Gray Iron Chill by Thermal Analysis

MeltLab Systems – 2020

Introduction

Chill is the tendency of gray iron to form carbides on rapid cooling. It is generally measured with a chill wedge with the chill being the thickness of the white or shinny part of the wedge. The wedge ranges in size from2.5 inches up to about 8 inches in length with the maximum thickness of up to ¾ inch. The theory is that if the chill wedge shows a white fracture up to 0.2 inches then any casting part less than 0.2 inches will have chill, and any part thicker than 0.2 inches will not. Of course there are assumptions.

Methodology

The first assumption is that the wedge rate of cooling will match the rate of cooling of the casting. The second is that the wedge test has little to no gage or repeatability error. The first can be ignored if you assume the test is a benchmark test and that values below a certain level will translate into chill free castings.

The second question of reliability can be improved by following a standard procedure of testing:

1. Quickly pour the wedge full.
2. Quickly wipe the missus off the top of the chill wedge with a second chill wedge mold. This controls the heat of the sample.
3. Dump the chill wedge into a bucket of water to end the test after a fixed time so that a rapid answer can be had (generally 1 minute for small wedges).
4. Break the wedge along the score mark halfway down the length of the wedge. Discard results from breaks that are not on or very close to the score mark. Close to the pouring basin will have less chill and those further away will have move chill.

Metallurgy

Chill makes a casting difficult to machine and more likely to chip rather than machine. This is difficult on machining tools and makes machining tolerances difficult to hold. The major cause is a low level of graphite nucleation and production. This is a two-fold problem: the desired chemistry may be tilted toward lower graphite and stronger iron, and the nucleation potential of the iron may be inadequate.

Assuming the chemistry is within bounds, then the main control is the inoculation added to the iron. Nucleation sites are tiny seed crystals of MnS and other combinations which have a lattice distance close to that of graphite. These nucleation sites decrease with holding time and increase with inoculant. The bases of most inoculants include FeSi which provides a temporary and very localized increase in silicon though something called a super-molecule. This effect is diminished with time as the silicon disperses though the iron. This effect is generally felt to last no more than 15 minutes.

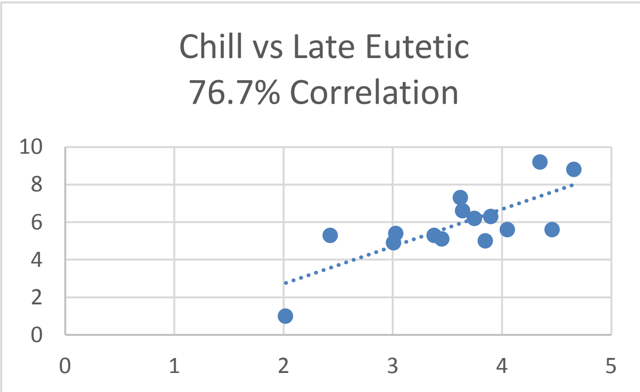
Gray Iron Phases and Chill

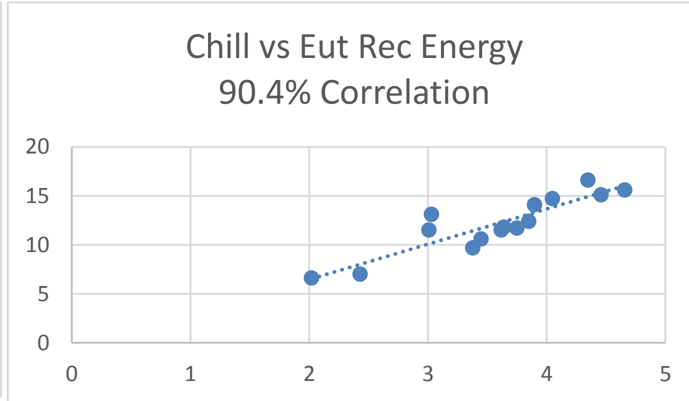
Graphite and Austenite are closely linked in Gray Iron metallurgy. Austenite will become pearlite in the final casting, and the formation of graphite lowers the overall carbon content of the liquid to allow more austenite to form. Iron Carbide, FeC_3, forms when graphite has not had a chance to form. Thus we have several indicators of potential chill from how the iron solidifies. Two correlations appear significant.

