Measuring Microscopic phases using Copper and Magnesium-silicide as an example

by David Sparkman August 4th 2010 all rights reserved

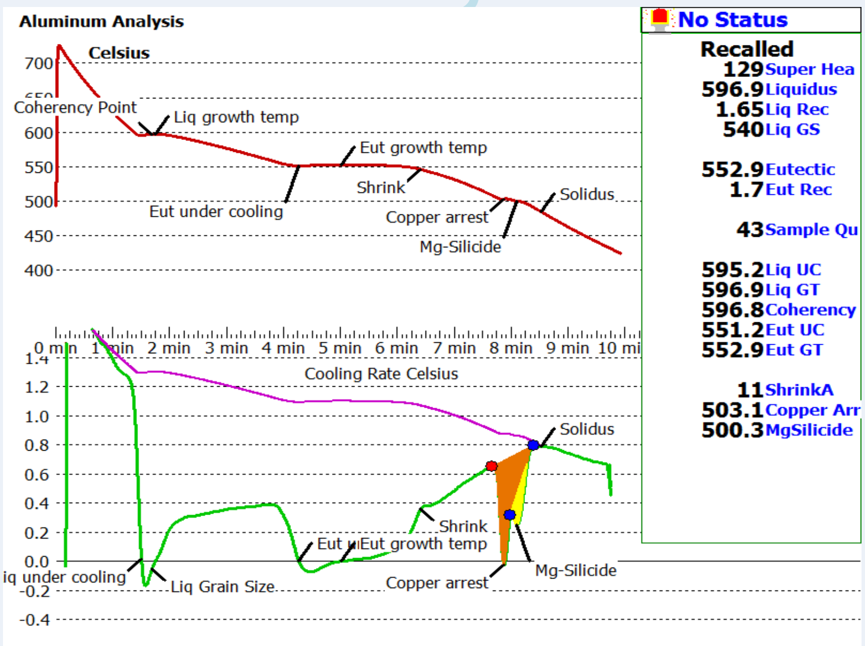
Last month we looked at detecting the elusive beta phase in Aluminum. This month we look at the more common phase arrests commonly found in A319, A355, and A356 alloys: copper and magnesium.

Copper is commonly used in the 319 alloys to provide matrix strength through heat treating. Most of the copper precipitates out during the casting's solidification, but some copper remains in the matrix as Al_2Cu. Typical composition in total copper is 3 to 4%. During heat treating, the casting is heated up to just below the solidus temperature and copper is absorbed from the grain boundaries back into the casting. On cooling, the copper stresses the matrix and prevents movement of the aluminum giving it added strength.

Magnesium is added to aluminum principally to provide hard spots in the aluminum for wear resistance. It forms a complex alloy called magnesium silicide. (Magnesium also has a limited effect on blunting the tips of Beta crystals.) Typical ranges are 0.1% to 0.5%[1].

Using some of the same techniques described last month (5th derivative), we have taught the program to locate the start and stop points of these arrests.

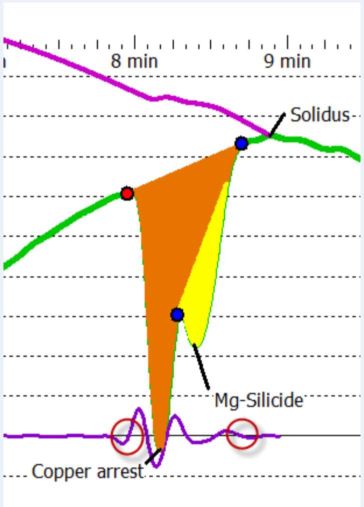
.



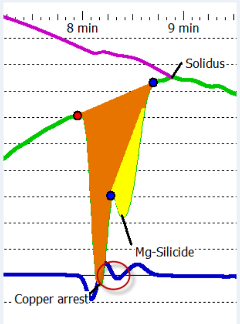
Typical 319 curve showing zero curve, shrinkage, copper and magnesium arrests

---

[1] L. Bäckerud "Solidification Characteristics of Aluminum Alloys volume 2, Foundry Alloys", pgs 86, 96 by AFS/Skanaluminum 1990.



As before, we use the high order derivatives, 4th and 5th, to define the beginning and ending points of the phases in the thermal analysis curve. The purple curve to the left is the 5th derivative. The zero crossover of the 5th derivative is used for the start of the copper arrest, and the end point for both the copper and magnesium-silicide arrests. The beginning of the Silicide arrest is of course the inflection point of the first derivative so it is defined by the zero pass of the second derivative to the right.



