Ductile Iron News

Ductile Iron Society

To Promote the production and application of ductile iron castings *Issue 3, 2004*

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One Solution For "Monday Morning" Iron

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Plant 2
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“Monday Morning” iron is a phenomenon that every iron casting facility faces. It is iron that has been sitting in some type of holding furnace over an extended period of time, which has lost its nucleation potential. The use of various tools can decrease the amount of time in which it takes to re-nucleate the iron, as well as, detect when the iron’s susceptibility for shrink defects often associated with “start-up” iron has decreased enough to make quality defect free castings. In order for the reader to fully comprehend the practices being talked about in this paper they must understand the operation in which they are being used. The author from this point forward will be referring to Neenah Foundry Company’s Ductile Iron production facility.

Neenah’s Ductile Iron foundry is a cupola melt shop. The cupola is a Modern 84” shell refractory lined to 66”. Recuperative hot blast along with supersonic oxygen injection is utilized. The cupola is capable of melting approximately 30 tons per hour. The iron from the cupola is transferred via a five-ton bull ladle to two 60-ton 800kW Whiting holding furnaces. From the furnaces, the iron is treated using a mod-tundish ladle process treating 7,500 pounds of iron at a time. The treated iron is then poured into two pressure furnaces, one on a 2070 Disamatic and one on a 2013 Disamatic. Finally, a late stream inoculant is added as the iron is being poured into the molds.

One advantage Neenah Foundry has is the ability to make salable municipal castings during start-up due to the fact the castings only have to meet 35-ksi tensile strength; this decreases the amount of iron “pigged” out during the start-up process. Even with this ability a quicker conversion to quality, defect free industrial casting production is always desirable. The start-up process at Neenah used to take upwards of two hours with a greater risk of making scrap castings, now with the tools that will be talked about in this paper Neenah can switch to full industrial casting production in usually one half to one hour. The tools and techniques being used will now be discussed.

Thermal Analysis systems give a great deal of insight into the solidification characteristics of a particular iron. Utilizing the full ability of each system along with normal control tools (chemistry, microstructural analysis and mechanical property information, etc.) and knowing the key parameters to look for can be invaluable when trying to decrease start-up times and find the iron’s nucleation potential. Neenah Foundry utilizes Novacast’s Adaptive Thermal Analysis System (ATAS)® Verifier version 4.1.1. The samples are poured into non-Tellurium cups after magnesium treatment and just prior to in-stream inoculation.

Another tool optimized by Neenah Foundry is adding a "pre-conditioning" inoculant to the start-up ladles. Neenah uses an inoculant with 10 X 25 mesh sizing and the following contents:

~73% Silicon

~1% Aluminum

~1% Calcium

~1.75% Cerium

~<1% Sulfur & <1% Oxygen

Neenah has found that the addition of this inoculant to the tundish ladle treatment has added significant robustness to the iron's nucleation, helped to offset the impact of extra magnesium additions at start-up, and it has also helped to delay graphite precipitation until late in solidification. Neenah has found that addition rates of between .3% and .1% are sufficient to achieve the benefits listed above. All these benefits will be evidenced later in the paper.

The author will now go through a typical Neenah Foundry start-up and show the related ATAS curves. As stated before 7,500 pounds is the normal treatment size, however to save capacity in the pressure pour furnaces during start-up Neenah uses a 6,500 pound treatment on the first ladle added. Typical alloys added include 5% MgFeSi, 50% FeSi, 10% Mg alloy, carbon raiser, pre-condition inoculant and copper as needed to make grade requirements. Normal holding furnace temperatures over the weekend are between 2600-2700 degrees Fahrenheit, and normal pressure pour holding temperatures are 2500-2600 degrees Fahrenheit. Normal chemistry results, which are taken about an hour before start-up are as follows:

Pressure Pour Furnaces

Si = 2.30

Mg = .002

S = .012

Holding Furnaces

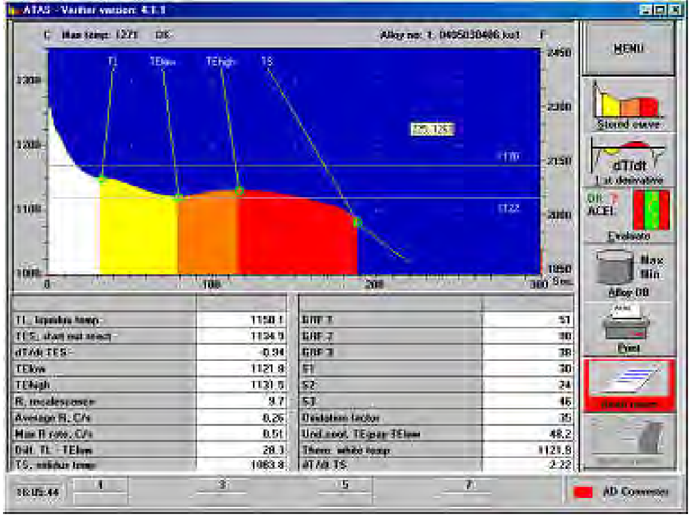
Si = 1.30

S = .018

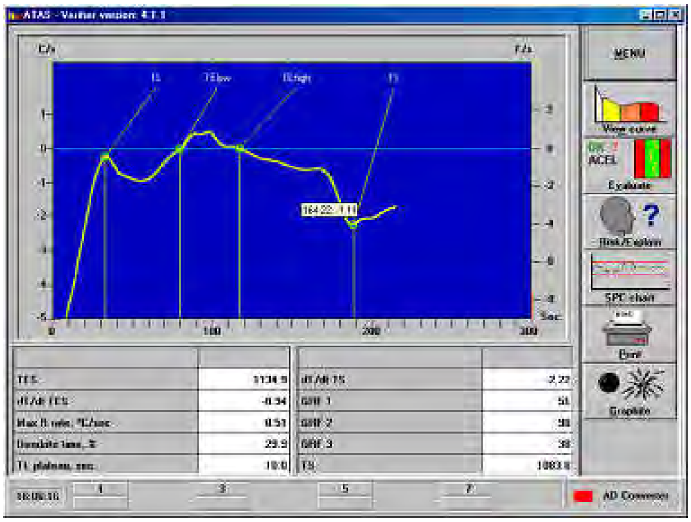
From these base chemistry results alloy addition recipes are calculated and the start-up process begins.

Once pouring begins ATAS samples are taken after each ladle addition. The curves below show the impact of the "pre-conditioning" inoculant and the ability of the ATAS system

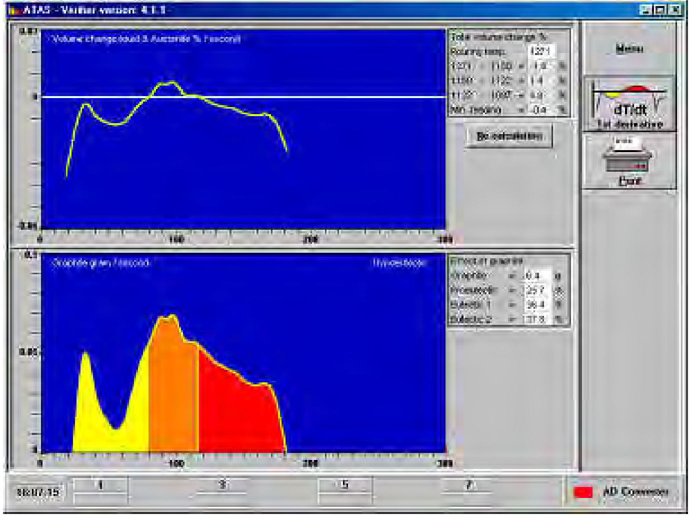
1st Curve of the Day, taken at 4:05 AM about 10 minutes after ladle was added to pressure pour.



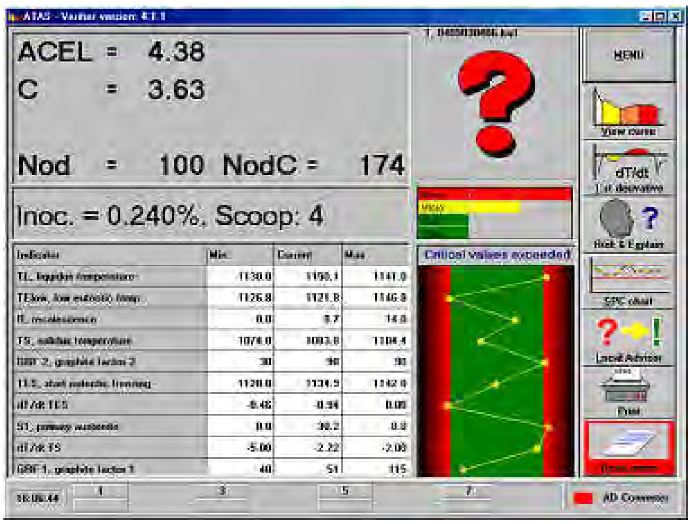
Items to note: Large yellow area (S1) which indicates a large amount of primary austenite. This is a critical measurement to show macroshrinkage tendency. The more primary austenite, the larger the dendritic growth making feeding with risers more difficult.



Items to note: Very erratic cooling, shown here by the 1st derivative curve. Graphite Factor 1 (GRF1) is low, indicating a low amount of eutectic graphite and Graphite Factor 2 (GRF2) is high, which is a measurement of the angle at the solidus on the 1st derivative curve. These two factors are an indication that the nucleation status of the iron is poor, which will lead to a lower nodularity and nodule count with an increased risk for shrinkage defects.



Items to note: Very erratic graphite precipitation. The eutectic two value is quite low, 37.8, indicating that only 37% of the graphite is coming out in the last stages of solidification to help offset microshrink that occurs at the end of solidifcation. This eutectic two measurement can be used as another measurement of metallurgical conditions, a higher value is desirable.



ATAS screen showing the iron's solidifications characteristics are not within limits set by Neenah Foundry.

The chemistry of the above curve is as follows:

Si = 2.56

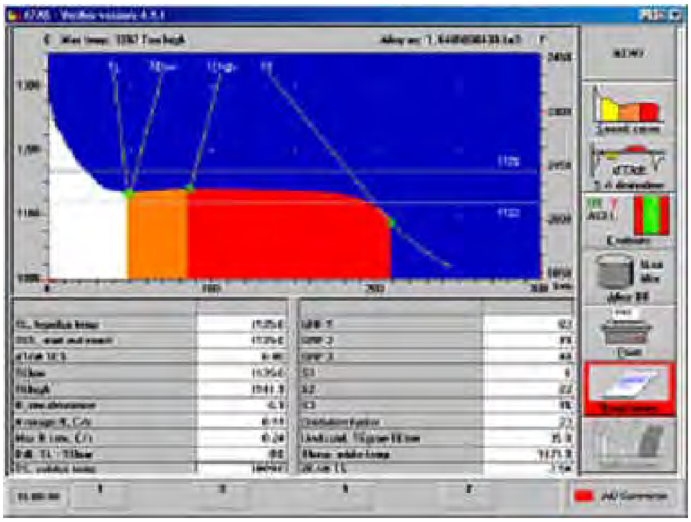
Mg = .043

S = .018

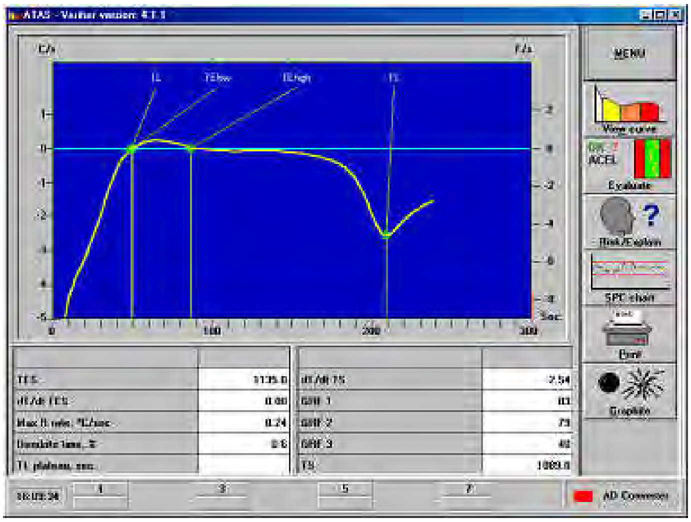
Even though this chemistry is respectable the above ATAS curves are showing poor metallurgical conditions, therefore Neenah would not switch over to industrial production. In the past once these chemistries would have been reached full industrial production would begin with an increased risk of making scrap castings

<u>2nd Curve of the day taken at 4:33 AM, sample taken after</u>

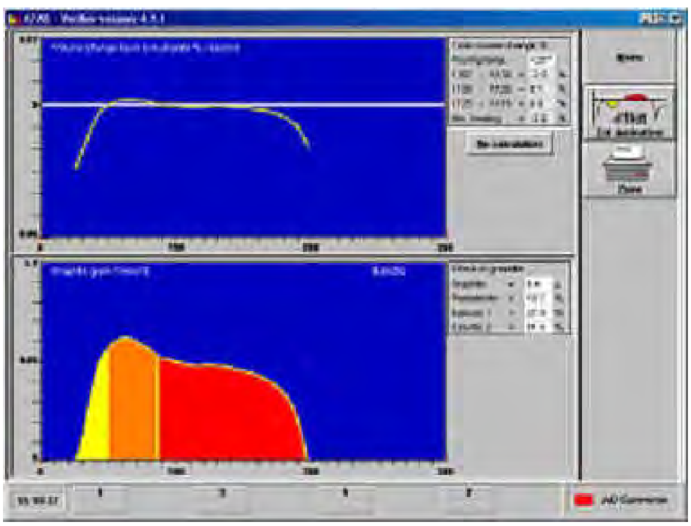
second ladle has been added to pressure pour furnace.



