing or CFF filtration influence metal quality. This is demonstrated in figure 4 which shows a Prefil plot for sheet/foil metal production after CFF filtration. Comparing the Prefil Characteristic with a FootPrint derived for sheet and foil production allows material to be quality controlled and scheduled appropriately.

Metallographic analysis of the residue that is retained on the filter after a Prefil test allows identification and quantification of the types of inclusions present in a metal sample to be carried out. The method of analysis is the well-established PoDFA technique developed and made available under licence from ABB. Oxides are reported as No/kg and other inclusions reported in mm²/kg. PoDFA analysis leads to fully quantitative inclusion profiles and identifies all the inclusions present in the metal. An example is shown in figure 5, in which the major inclusion present is grain refiner, which pushes the overall metal quality above the product target. Re-plotting the data without the grain refiner shows that magnesium oxide is the major impurity. The analysis helps decisions to be made on both grain refinement practice and the root cause of magnesium oxide generation.

In this case a casthouse improvement programme might focus on reducing TiB2 by optimising the grain refining process using the Opticast system and by using Optifine, a highly effective grain refiner. Optifine is proven to achieve satisfactory grain refinement at addition levels up to 80 % less than standard TiBAl grain refiners, and so substantially reduce the amount of residual TiB2 particles. Inclusion profiling is an essential feature in the implementation of a casthouse quality improvement programme, as it identifies the root cause of inclusions that need to be eliminated or substantially reduced, in order for melt quality to achieve the required standard.

**SPC charting**

In a casthouse quality improvement programme, once the optimum mix of equipment selection, process changes, metal treatment and grain refinement have been selected, then the final phase of the project would be entered into. This is when the new total melt treatment practice is applied on a production basis to produce quantities of the target alloys. Prefil FootPrinter testing is used to generate profile curves for the enhanced melt.

As part of the Footprinting process N-Tec has developed a new procedure for extracting a metal quality index from Prefil curves. This has been tested by correlation with PoDFA data and will be presented at the forthcoming TMS conference being held in San Diego in February 2014. Essentially, each Prefil curve can be represented by two numerical values referred to as Prefil Metrics:

- **PCS21** - this value represents the primary slope of the Prefil curve and indicates the oxide film content of the metal.
- **PCA150** - this value represents the area under the Prefil curve within the standard Prefil Charting window and relates to the total inclusion content of the metal.

These parameters are then processed to provide a single molten metal quality index, referred to as PCA*21.

MeltClean® is a new software package developed by MQP and N-Tec in cooperation that enables the Prefil Metrics to be extracted automatically from the Prefil Curves, then processed and plotted on an SPC chart to verify that the enhanced melt quality conforms to the target Footprint for the alloy being tested. Figure 6 shows a MeltClean generated SPC plot for trial production of 6063 billet using a modified process route. Prefil Metrics® and MeltClean extractive software facilitate the plotting of SPC charts and represent a new and valuable step forward in the continuing quest for total control of metal quality in a casthouse environment.

**Acknowledgement**

MQP wishes to thank Phil Enright of N-Tec Limited for providing insight, information and images to use in this article.

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