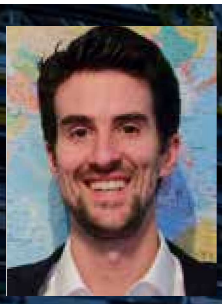
GRAIN REFINEMENT AND THERMAL ANALYSIS OF LIQUID ALUMINUM; DON'T HURT YOUR MELT!



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ARTICLE TAKEAWAYS:

- Grain refining/cleaning flux additions to liquid aluminum prevent casting defects
- Grain refiner additions without measuring the melt properties is counter-productive
- Thermal analysis measures the solidification properties of your liquid aluminum
- You might not need to add grain refiner at all - let's use data-driven decisions!

MEASURE YOUR MELT PROPERTIES:

Variations of your melt properties need to be minimized and measured from shift to shift if you want to grow your business into higher value casting jobs or just decrease your cost of operation.

The Reduced Pressure Test (RPT) density gives a melt quality index: a mixed value of the hydrogen and oxide content of your melt that contribute to porosity formation. The spectrometer tells you the chemical presence % of a given element in the liquid alloy. A thermal analysis system measures the solidification properties of the shop-floor alloy within 8 minutes; is what your casting simulation software uses? Are the chemical elements measured by the spectrometer available to participate in the solidification events as measured by the thermal analysis system? For example, the titanium % value given by your spectrometer might not be active in the form you need it to be to perform effective grain refining; thermal analysis will let you know about that. The goal is to always start with the same quality melt.

After that, we know our efforts for melt properties control are often wasted around the world by a dirty furnace, turbulent transfer, air aspiration from the pouring basin of the mold and a bad gating design. Each day the environment in the foundry can change, affecting the process parameters like the mold thermography, pickup of moisture by the melt, reoxydation and the fading of properties like the grain refinement or nucleation potential. Why do you need to degas more today than yesterday? Let's record the process data to understand and discuss as a team. What's happening on the shop floor today that is causing more scrap than 6 months ago? With data, we'll have the first step accomplished to prevent defects scientifically and win higher value jobs.

THERMAL ANALYSIS OF ALUMINUM-SILICON ALLOYS:

All thermal analysis systems are not the same. Make sure to ask how the solidification events are calculated during your demonstration of a thermal analysis system to confirm

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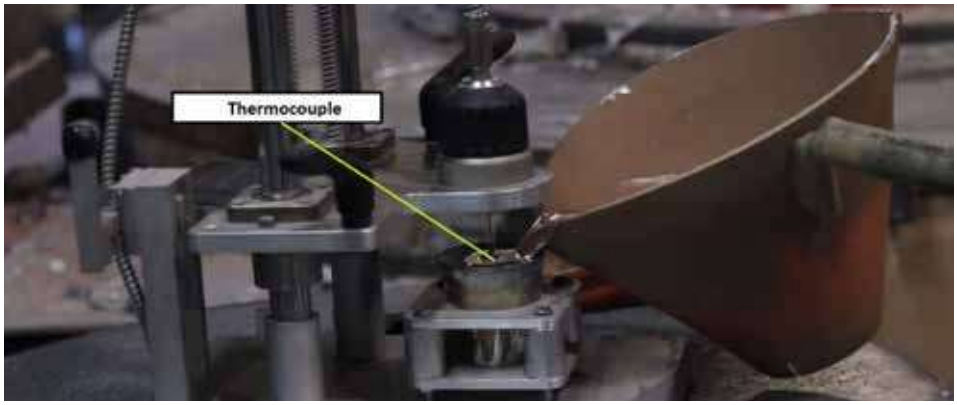

Figure 1. *A liquid aluminum sample being taken for thermal analysis of its solidification properties with the SF system. The thermocouple is surrounded by liquid metal.*

its repeatability, for instance. **Figure 1** shows a liquid aluminum 356 sample being taken for thermal analysis. Among the different solidification characteristics, we look at the liquidus, the mushy zone, the critical fraction solid, the eutectic, the late phases (MgSi, MgCuAl), the solidus and many more based on applications requirement. During the solidification, each event releases or absorbs energy. Your thermal analysis system should measure the relative energy of each event by integrating the cooling curve. This method gives better accuracy and repeatability than comparing curves or only using temperature points, but requires a new generation system.