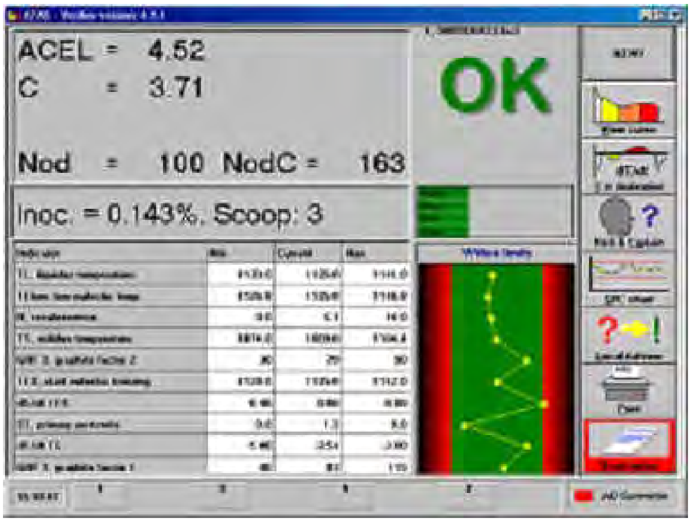
Items to note: S1 value is low indicating very little primary austenite. The chances for macroshrinkage are significantly decreased.



Items to note: Even cooling throughout solidification. The angle at the solidus is less indicating a better nucleation status, which should yield better nodularity and higher nodule count.



Items to note: Much smoother graphite precipitation. The Eutectic 2 value is much higher 55, showing 55% of the graphite precipitated is late stage. This will give a much higher nodule count and help offset microshrink.



ATAS screen showing all the parameters fall within Neenah Foundry limits and it is OK to pour industrial castings.

The Chemistry of the above curve is as follows:

Si = 2.47

Mg = .042

S = .003

The chemistry results of this second curve are not that much different than the first one however, the solidification characteristics of the iron are much different as shown by the ATAS curves. At this point it would be acceptable to switch over to full industrial production, with a significantly decreased risk of making scrap. The process of re-nucleating the iron used to take up to two hours and this particular start-up took about one-half hour.

In conclusion the author would like to make the following points. Using a thermal analysis system and being able to find the parameters key to each particular operation can give foundry people a much better insight as to their iron's metallurgical personality. Using a "pre-conditioning" inoculant can add robustness to a foundry operator's iron and aid in reducing start-up times with a decreased risk of making scrap castings. All of the above mentioned can be a significant cost savings for the foundry operation.

References

1) ATAS® Verifier "User's Guide" NovaCast Ronneby-Sweden

2) A. Udroiu: " The use of Thermal Analysis for Process Control of Ductile Iron"

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U.S. Metalcasting Industry Testifies Before U.S. ITC in Section 332 Investigation

Washington, D.C. Continuing the passion that has become a trademark of its Section 332 Investigation with the U.S. International Trade Commission (ITC), the U.S. metalcasting industry, with the support of the American Foundry Society (AFS), testified before the ITC during a public hearing held October 14 in Washington D.C. This hearing was the sole opportunity for representatives from both sides of the Section 332 Investigation—U.S. producers of metal castings and foreign producers of metal castings importing low-price product into the U.S.—to provide verbal comments to the ITC.

This public hearing is the last formal step for the ITC in its Section 332 Fact-Finding Investigation to determine the extent to which the U.S. metalcasting industry has been harmed by low-price foreign competition. The first step was a survey distributed to more than 1,000 U.S. producers of metal castings, followed by surveys distributed to U.S. purchasers of castings and foreign producers of castings importing components to the U.S.

According to Federal Law, the ITC must complete the Section 332 within 12 months from the initiation date of the investigation—May 3, 2005. Once the Section 332 is complete, U.S. metalcasters can use the published report that is generated as a foundation for further trade action against foreign producers of metal castings to pursue tariffs, quotas, antidumping duties or other trade remedies.

Section 332 Hearing Testimony

At the public hearing, the U.S. metalcasting industry had 11 speakers (nine were representatives of AFS) provide statements on its behalf and three other representatives (including AFS President Chuck Kurtti) available to respond to questions before six commissioners of the ITC.

The nine representatives of AFS were: Albert Lucchetti, Cumberland Foundry Co., Dave Bumbar, Aurora Metals Div. LLC, George Boyd, Goldens' Foundry & Machine Co., Jim Keffer, EBAA Iron Sales Inc., Kory Brockman, Wisconsin Aluminum Foundry Co., Larry Comunale, Doncasters Southern Tool, Randall Lawton, Bay Engineered Castings, Roy Hanks, ThyssenKrupp-Waupaca, and Tim Brown, Benton Foundry Co.

The goal of each speaker was to present the ITC with first-hand descriptions of their segment of the industry, the products they produce, the competitive conditions in the marketplace and the difficulties their operations are facing. Each speaker, representing their own metalcasting facility and industry segment, then proceeded to give specific instances, when possible, and the affect these actions had on their firm.

"Our goal when initiating the Section 332 was to energize the industry where possible to speak as one voice. With the opportunity to tell our story at the public hearing, we feel we have accomplished this objective," said Kurtti after the hearing. "We now must wait for the results of the study for the facts on how the pricing policies of our foreign competitors have impacted our industry and its ability to remain viable within our own country and competitive in the global economy."

Questions from the ITC

Once the statements were read by representatives from the U.S. metalcasting industry and one representative for an importer of low-price foreign castings, the six ITC commissioners proceeded with questions for the industry representatives. The questions focused on:

- clarification of testimony;
- an attempt to understand how to measure growth and/or declines in sales and production for the U.S. metalcasting industry;
- prices pressures from foreign competition and the discrepancy between U.S. and foreign pricing for like products;
- what countries pose the greatest competitive threat and in what markets;
- level of technology in the U.S. vs. that of foreign competition;
- what U.S. metalcasters must do to compete with foreign competition;
- export competitiveness of U.S. metalcasters;
- the make-up of the industry and its ability to produce low-volume vs. high-volume work;
- current leadtimes for U.S. casting production;
- tooling production in the U.S. and overseas;
- environmental, safety and health compliance in the U.S. vs. foreign competition;
- raw material pricing in the U.S. vs. foreign competition;
- what the U.S. metalcasting industry hopes to gain from the results of the Section 332 Investigation.

With each question, one industry representative was directed to respond, with other panelists invited to add comments if they desired.

Pre-Hearing Brief

Supporting the verbal testimony was the pre-hearing brief supplied by AFS that established a foundation of data supporting the contention that U.S. metalcasters are being harmed by low-price competition.

Quoting from the brief: “The U.S. foundry industry is at a critical juncture. The industry has been undergoing a massive restructuring, and the pace of closures of production facilities has escalated in recent years. Industry members that still remain have worked hard to reduce costs and improve efficiency while complying with numerous regulations concerning environmental protection and worker safety. In the face of these efforts, the number of foreign sources of foundry products has increased and the output and aggressiveness of producers in low-price sources such as China, Brazil, India and Mexico has risen dramatically. As imports of foundry products have increased, the ability of U.S. foundries to compete has become a consistently greater challenge.”

Some of the statistics presented in the brief in support of this statement included data supplied by U.S. metalcasters in the surveys they completed for the ITC investigation. Quoting the brief,” As U.S. imports of foundry product have increased in the 1999-2003 period, the domestic industry as a whole has suffered declines in almost all of its trade and financial indicators”:

- employment of production and related workers among responding producers has declined 16.9%, and hours worked by production workers has declined 25.1%;

- total net sales of responding producers has declined 7.2%;

- operating income for the industry as a whole fell 65.3%;

To illustrate that prices have been suppressed in relation to production cost trends, the ratio of the industry’s cost of goods sold to net sales value increased in each year from 1999-2003 for a 9.2% jump over the four-year period.

Quoting the brief, “Imports have come to account for a significant and growing share of the U.S. market for foundry products. An increasing number of imports has displaced U.S. sales of the domestic industry via two forms of competition. First, imports of foundry products themselves into the U.S. have taken sales directly from the domestic industry, as purchasers such as automotive OEMs have increased foreign sourcing of foundry products. Second, further-manufactured products and finished products that contain foreign-made castings (such as imports of finished construction equipment) have been increasingly imported, thereby supplanting sales by domestic producers and reducing demand for foundry products within the U.S. market.”

“Based on the industry’s inability to obtain reasonable margins for its value, the continued erosion of its domestic base seems inevitable unless pricing power and raw material stability is realized,” said Kurtti after the hearing. “Presently, the loss of R&D, intellectual capital, an educated and capable labor force, and the ability to re-capitalize facilities due to low margins is challenging the metalcasting industry's existence as viable and capable of sustaining an essential domestic presence. With 90% of all manufactured goods in this country and our national defense dependent on the health of metalcasting, we are left no choice but to continue our quest to define a business plan that assures survival."

Section 332 History

For the past two and a half years, the U.S. metalcasting industry and its AFS Trade Commission (lead by AFS President Chuck Kurtti) have been working with the ITC to determine the extent to which the industry has been harmed by low-price foreign competition. The result from this cooperation is the Section 332 Fact-Finding Investigation that currently is being administered by the ITC.

The thrust of this Section 332 Investigation is a survey that was completed by U.S. metalcasters in September. This survey requested specific data and descriptions about the current state of the U.S. metalcasting industry and the conditions of competition between the U.S. industry and certain foreign countries. The survey was focused on 10 different metal/product groups, covering 24 different NAICS codes (Table 1). These metal/product groups were cooperatively developed by the AFS Trade Commission and the ITC in an attempt to cover as many segments of the U.S. metalcasting industry as possible.

This survey was followed by two others—one sent to casting purchasers in the U.S. and one sent to foreign producers of castings. The ITC uses these surveys as the foundation for its investigation.

From the results of the surveys as well as the public hearings and supporting documentation submitted by all affected parties, the ITC issues a final report that documents facts about the industry and the competitive conditions. While this report makes no formal recommendations on what should be done to help the metalcasting industry (tariffs, quotas, etc.), it is a highly respected Federal document that would serve as the foundation for all future trade action by the industry as a whole or individual segments of it.

For More Information

For more information on the Section 332 investigation, contact Alfred Spada, American Foundry Society Inc., at aspada@afsinc.org or 800/537-4237 ext. 281, or visit the AFS website at www.afsinc.org and click on the AFS Trade Commission link.

Headquartered in Schaumburg, Illinois, AFS is a not-for-profit technical and management society that has existed since 1896 to provide and promote knowledge and services that strengthen the metalcasting industry for the ultimate benefit of its customers and society.

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Determining the Optimum Level of Inoculant Addition by Thermal Analysis – A Case Study

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Introduction

The primary objective of inoculation is to produce carbide-free microstructures. At the same time, the foundry seeks to minimize the shrinkage tendency of the iron. These properties are influenced to a large extent by the type of inoculant and its addition rate to the iron.

Poorly inoculated liquid iron cools to temperatures below the white eutectic. Carbides will form under these conditions. Inadequate inoculation therefore results in carbides and associated shrinkage due to the unavailability of carbon for graphite expansion throughout the solidification range. Simply stated, carbon that preferentially should produce expanding graphite is tied up as dense, non-expanding, hard, and shrinkage promoting carbides.

