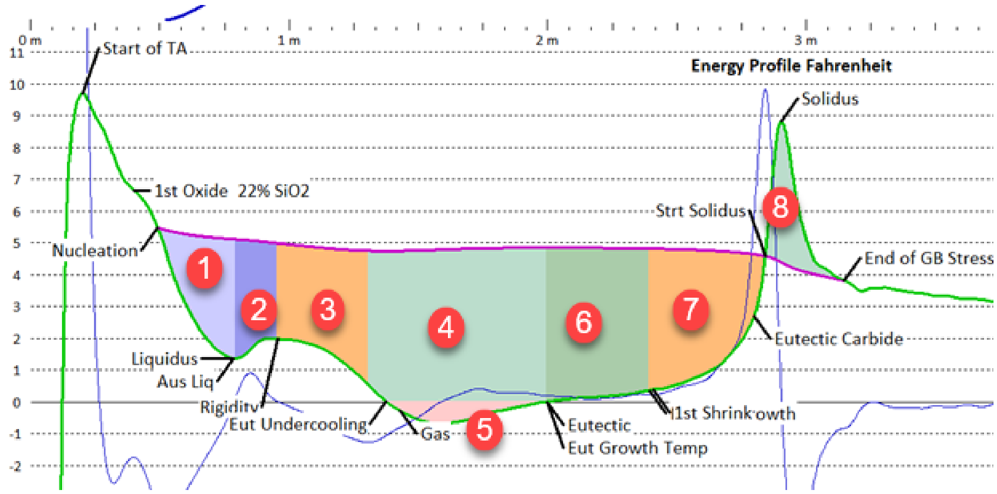
Understanding Gray Iron Micro-Thermo-Analysis



Introduction

Micro Thermal Analysis is a method of determining what the microstructure of a metal is, the percent of the different components, the fraction solid of the metal at different temperatures and how inoculation and treatments of the iron will affect the final product. Common Defects such as gas and shrinkage are measured and reported for quality control. It is a useful tool to standardize both the metal and the nucleation potential of that metal to make a more consistent casting.

Method

A small sample of liquid metal of 250-280 grams is poured into a sand cup with a horizonal thermal couple and allowed to solidify. The temperature of the metal is rapidly sampled during solidification, and the information fed into a real-time computer program. This data is then transformed into a visual interpretation of the various phases and mathematically transformed into the percent of each zone of solidification as explained below. From pouring the sample to final analysis takes from 2 ½ to 3 minutes. The data is then reported out to a spreadsheet compatible file (.Txt, .CSV, or .XLS format), and the actual curve is also saved for recall. The curves available include Temperature, Rate of Cooling, Base Line, and Fraction Solid and this data can also be reproduced in a spreadsheet compatible file. The data is processed through a proprietary signal processing that preserves minute effects such as gas and shrinkage while removing noise.

Key Curves

- The Rate of Cooling curve is the rate of change from the temperature curve. Mathematically, this is the first derivative inverted. A derivative is just the instantaneous slope of the previous curve. It is the green line shown in the curve above.
- The Base Line curve encloses the heat energy or heat of fusion of the sample. It is the magenta line shown in the graph above.
- The Base Line curve starts at the start of nucleation data point. This is where heat energy is first detected and where the RoC bends toward zero.

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Key Data Points

- The Liquidus Point is the point of maximum heat generation in the liquidus zone defined below.
- The Rigidity Point is the point of minimum heat generation between the liquidus and eutectic points.
- The Eutectic point is the point of highest temperature in the eutectic zone. This is sometimes referred to as the Eutectic Growth Temperature.
- The Eutectic Undercooling temperature is the minimum temperature in the eutectic zone before the eutectic arrest.
- The End of Eutectic Energy point is where the main heat production of the eutectic arrest starts to die off.
- The Start of Solidus is where the grain boundaries begin to form. Grain boundaries are chaotic and so absorb heat energy.
- The Solidus point is where the grain boundaries reach the greatest heat adsorption (endothermic) rate.
- The End of Grain Boundary Stress anchors the end of the Base Line curve and is where the RoC curve assumes a steady black box type of cooling. Energy absorption has finished.

The Different Cooling Zones

1. Early Liquidus is where the primary austenite dendrites form. It is bound by the start of nucleation and the Liquidus arrest.
2. Late Liquidus is where secondary branching and dendrite thickening occurs. It is bound by the Liquidus arrest and the Rigidity Point.
    a. The total Liquidus zone is Early Liquidus plus Late Liquidus.
3. Early Eutectic is where the eutectic material slowly starts to connect the dendrites together. It is bound by the Rigidity point and the maximum acceleration into eutectic point. If there are any pre-eutectic carbides, they will form at or around the Rigidity point.
    a. The maximum acceleration point is interesting in that it seems to differ greatly in its slope and shape with Ductile, CGI and Gray irons.
4. Main Eutectic Growth is where the eutectic rapidly grows and produces abundant energy as seen in zone 5. This is bound by the Maximum Acceleration point and the Eutectic point and includes the recalescence zone.
5. Recalescence zone is the surplus energy produced during the eutectic reaction. It’s shape and size can differ greatly with inoculation, chemistry and processing. It is bound left and right by the same points as the main Eutectic Growth but is only energy that is below the zero line (excess energy).
6. Late Eutectic zone is where the eutectic formation is still strong enough to produce significant heat but is beginning to slightly decline in heat production. This is bound by the Eutectic Point and the End of Eutectic Energy point.
7. Eutectic Contraction is where most of the casting’s major contraction occurs. It is bound on the left side by the End of Eutectic Energy Formation (EEEF). This point is also the point of maximum stress in solidification. Some gas and micro-porosity may have formed previously, but major shrinkage if it is t happen, will occur in this zone. Considerable micro-shrinkage can also happen

in this zone. It is bounded on the right size by the Start of Solidus point. Eutectic carbides form in this zone.

   a. The total Eutectic energy is the sum of areas 3,3,6 and 7. Area 5 is already included in zone 4.

8. Solidus is the endothermic energy absorbed by the formation of grain boundaries. It is bounded by the start of Solidus point and the End of Grain Boundary Stress.

Discussion

These zones and their percentages provide added information on the variability of our castings. Lower carbons yield increasing an increased percent of dendrite formation and a stronger iron. Increase in the contraction zone indicates a harder iron. Inoculation affects many aspects of the eutectic zones. There are clear differences between high sulfur and low sulfur irons due to MgS nucleating graphite. Gas entrapment and shrinkage both micro and macro have clear indicators. Carbides, both pre-eutectic and in the contraction zone can be measured.

Conclusion

Micro-thermal analysis is a useful tool to characterize and iron and to be able to see changes and differences in the iron quickly and easily. Together with physical testing, it will improve the casting process and help understand our processes and make a better more consistent product.