For example, a lack of nuclei in the melt strongly affects the energy necessary to start the solidification. As a consequence, we're seeing a recalescence on the liquidus. The addition of grain refiner increases the nucleation potential of the melt, which eases the start of solidification. However, how do you know when and how much grain refiner you should add to the melt? Is it good or bad for the castings you make and the raw material you use to melt? What's the efficiency of your melt treatment and the fading of their effect over time? Does your operator understand why he's doing it?

The industry recognizes several solidification events for which thermal analysis is great and faster to measure, like grain refinement and eutectic modification level in aluminum 356. In 2020, advanced thermal systems allow you to measure solidification events easily in a repeatable and accurate way by the shop-floor operator, right next to the furnace; no need for the lab technician. Of course, we'll measure grain size using metallography like the Barker method follows. Still, your thermal analysis system should be able to provide you with an answer as accurate to run your foundry operations within 8 minutes.

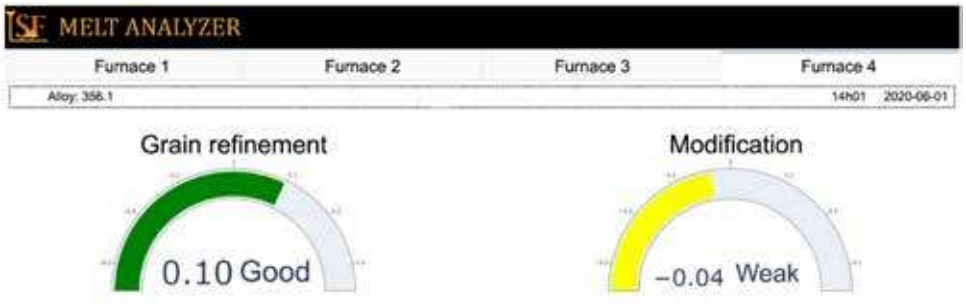

Figure 2. *The furnace operator interface of a user-friendly thermal analysis system for grain refinement and modification level evaluation in aluminium A356. The other melt properties are recorded and used to close the loop with the casting simulation software.*

CASE STUDY - REAL COST SAVINGS:

The furnace operator doesn't need to understand the cooling curve of the thermal analysis sample. He only needs the solidification property data of the last melt sample to take action. Like he often needs the RPT density value in order to confirm his melt has the target cleanliness. **(Figure 2)**

Now the operator or flux injector machine knows when any grain refining/cleaning flux should be added, if any, and how much of it in case the melt would need some. The quality manager will make sure to extract the cooling curve and the critical fraction properties that lead to sound castings and export the data for the mold filling and solidification simulations. Now the loop between the simulated alloy properties used by your software and the shop-floor data of the alloy is more accurate; let's avoid garbage in and garbage out.

For many years, a foundry procedure was to add between 0.1 to 0.5% of grain refiner to the melt. Finally, we could add only 0.05% and the fading effect occurred 3 to 4 hours later, for that particular casting job and foundry equipment and environment on that shift, it was enough to have optimal quality versus cost of operation. Trust your data! The liquid aluminum properties will change from day to day and often from batch to batch. Let's measure how the solidification events are affected during the casting process in order to make a justified action per casting job requirement. Then we'll have a good, stable melt to cast more and more difficult castings. We will better understand how to prevent defects. For example, what is the fault of an off-target melt quality or the fault of a bad gating design? Indeed, the party is just getting started; don't hurt the melt between the furnace and the last point to solidify in the casting.

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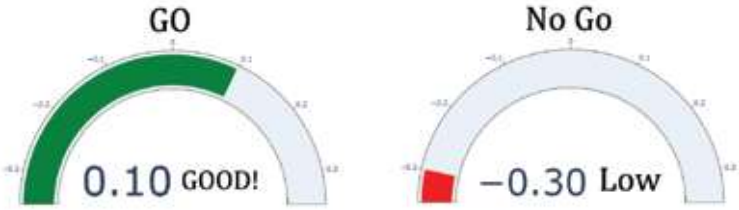

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