Over-inoculation is costly and can also result in shrinkage. This is because over-inoculation can cause excessive early graphite growth that may result in a lack of available graphite for expansion at the end of freezing. This in turn leads to the possibility of micro-shrinkage formation. Also, excessive early graphite growth may cause mold wall expansion effects resulting in macro-shrinkage.

These factors mean that it is important for the operating foundry to determine the optimum addition rate of inoculant that takes into consideration chill resistance, shrink protection, and cost of alloying. It can be a balancing act! Over-inoculation, as well as under-inoculation may cause several potential quality issues, and the addition rate of inoculant should ideally be adjusted to each individual casting need.

Thermal analysis is a powerful tool to determine the correct level of inoculant addition to liquid iron that can result in significant cost savings and scrap reductions due to carbides and shrinkage. Also, there exists the possibility that the foundry is using too much or too little inoculant. The optimum inoculant addition rate for one particular casting requirement may not be the optimum addition for another requirement. Special castings may need added protection against shrink, while other castings may need improved protection against chill. Thermal analysis is a useful means to fine-tune and adjust critical inoculant addition rate and also to select the best-suited inoculant material for each individual requirement.

Experimental Work

A series of experiments was conducted in a ductile iron foundry to determine the optimum addition rate of inoculant for their given casting application. The long-time practice at this foundry has been to inoculate all ductile iron by a fixed 0.7wt% addition of calcium-bearing 50% ferrosilicon inoculant to the pouring ladle. Some studies have shown that a drop in addition rate to 0.4wt% resulted in beneficial effects on process costs without impairing casting quality. The objective of the investigation was to acquire quantitative data through thermal analysis in order to verify this and determine the optimum addition rate of the specific inoculant in use.

The foundry is treating ductile iron by the sandwich process, using a 5% magnesium-bearing ferrosilicon alloy at an addition rate of 1.8wt% and cover steel at an addition rate of 1.3wt%. Treated metal is then transferred into the pouring ladle and inoculant added to the metal stream simultaneously.

In this experiment, four different addition rates of inoculant were tested (0.2%, 0.4%, 0.6wt%, and 0.8wt%). Thermal analysis samples were taken and cooling curves recorded with the ATAS system immediately after inoculation and approximately every two minutes thereafter for about 15 minutes.

The ATAS system records and generates several numerical parameters. When analyzing the effect of inoculation, this study looked specifically at the effects of four characteristic parameters: TE_{low}, R, GF1, and GF2. The significance of these terms is explained below.

TE_{low} is the low temperature of eutectic undercooling. A higher TE_{low} value indicates that eutectic undercooling is at a temperature farther from the (white) carbide eutectic and the metal is therefore more resistant to chill than with a lower TE_{low} value. **R** is the eutectic Recalescence. This value represents the temperature increase from latent heat during eutectic solidification. Higher R values may indicate undesirable, early graphite expansion that increases the risk for wall expansion effects and primary shrinkages. Also, early graphite expansion may reduce the available carbon for later graphite expansion at the end of solidification and thus increase the risk for micro-shrinkage porosity formation. **GF1** is the ATAS Graphite Factor 1 and it is an indicator of overall eutectic graphite precipitation. A higher GF1 is desirable because it indicates more continuous graphite expansion and less overall risk for shrinkage. **GF2** (Graphite Factor 2) is determined from the first derivative of the cooling curve and describes the degree of late graphite formation. A lower GF2 is desirable and indicates late-forming graphite that counteracts shrinkage in the last metal to freeze.

Experimental Results

Figure 1 shows a spread in TE_{low} values over six degrees C for samples taken immediately after inoculation (time 0). TE_{low} drops slightly for all addition rates as a function of time, indicating a certain dissipation of the initial graphitization temperature for all addition rates of inoculant. The 0.4wt% addition rate maintained the highest TE_{low} value during the holding time. Furthermore, the higher addition rates generated lower TE_{low} values consistently as time passed. The conclusion to be drawn from these data is that 0.4wt% is the correct addition rate since it gives the highest TE_{low} as a function of hold time. A secondary observation from this is that adding more inoculant does not necessarily mean that the metal will be more chill-resistant over time.

Figure 2 shows that Recalescence increases with higher addition rate of inoculant. This is consistent with existing theory in that extra inoculant is causing more graphite to come out of solution early in solidification. Lower Recalescence values are desirable and Figure 2 shows that either 0.2wt% or 0.4wt% additions generated lower Recalescence.

Figure 3 shows that Graphite Factor 1 increases in the first 3 to 4 minutes after inoculation for most addition rates of inoculant. For most data points, the 0.4wt% addition rate generate the highest GF1 values. After about 5 minutes, GF1 is falling weakly throughout the remaining hold time.

Figure 4 shows that Graphite Factor 2 is lowest for the two lowest addition rates of inoculant. This is consistent with the finding that Recalescence is lower for the lower addition rates – i.e. less early graphite means more late graphite formation. In most conditions, later graphite is desirable since it counteracts difficult micro-shrinkage porosity. Note also that Graphite Factor 2 drops in the first three minutes after inoculation for all four addition rates of inoculant. Thereafter, the GF2 remains fairly constant for the remaining hold time.

Conclusions

The experimental ATAS thermal analysis data indicates that a 0.4wt% addition rate of inoculant produces metal that is more resistant to shrinkage porosity formation than either lower or higher addition rates. The 0.4wt% addition rate is also found to be more chill resistant than higher or lower addition rates, especially as time is passing after inoculation. These results confirm that the 0.4wt% addition rate of inoculant is the optimum for this specific foundry condition.

The present work also suggests that adding more inoculant will not necessarily produce a more inoculant fade-resistant iron.

The data also suggest, at least for this foundry, that thermal analysis properties can change dramatically over time after addition of inoculant. Analyses suggest that the metal becomes substantially more resistant to shrinkage formation after 3 to 4 minutes hold time after inoculation.

The foundry has been operating for a year at this lower addition rate now and has seen no increase in the scrap rate from carbides or shrinkage. At the same time, inoculant usage has been reduced by 43%. These facts are clear evidence that thermal analysis can be a powerful tool for documenting improved metallurgical performance and reducing raw material costs, and optimizing additions of alloys.