The copper area is represented by a copper colored orange, and the mg-silicide area is represented in yellow for contrast.

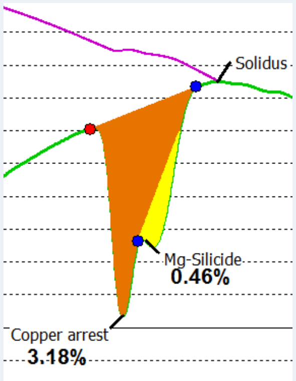
The actual math is based on internal numbers, as there is some loss in rounding in presenting them on the screen. This allows us to keep a higher level of precision in the calculations. As in last month's discussion, the comparison of the 5th derivative inflection points with the background noise just before the arrests shows the variation in these arrests exceeds 10-sigma. There is no question statistically that these arrests are real and that the noise filtering hardware and algorithms are working properly – the signal is clear and the noise alone has been filtered. For those using MeltLab, these graphs were made using a smoothing level of 25. The scaling of the derivatives was set low so as not to detract from the presentation of the curves.

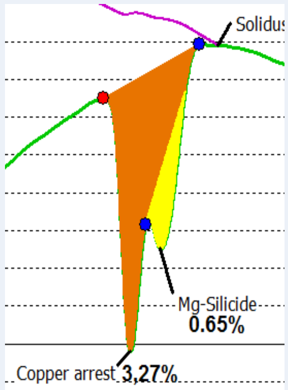
The area of each phase is measured in the units of the 1st derivative or degrees/second. This is then divided by the total area between the base curve (pink) and the rate of cooling (inverted 1st derivative) to yield a unitless percentage. This percentage is then the percent of total energy released by that phase during solidification. If we knew the specific heats and specific densities of all the phases present, we could solve for the actual percent weight and percent volume of the individual phases. But since we don't know those values, we take an engineering approach, and throw in a fudge factor to at least approximate chemistry.

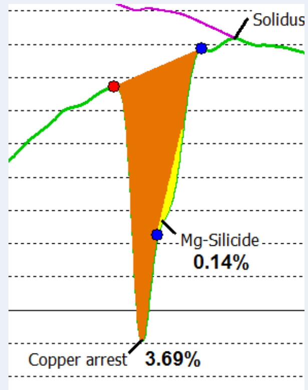
Take the measured percent of Magnesium-silicide and divide it by the measured magnesium and you will produce a correction factor which will allow you to estimate the actual magnesium in the aluminum from the thermal analysis curve. Surprisingly, that number seems close to 1.0. Likewise, copper can be estimated, but not as accurately because a good deal of the copper is retained in the matrix. So a 6% copper is yielding a 4% area. It might be better to look at comparing the amount of grain boundary copper seen under a microscope with the thermal analysis value. Here the factor comes out very close to 1.0 again. Ford Motor Company, under the direction of the scientist Jake Jacoby, was able to use a similar process (using MeltLab) to determine the best amount of copper to use in their engine blocks based on the copper phase area and physical testing.

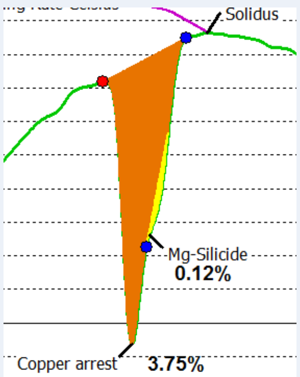
MeltLab Systems – Using Thermal Analysis in the foundry

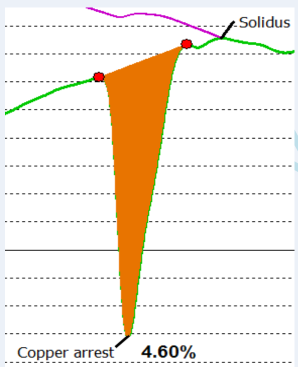
Here are some additional examples of magnesium and copper phases:











So Somewhere below 0.1% magnesium Silicide the Silicide arrest seems to disappear. We would welcome the ability to research this further.

The formula for Magnesium-silicide is $Al_5Mg_8Cu_2Si_6$ and for the Copper phase it is Al_2Cu.

Next month, we will look at ductile iron nodularity and how it can be measured using the thermal analysis. If you have any questions or would like to direct us to discuss a certain topic, please drop me a message at david@meltlab.com.

Meanwhile, we have a summer sale going on through the end of August on all MeltLabs. Click here for more information www.meltlab.com. We are less expensive than the competition, *and* you get all the “bells and whistles”.