Gray Iron Chill by Thermal Analysis

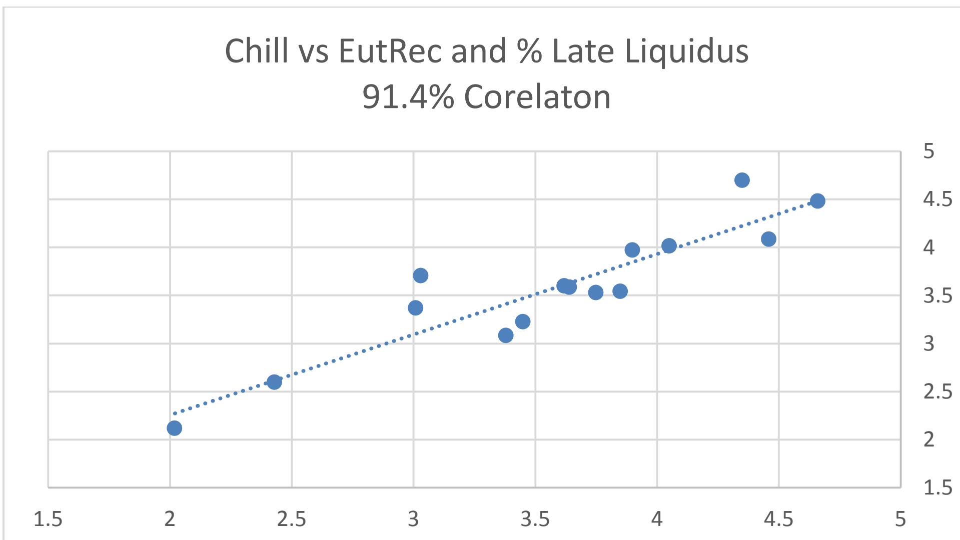
MeltLab Systems – 2020

There is some correlation between the last liquidus and the eutectic recalesence energy. This can be deemed auto-correlation. Thus adding in the late liquidus energy only improves the correlation by 0.4%.





The first says that delaying the eutectic arrest produces more chill. The second, which is a better correlation, says that the size of the recalescence area is the best predictor of chill.



Combining the two best causes gives us an overall correlation of 91.4%

Gage Reliability and Repeatability issues

Having been a quality manager in a major automotive supplier, it was important to determine how accurate our testing was. Some technicians were more skillful than others and had better repeatability. There are two ways to check the chill wedge test for accuracy. First pour two wedges from the same spoon of iron and see how they repeat. Five samples should give a good idea and help determine what if any techniques are better for repeatability. The second test is to mark ten wedges with letters only and have two or 3 technicians independently rate the chill on those wedges. This will indicate how reliable each technician is compared to the other technicians and may indicate where further training is required.

Gray Iron Chill by Thermal Analysis

MeltLab Systems – 2020

Outliers

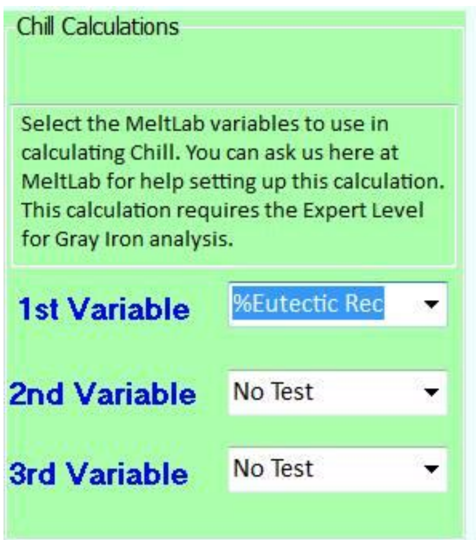
Several tests came out with a 7 mm chill rating. This was the maximum thickness of the chill wedge and should properly be interpreted as “more than could be measured with this size chill wedge.” Chill wedges are normally selected to match casting thickness. So if chill in a ½ inch section size is important, then the chill wedge should have at least a half inch width.

Benefits of Micro-thermal analysis

Micro-thermal analysis, which uses the energy of recalesence for chill, not only saves time and labor, it avoids the issue of variability in testing. With sufficient superheat to see the liquidus arrest, the eutectic recalesence is driven by the undercooling necessary to start graphite nucleation. The resulting energy production becomes a reliable indication of chill or the lack of it.

Different foundries and different methods

Because foundries use different molding methods and materials, chill characteristics may vary. Because of this, the chill calculation equation can be adjusted for different molding methods and iron types. Using Excel or Mini-Tab, two popular math tools, the foundry can determine the best correlations for their situation. This tool is included in the Gray Iron equations page for the Expert system.



This lets the foundry set up to 3 variables for a chill calculation that looks like this:

Chill = (1st Variable * Slpe1) + (2nd Variable * Slope 2) + (3rd Variable * Slope3) + Offset

Variables 2 and 3 are optional for those who want to keep things simple.

The slopes are then entered into the equation table for each iron grade.

David Sparkman
March 2020