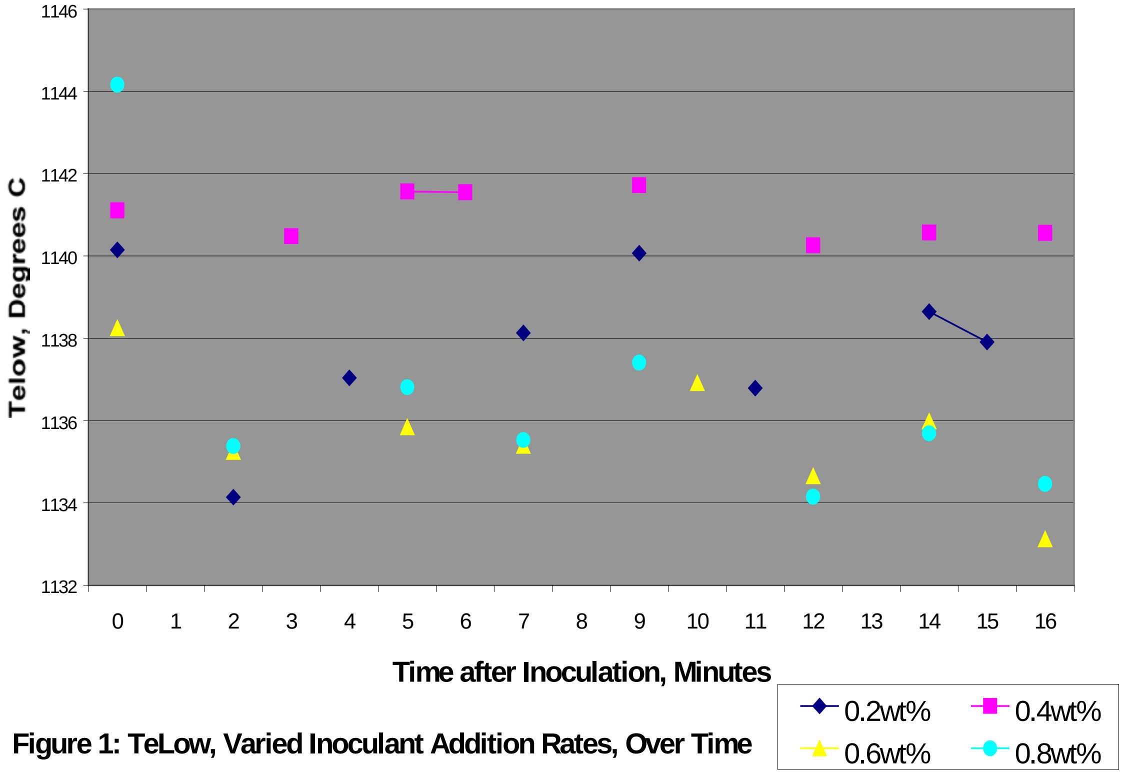

Figure 1: TeLow, Varied Inoculant Addition Rates, Over Time

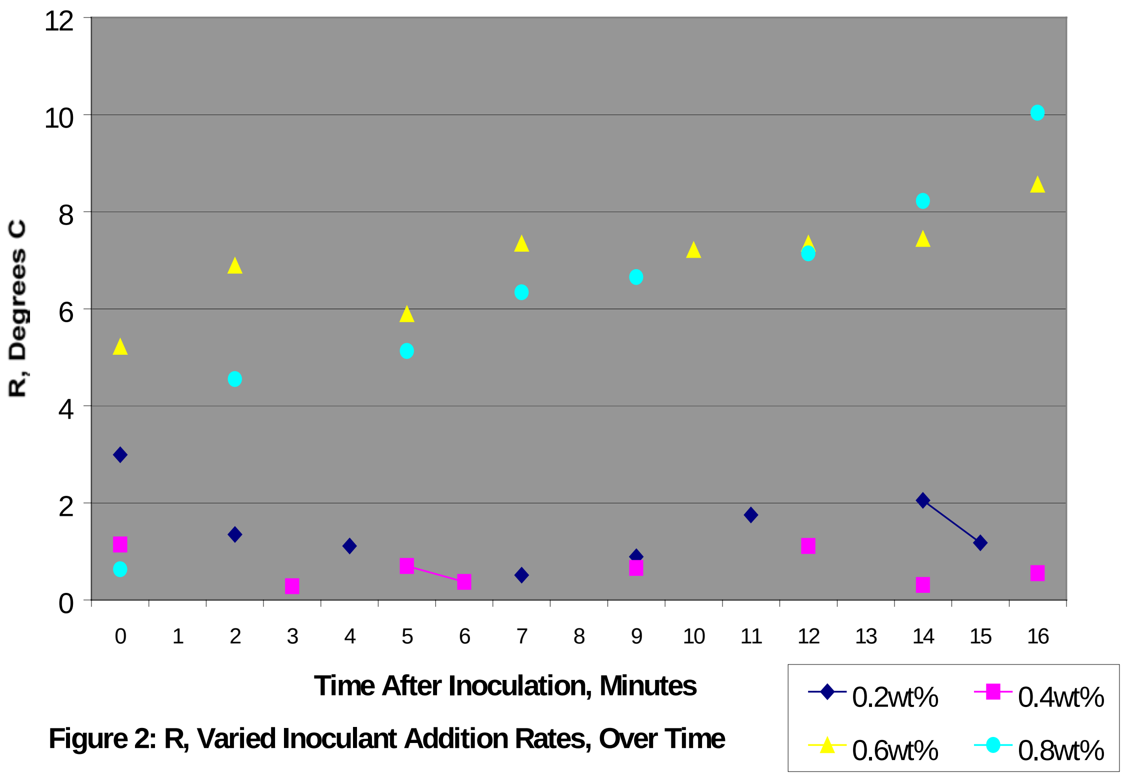

Figure 2: R, Varied Inoculant Addition Rates, Over Time

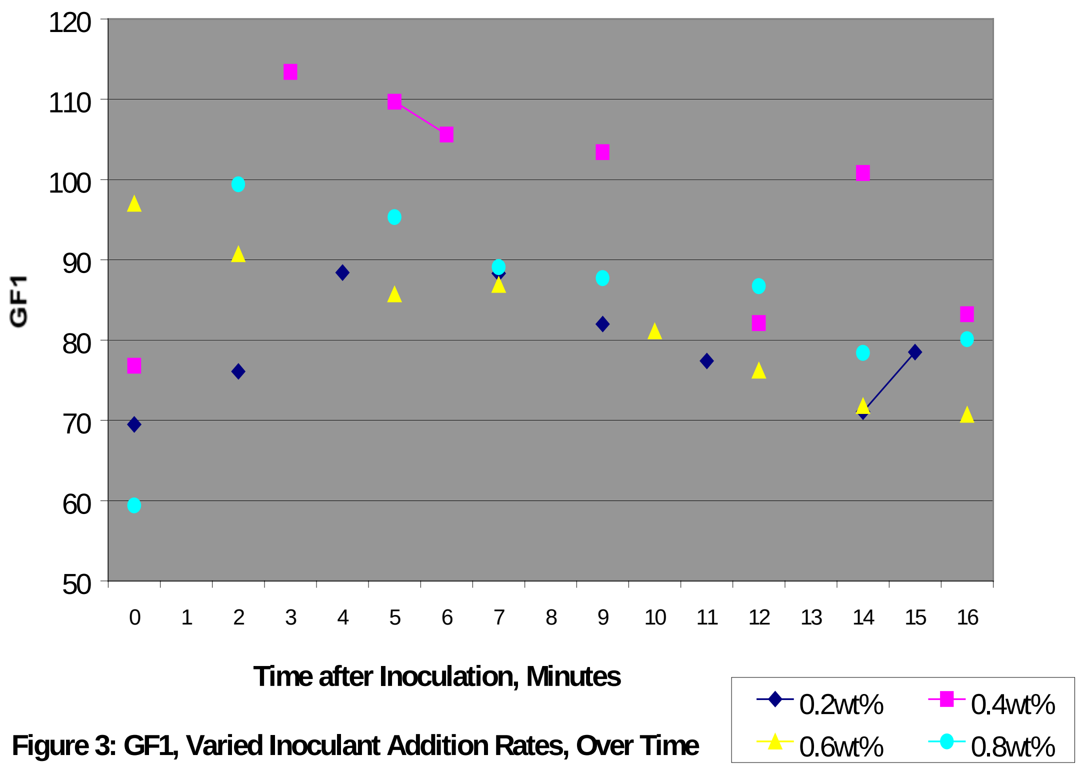

Figure 3: GF1, Varied Inoculant Addition Rates, Over Time

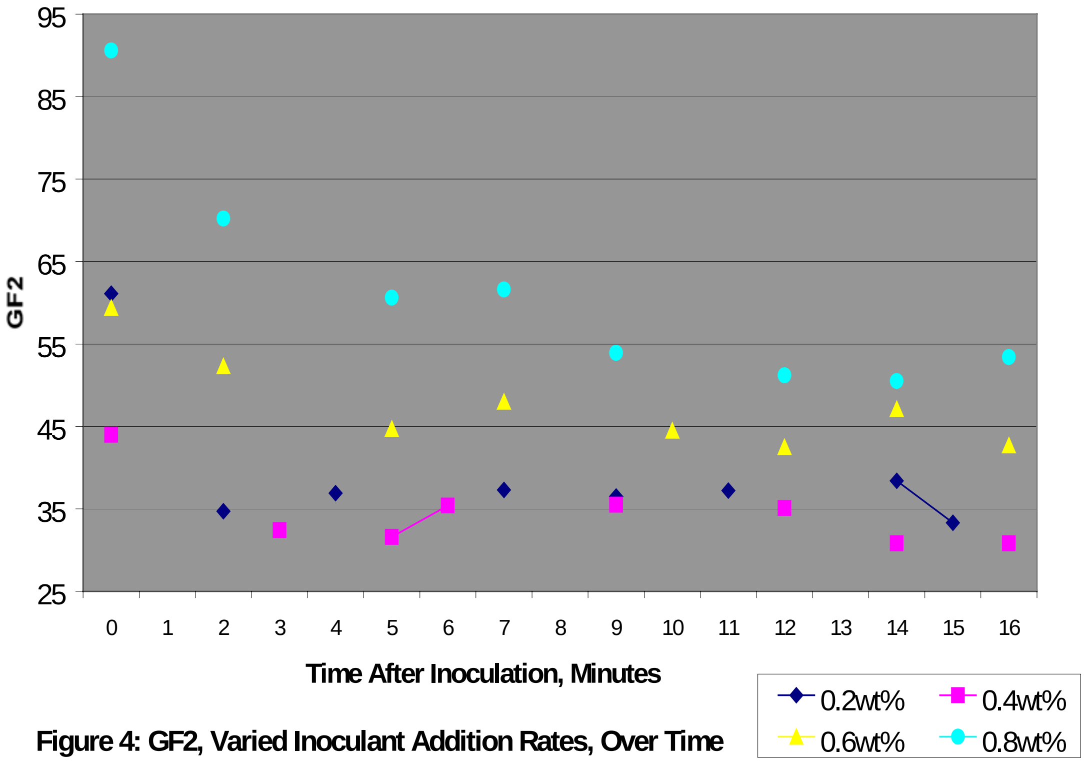

Figure 4: GF2, Varied Inoculant Addition Rates, Over Time

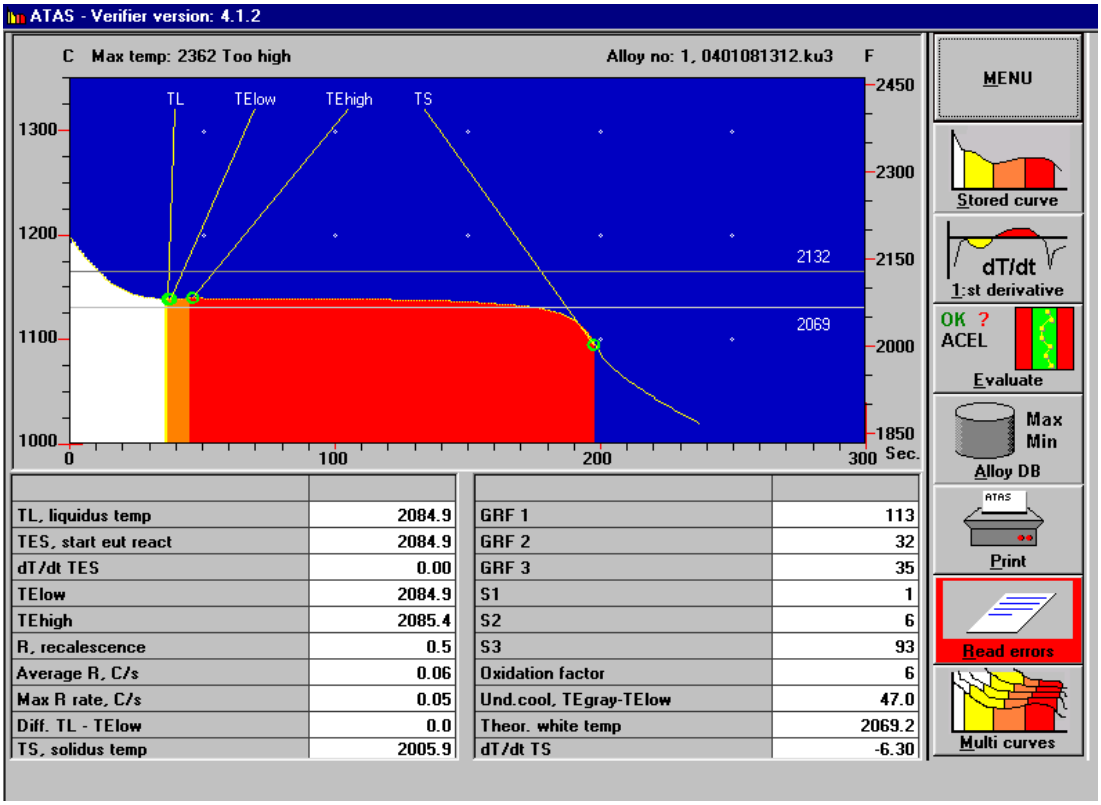

Figure 1: Actual Cooling Curve Taken from Heat Made with 0.4wt% Inoculant

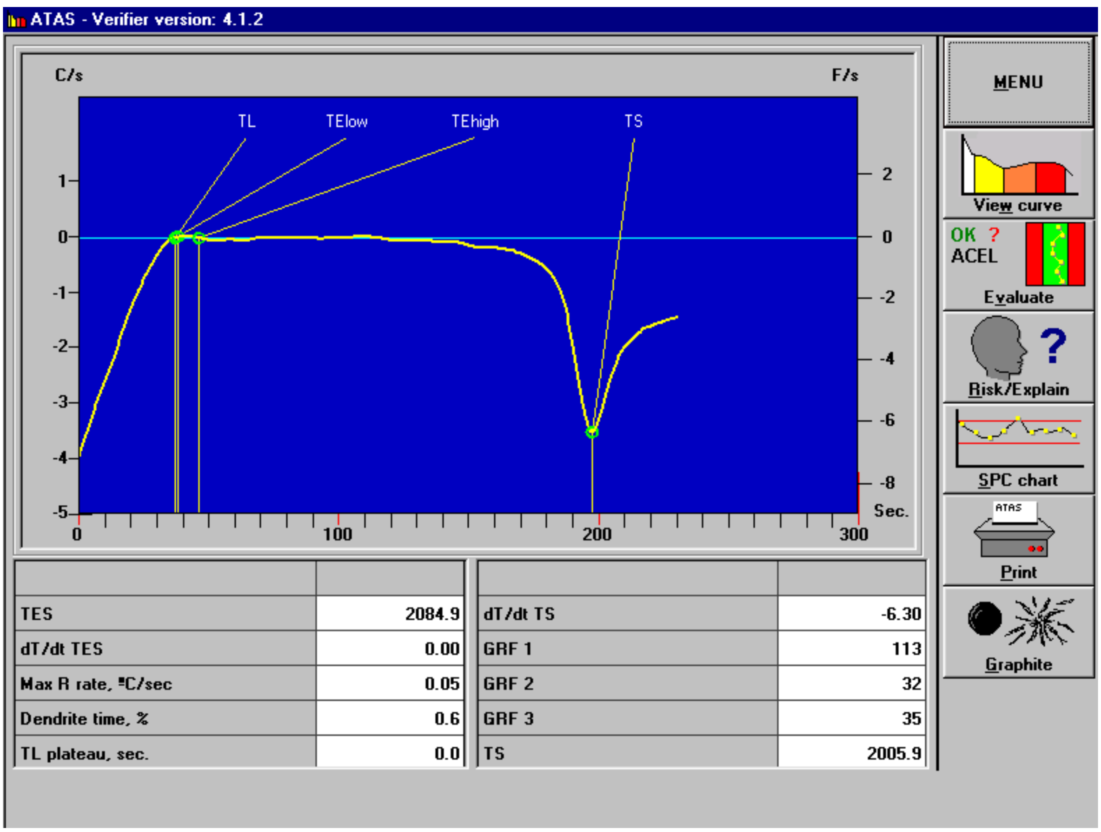

Figure 2: First Derivative Curve Associated with Figure 1

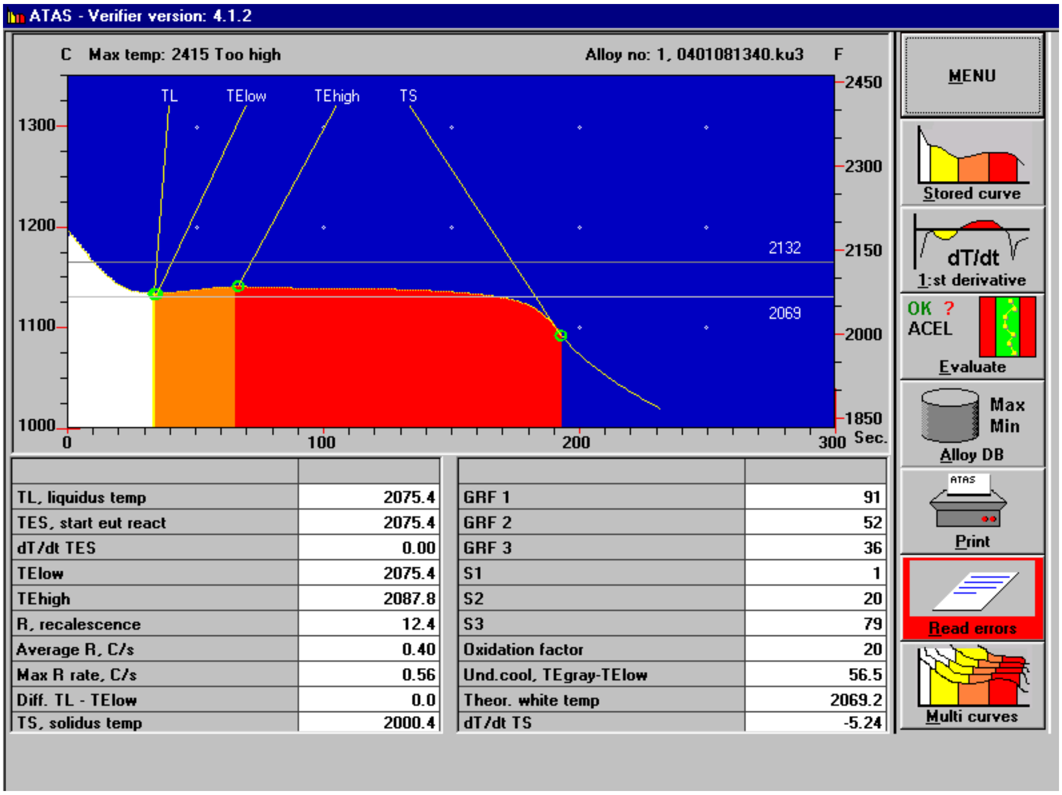

Figure 3: Actual Cooling Curve Taken from Heat Made with 0.6wt% Inoculant

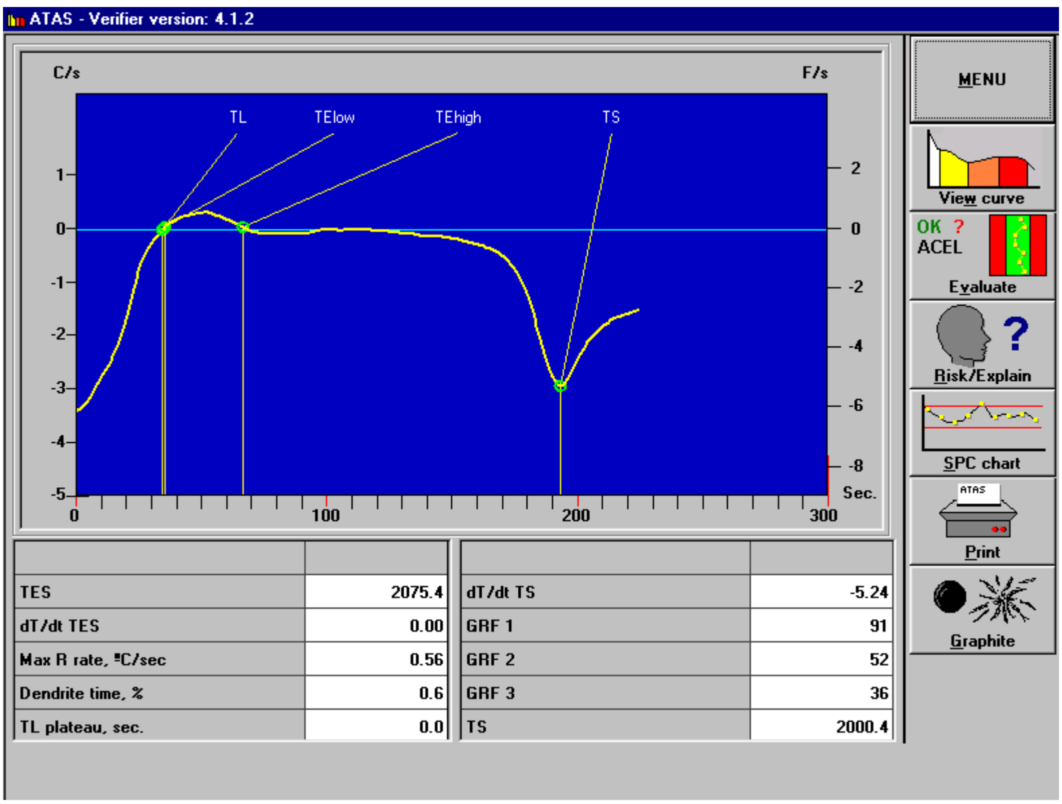

Figure 4: First Derivative Curve Associated with Figure 3

Application of Solidification Modelling in Predicting Alloy Content.

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ABSTRACT

The purpose of this paper is to provide an outline for the process of developing a computer model to predict the alloy content required, thus ensuring the correct heat treatment of both simple and complex castings.

INTRODUCTION

The estimation of required alloy content using casting section can sometimes be difficult, depending on the complexity of the casting geometry. With foundries wanting to use the minimum amount of alloys, or existing Ductile Iron Grades, in an effort to maintain or reduce casting cost, it has become even more important to be able to accurately predict the minimum alloy content which will guarantee full through hardening of the casting.

BACKGROUND

As all castings which require Austempering cannot be considered as having a plate type geometry, using the heaviest casting section for the calculation of alloy content may not always be the most accurate way.
It was thought that the use of modulus (casting cooling rate) rather than casting section would be more precise in the calculation of the required alloy content.
The prediction of modulus was the next problem. The casting modulus can be calculated relatively easily for simple shapes. Complex shapes become more difficult as allowances are required for adjacent changes in casting section, drilled or cored holes, deep pockets, re-entry angles and other areas which may have the effect of changing the cooling rate.
After consideration of these difficulties, it was decided to use an existing solidification modelling program to calculate modulus, and from this calculate alloy requirements.

MODULUS

Casting section is not sufficientlly accurate to describe cooling rate. Cubes, plates and bars with thicknesses of 25mm will all cool at different rates. Modulus more accurately describes cooling rate.

$$\text{Modulus} = \frac{\text{Volume}}{\text{Effective Cooling Surface Area}}$$

SOLIDIFICATION MODELLING

Initially this project started with the concept of modelling the cooling rate of the castings when they were quenched in the salt bath.

Various sized cube shaped castings were poured and then drilled, to allow thermocouples to be placed in the geometric centre of the block. The size and modulus of the blocks are listed in **Figure 1.**

Modulus	Dimensions (Cube)
0.75 (cm)	4.5cm x 4.5cm x 4.5cm
1.00 (cm)	6.0cm x 6.0cm x 6.0cm
1.50 (cm)	9.0cm x 9.0cm x 9.0cm
2.00 (cm)	12.0cm x 12.0cm x 12.0cm
2.50 (cm)	15.0cm x 15.0cm x 15.0cm
3.00 (cm)	18.0cm x 18.0cm x 18.0cm

Figure 1 : Size of Modulus Blocks

These blocks were weighed, then placed on a basket along with some other castings used as balast. The whole load was then weighed. **Figure 2.**

Block Size (mm)	Weight (kg)
4.5cm	0.70kg
6.0cm	1.73kg
9.0cm	5.70kg
12.0cm	13.90kg
15.0cm	26.60kg
18.0cm	45.60kg
Total Basket Weight	**270kg including ballast**

Figure 2 : Block Weight

The basket was loaded into a furnace which was heated to a temperature of 900°C and held for 2 hours. The basket was then quenched into a water saturated salt bath held at a temperature of 375°C.

This thermal information was captured using Type K thermocouples connected to a 10 channel Data Logger at 1 second intervals. **Figure 2 & 3.**

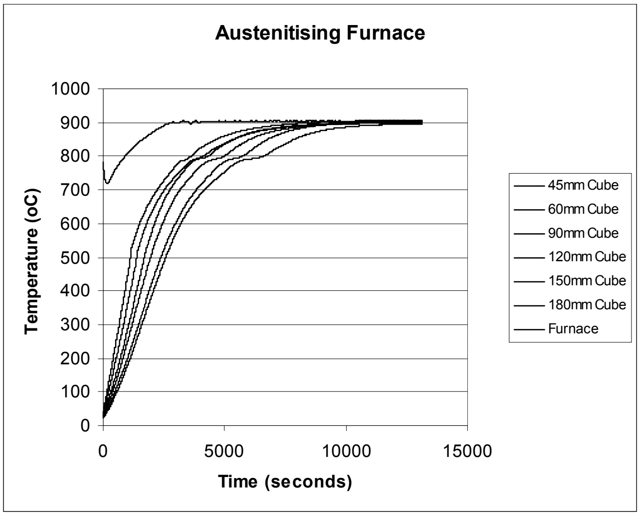

Figure 2 : Heating to 900°C (Time vs Temperature °C)

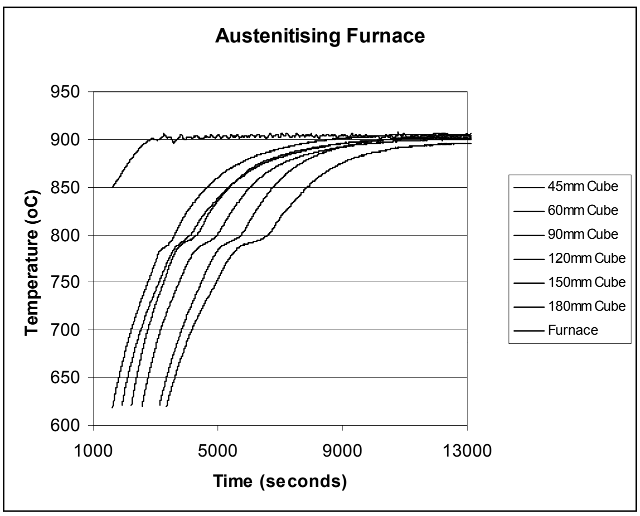

Figure 3: Arrest at Upper Critical Temperature

Figure 2 & 3 shows the thermal arrest for the upper critical temperature to be at 794°C for the analysis of these test blocks.

%C	%Si	%Mn	%Cu	%Ni	%Mo
3.65	2.56	0.31	0.74	0.21	0.03

Critical
Temperature (C°) = 730 + 28 x (%Si) – 25 x (%Mn)

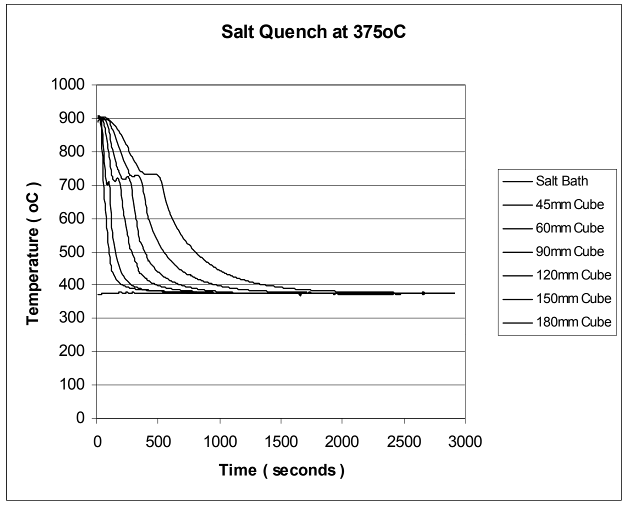

Figure 4 : Salt Quench at 375°C (Time vs Temperature oC)

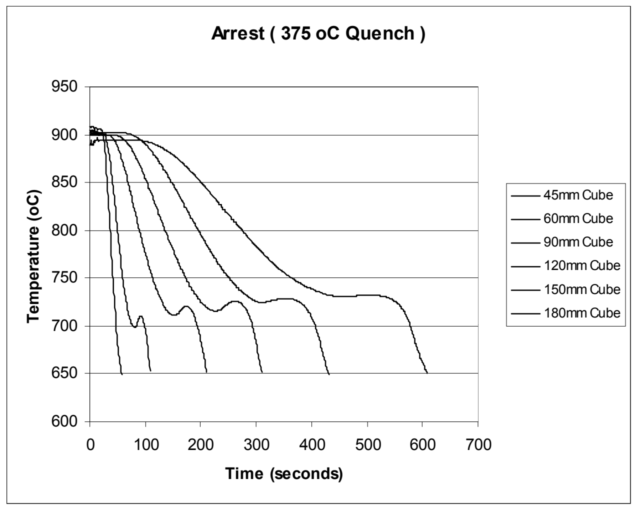

Figure 5 : Arrest during Salt Quench

Figure 4 & 5 show thermal arrest at various temperatures and for an increased length of time, dependant on block size.

Some problems encounted with the concept of using a casting solidification modelling program to model cooling in salt were:

1. Allowing for the length and temperature of the arrest depended on knowing the modulus prior to actually calculating the modulus.

2. A constant cooling rate was used.
The salt temperature in the model would have to be set at a constant temperature. In practice, deep pockets and cored areas have a lower salt flow over their surfaces. This could not be allowed for easily in our existing modelling program.

3. The correct thermal coefficients in a casting solidification model would be needed to accurately predict cooling in the salt.

It was decided to use the solidification time, as calculated by the solidification model as the variable in caculating the required alloy content.

An advantage of modelling the solidification of the casting is that slow cooling areas would be similar in both the mould and on quenching in the salt bath.

Modeling of shapes and sizes with calculated modulii could be used to generate solidification times. From these data a formula could be generated which would calculate the casting modulus from its predicted solidification time. **Figure 6.**

	Shape		
Modulus (cm)	**Cube** (side length)	**Plate** (thickness)	**Round** (diameter)
0.75	4.5cm	1.5cm	3.0cm
1.00	6.0cm	2.0cm	4.4cm
1.50	9.0cm	3.0cm	6.6cm
2.00	12.0cm	4.0cm	9.0cm
2.50	15.0cm	5.0cm	11.0cm
3.00	18.0cm	6.0cm	13.0cm
3.50	21.0cm	7.0cm	15.2cm
4.00	24.0cm	8.0cm	17.2cm
4.50	27.0cm	9.0cm	19.5cm
5.00	30.0cm	10.0cm	21.7cm
5.50	33.0cm	11.0cm	23.8cm
6.00	36.0cm	12.0cm	26.0cm
6.50	39.0cm	13.0cm	28.2cm
7.00	42.0cm	14.0cm	30.3cm

Figure 6 : Modulus vs Shape and Size

Cube - length x width x height
Plate - thickness x length x width (length & width 10x thickness)
Round - diameter x length (length 6x diameter)

The different size cubes, plates and round bars were modelled. The solidification times are indicated in **Figure 7.**

	Solidification Time (minutes)		
Modulus	**Cube**	**Plate**	**Round Bar**
0.75	3.46	4.30	3.20
1.00	6.20	8.00	5.80
1.50	14.2	13.2	13.0
2.00	24.7	23.2	23.6
2.50	38.4	34.5	36.1
3.00	57.7	58.4	52.4
3.50	73.6	75.4	71.4
4.00	93.4	96.0	90.0
4.50	118.9	123.2	115.2
5.00	154.4	157.4	142.3
5.50	184.7	190.8	169.9
6.00	216.5	216.3	207.7
6.50	246.6	252.2	238.3
7.00	290.0	294.3	280.3

Figure 7 : Modulus vs Calculated Solidificaion Time

These figures are represented graphically in **Figure 8.**

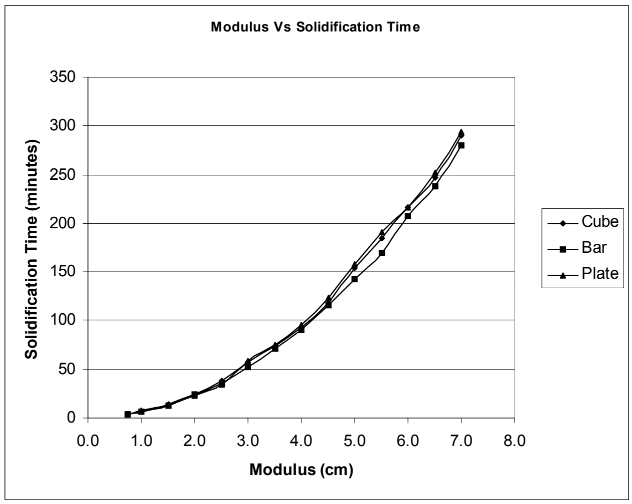

Figure 8 : Modulus vs Calculted Solidification Time

Wanting to allow some safety margin in the calculation the more conservative figures produced by the round bar will be used. **Figure 9.**

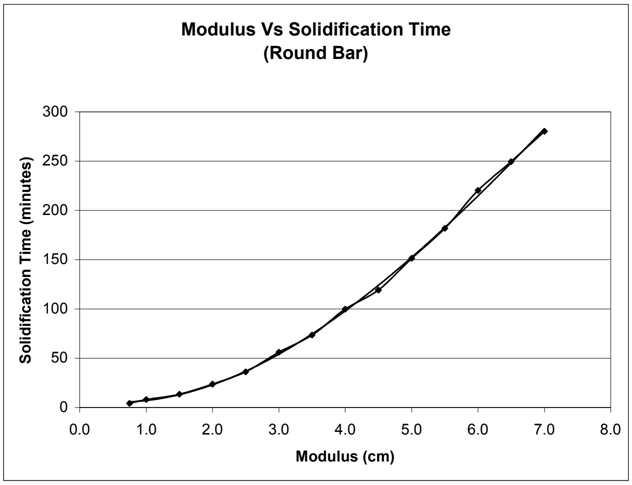

Figure 9 : Modulus vs Calculated Solidification Time of a Round Bar

The equation as follows:

Solidification Time = $-0.3914 \times (\textbf{modulus})^3 + 9.9195 \times (\textbf{modulus})^2 - 11.08 \times (\textbf{modulus}) - 8.5676$

The graph is now converted to Solidification Time vs Modulus, as the Modulus is the unknown. **Figure 10.**

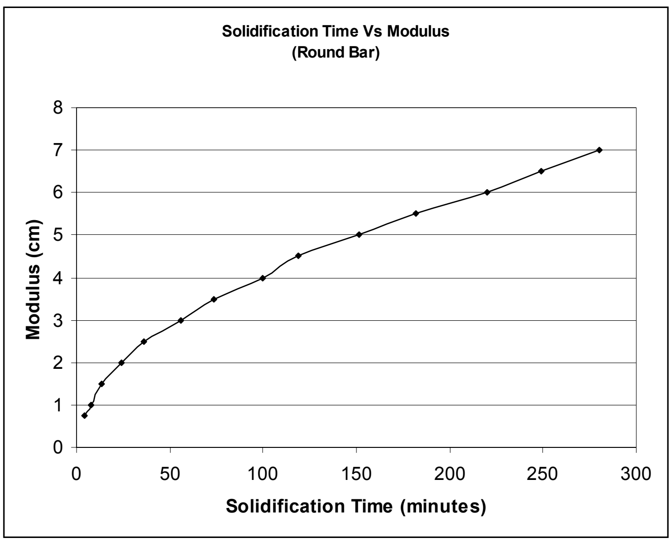

Figure 10 : Solidification Time vs Modulus.

To generate a line of best fit, two formulas have had to be generated. One for 0 to 60 minutes. **Figure 11.** The other one for 61 to 300 minutes. **Figure 12.**

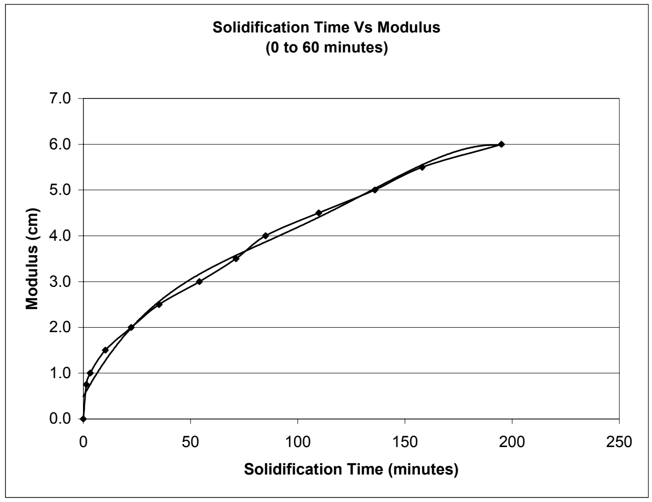

Figure 11 : Solidification Time vs Modulus (0 to 60 minutes)

The equation as follows:

Modulus = $(-1 \times 10^{-8}) \times (\textbf{solidification time})^4 + (6 \times 10^{-6}) \times (\textbf{solidification time})^3 - 0.001 \times (\textbf{solidification time})^2 + 0.00857 \times (\textbf{solidification time}) + 0.5172$

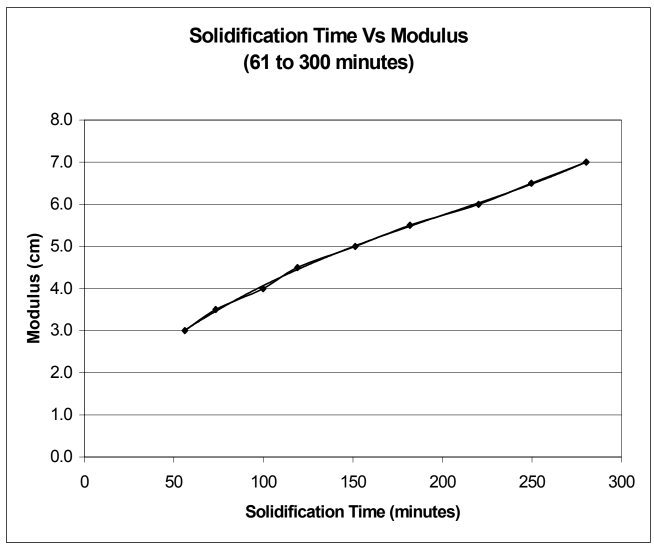

Figure 12 : Solidification Time vs Modulus (61 to 300 minutes)

The equation as follows:

Modulus = $(2 \times 10^{-10}) \times (\textbf{solidification time})^4 + (9 \times 10^{-8}) \times (\textbf{solidification time})^3 - (1 \times 10^{-4}) \times (\textbf{solidification time})^2 + 0.0377 \times (\textbf{solidification time}) + 1.3109$

These two formulae are combined and are represented graphically in **Figure 13**.

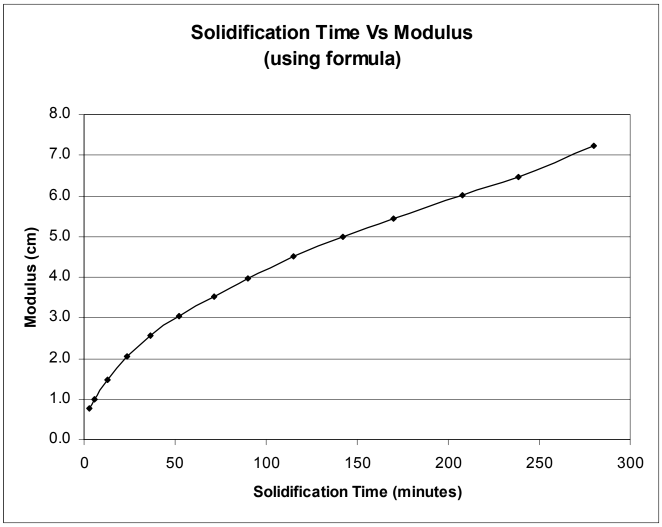

Figure 13 : Solidification Time vs Modulus (using combined formula)

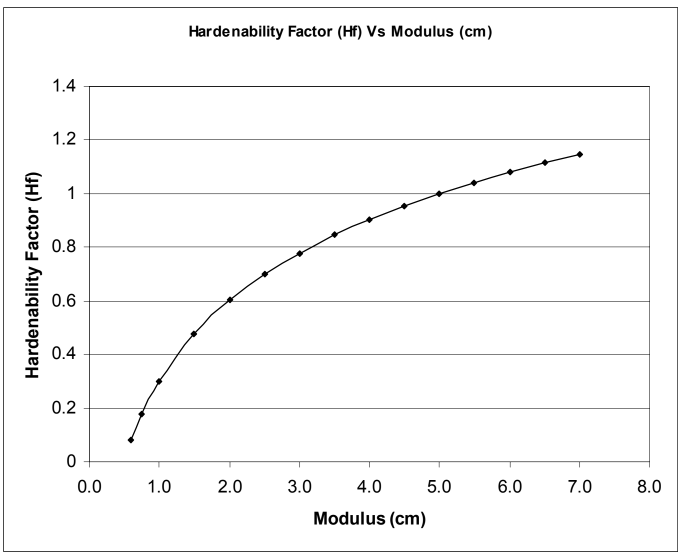

Figure 14 : Modulus vs Hardenability Factor

Having developed a method for converting calculated solidification time into casting modulus **Figure 13**. We can then use **Figure 14** to determine a required hardenability factor.

Using an internally developed Hf formula alloying content can be calculated.

Alloying conent required for various modulii. **Figure 15**. Calculated from solidification time converted to modulus and then using a hardenability factor to predict required alloy additions.

Solidification Time		Alloy Content			
	Modulus	Mn	Cu	Ni	Mo
2.8 min	0.75	0.30	0.19	0.00	0.00
6.1 min	1.00	0.30	0.67	0.00	0.00
22.4 min	2.00	0.30	0.75	0.95	0.00
91.3 min	4.00	0.30	0.75	1.98	0.00
268.3 min	7.00	0.30	0.75	2.20	0.18

Figure 15 : Alloy content for various Modulii.

CONCLUSION

By using a modelling program to calculate the solidification time of cast shapes of known modulii, the solidification time of a casting can then be used to determined its modulus. From this, we are able to predict the minimum alloy content required to ensure full through hardening of the casting during the Austempering process.

Modulus rather than section size should be used in the calculation of Alloy Content and in the determination of Austenitising and Austempering times. Modulus more accurately represents the heating and cooling properties of the casting.

Examples of castings:

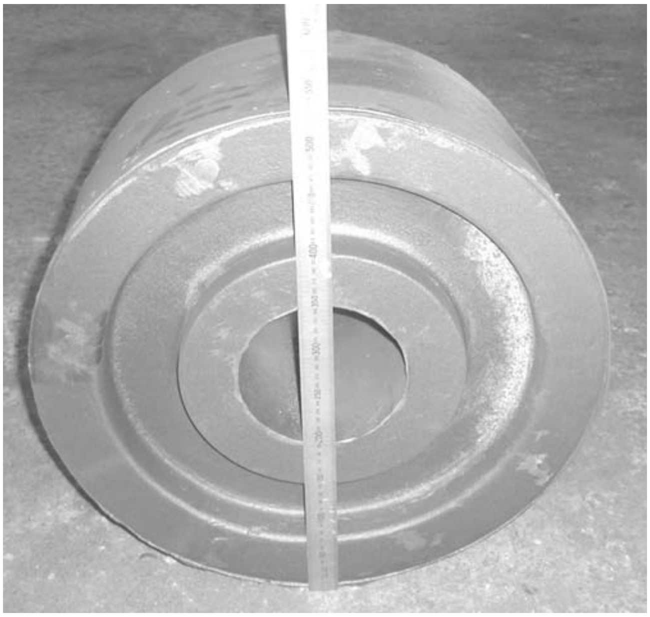

Figure 16 : Roller Casting – 530mm dia x 300mm high

Solidification Time – 152.2 minutes

Modulus – 5.16 cm

Analysis – 0.3%Mn 0.75%Cu 2.20%Ni 0.05%Mo

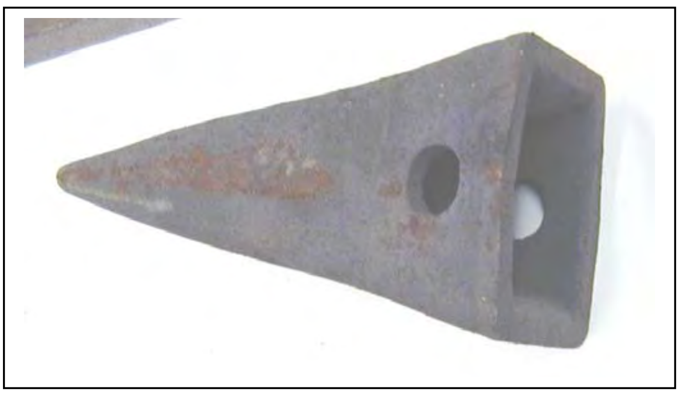

Figure 17: Digger Tooth

Solidification Time -12.1 minutes

Modulus - 1.42

Analysis - 0.3%Mn 0.75%Cu 0.45%Ni

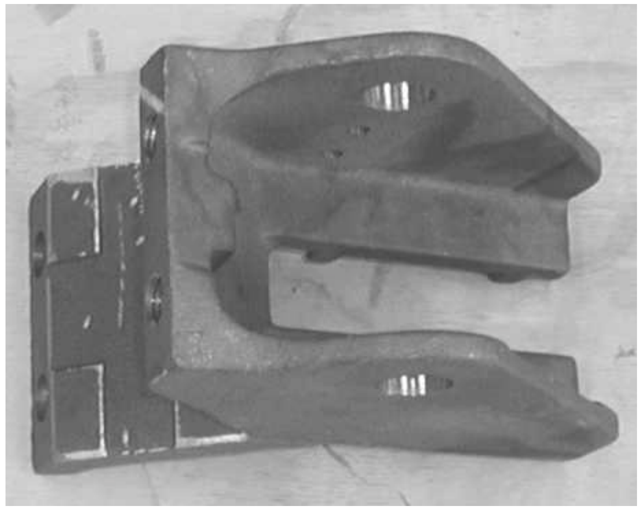

Figure 18 : Tyne Pivot Casting

Solidification Time - 5.3 minutes

Modulus - 0.94 cm

Analysis - 0.3%Mn 0.55%Cu

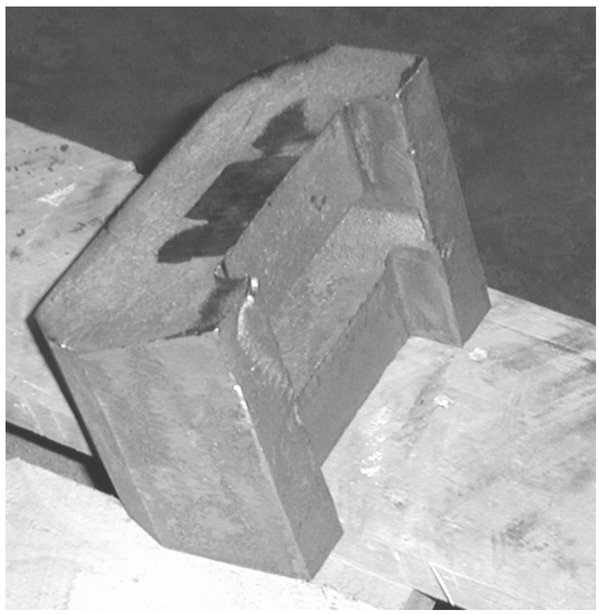

Figure 19: Mulching Hammer

Solidification Time - 15.5 minutes

Modulus - 1.63 cm

Analysis - 0.3%Mn 0.75%Cu 0.65%Ni

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Ms Cathy Smith – Materials Science, Monash University
Melbourne, Australia

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1. "DUCTILE IRON – The essentials of gating and risering system design." Seminar Lecture Notes. Revised 1993. QIT – Fer et Titane Inc

ADDITIONAL RESOURCES

ADI Engineering Process & Heat Treatment - internal research.

Applied Process - Internal Research, Hf Alloying Hierarchy.

New ADI-production technology

Dipl.Ing. Matti Johansson
Componenta CPC,Finland

ABSTRACT

After three years research work a new ADI-production technology was developed to enhance the productivity and the properties of the castings. The idea was to benefit the expansion force of the solidification. By using this means, two different components were produced and tested. The results were amazingly good. The main reason for the excellent properties of the castings was a very fine microstructure with low segregation and no porosity or defects. This new production technology will also make the production costs lower and the foundry environment better than conventional sand cast technology. The new production line makes it possible to develop new products with reduced weight and costs, replacing steel forgings and aluminium components.

INTRODUCTION

Austempered ductile iron was first developed for heavy loaded gear wheels and the production started in Finland in 1973. Soon after that, many wear resistant components such as spring seats, wear plates and rail wheels were produced. Additionally, other high loaded components in the car industry were developed. Some of these applications were of limited use because of safety reasons or production costs. In this work, new ideas were used to solve the problems of ADI-production. The aim was to make better products with less money. The most important consideration in making a high strength material is to minimize the defects inside and on the surface of the castings. That gives us the possibility to increase the fatigue strength and, as a result, save on the weight of the component. Near-net-shape casting technology will, thus, reduce the costs of the production.

BACKGROUND

Austempered ductile iron has been a very promising material for many kinds of applications. When utilizing high strength properties, the quality of the castings must be much higher than conventional ductile iron grades. The safety reasons and the production costs have become more important in high series production. That is why we started to study some sand cast applications, which had high production costs. As an example, a ring gear was taken for the preliminary testing. The properties of an ADI ring gear are interesting, for example in an automatic transmission because the noise reduction is remarkable. But when using the sand cast process, very big feeders have to be used to guarantee the soundness of the casting**, Figure 1**.

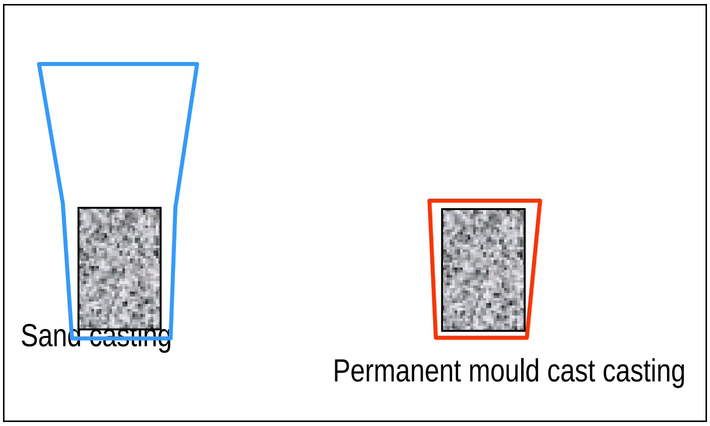

Figure 1 : Sand casting compared to permanent mould casting.

In the first preliminary permanent mould castings, only a small feeder and an ingate system were needed. The mechanical test results were good enough, but sometimes porosity was also found in this process. Because of promising results, a new project was started to develop squeeze cast technology for the production of ADI. The goal of the project was to decrease production costs, reduce

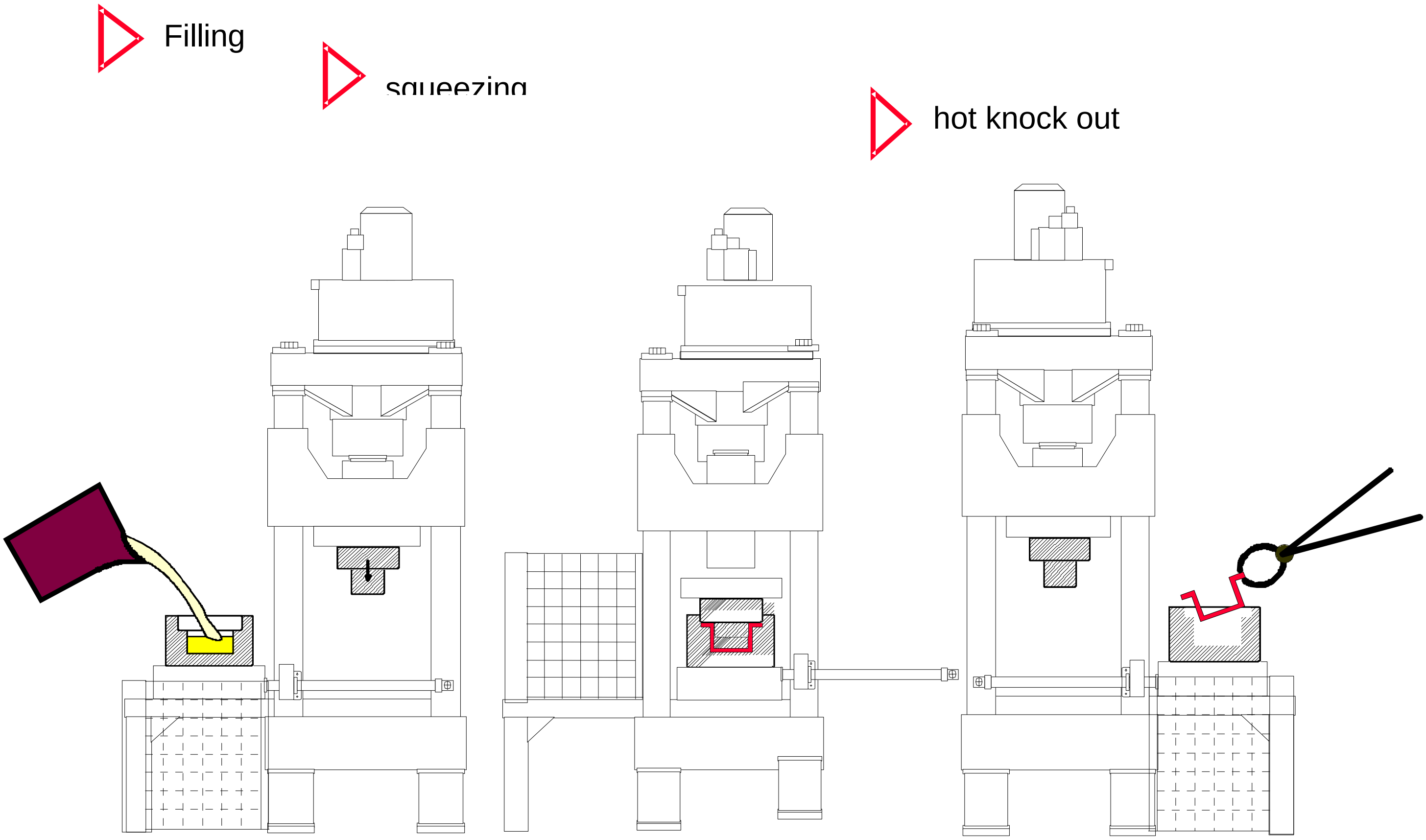

Figure 2 : Squeeze casting process

the weight of the components and to use the damping properties of ADI for the reduction of the noise in the gears. In addition, the goal was to make a better environment in the foundry as well as get more reliable and near-net-shape castings.

PROCESS DEVELOPMENT

In the squeeze cast process, the expansion of the solidification was used to obtain sound castings without feeders and gating systems. The casting process is described in the **Figure 2**. The iron was poured in the metal mould and squeezed in the press. Because no sand is used, the direct heat treatment can be made without cooling the casting. This makes the process time short and decreases the energy needed.

The ring gear was the first real component in this project. Compared to the earlier experiments with sand and permanent mould processes, a much better microstructure was achieved. The graphite nodule size was small and the distribution was fine, **Figure 3**.

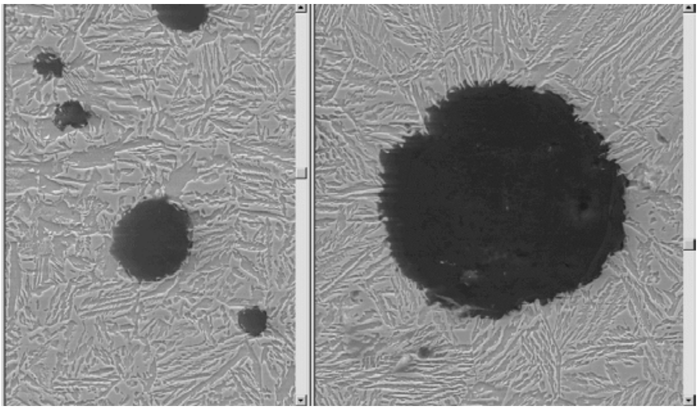

Figure 3 : Microstructure of squeeze casting (left) and sand casting (right)

Additionally, no porosity or other defects were found in the optimized casting process.
Due to the fine microstructure, the mechanical properties were much better than sand cast and austempered ductile iron. Elongation and ultimate tensile strength were much higher. This will mean that fatigue strength also increases compared to sand cast material, **Table 1**.
A very important feature is the surface structure of the casting, **Figure 4**. There is no surface defects like we have usually seen in sand castings. The surface of the squeeze castings is clean like the machined surface. Graphite nodules are under the thin skin of the casting and we can estimate that this makes the component more resistant against fatigue loads.

Table 1. Some tensile test results of squeeze cast test samples compared to EN standard .

	Test 1	EN	Test 2	EN
Tensile strength MPa	1238	1200	1115	1000
Yield strength MPa	968	850	839	700
Elongation %	13,4	2	15,3	5
Hardness HB	388	340/440	363	300/360

COMPONENT TESTING

A ring gear was tested in the Valtra tractor both in field and bench tests. The tested tractor was loaded with maximum engine power in the bench test. After 296 hours (corresponding 10,000 hours average use), the test was stopped because of pitting in the case hardened steel gear and some other failure in the transmission. Testing showed us that the ring gear was good enough and not the weakest part of the power transmission. The field test is on-going. The same result was proved with another analog test machine in RWTH Aachen. The roll testing machine was operating with the rotational speed of 2870 r/min and the mating roll is case hardened steel. For the testing of gear material, 24% slip was used. With the Herzian pressure of 1350 MPa, no pitting was seen after 50,000,000 cycles. In the microscope, small cracks were seen starting

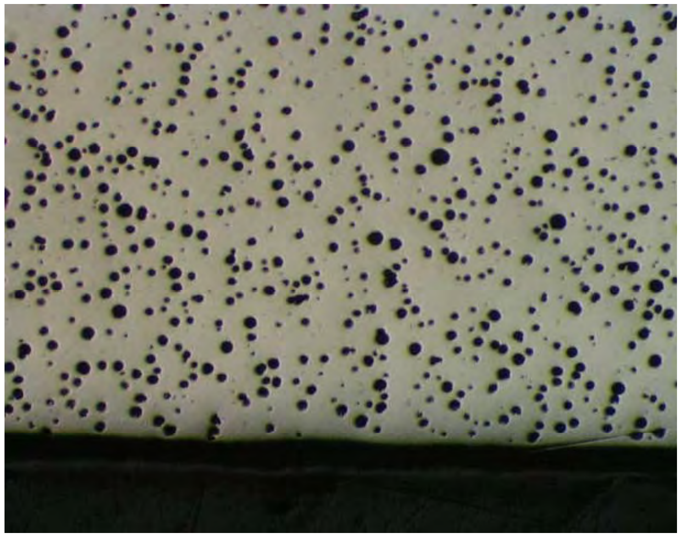

Figure 4 : The surface of the casting is without defects, which increase the strength of the component.

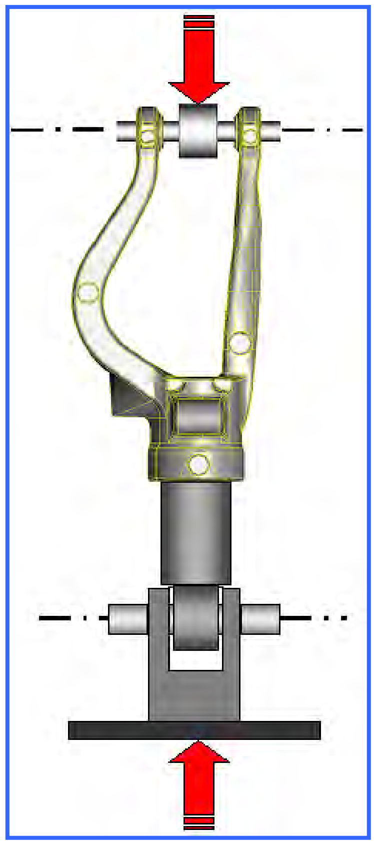

Figure 5 : Fatigue testing of the suspension fork

from the surface usually ending at the graphite nodules.

Another component was tested by Fiat. A suspension fork was optimized and the reduction of weight was 21 % compared to GJS 600-10 (special elongation limit). Only 8 pieces were cast because of the simple mould technique, which made the continuous casting process difficult to carry out. All these castings were used to analyse the microstructure and mechanical properties. All specimens from different parts of the suspension fork were homogenous in microstructure. No carbidic or martensitic microstructures were seen. Some larger nodules were found in the middle of the section. Also, some porosity was seen, with a maximum size of 125 µm in those two castings in which we found cold runs. Other components were sound and good. The component has to pass the test without cracks loaded with 2500 kN and life time 300,000 cycles. In this case, with squeeze cast forks, the load was 5000 kN and all tested components were without failure after 3-10,000,000 cycles, **Figure 5**. A tensile test bar was taken in the fork, **Figure 6**. Test results were much higher than pearlitic ductile iron or even better than microalloyed steel. No martensite or carbide was seen in the microstructure.

Table 2. Comparison of different suspension fork materials.

	GJS-600-5	SQ ADI (tested)	Microalloyed steel
σ_R MPa	600	950	1000
σ_y MP	370	750	550
ε %	10	11	12

As a summary, the test showed very high strength properties for squeeze cast ADI. Yield strength was much higher than steel and elongation about the same, **Table 2**. The Ausferritic structure was fine and without porosity. Bench tests showed very good fatigue strength with the weight reduced component and the material was machinable after the heat treatment.

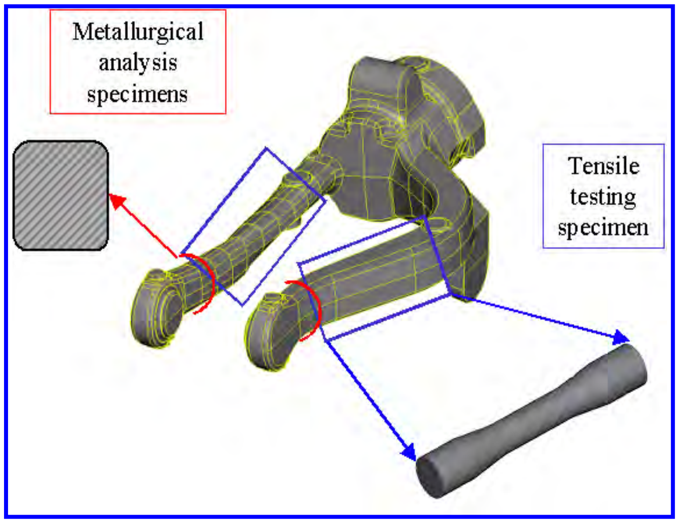

Figure 6 : Tensile test specimens were taken from the fork.

ADI has the properties, which can be compared with steels. The squeeze casting technology makes it possible to increase the strength and reliability of the ADI components. In the future, the designers will be able to reduce the weight of the components by using squeeze casting technology which is also an economical and environmentally friendly process.

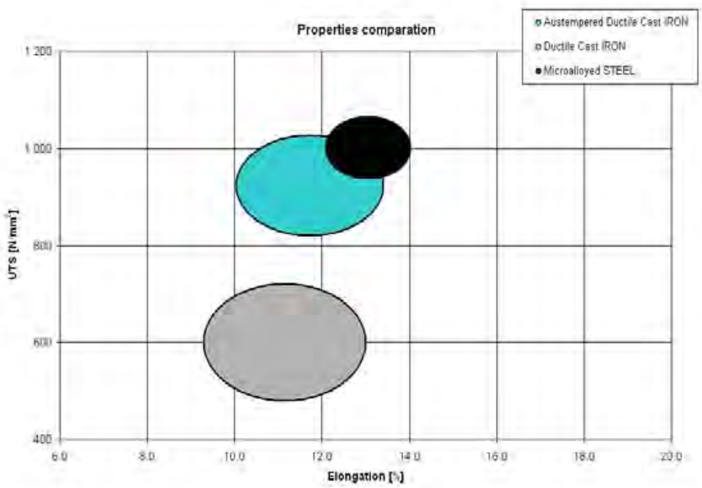

Figure 7 : ADI can replace microalloyed steel in the automotive industry.

SUMMARY

Squeeze casting technology was developed and two different applications were tested with very good results. As the conclusion of the results, the following features could be mentioned.

- Excellent yield strength/elongation combination
- Excellent fatigue strength of the components
- Good contact fatigue strength
- Better machining properties than sand cast ADI
- Low production costs
- Environmental benefits of the foundry process

Squeeze cast ADI has properties never seen before.

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Dipl.-Ing. Harri Nordlund and Matti Johansson, Componenta CPC

ADDITIONAL RESOURCES

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Precision Metalsmiths, Inc. Receives Patent

Cleveland, Ohio and Markesan, Wisconsin June 2004 - Precision Metalsmiths, Inc. – ***PMI***, with corporate headquarters in Cleveland, OH announces it has been awarded a new patent for investment casting.

A totally new, solid mold investment specifically developed for investment casting platinum jewelry, but also suitable for other applications, and for other high melting alloys such as cobalt chromium, nickel chromium and steels including stainless.

Precision Metalsmiths, Inc., (supplying materials through its subsidiary Wattsworks), announces the availability of a unique new solid mold investment material for casting platinum jewelry and for other uses.

This totally new investment material provides significant advantages over all of the existing platinum investments, whether of the older magnesium phosphate type, or the dental investments which have been adapted to jewelry casting or of the phosphoric acid types which up to now have been preferred for the most demanding work.

Compared to magnesium phosphate jewelry investments of the older type or the more recent dental adaptations, the new investment provides superior finishes, while still providing the capability to be invested and cast the same day.

Compared to the phosphoric acid investments, it provides the great advantage of being used with water. No acid or other liquid are required. The need for the expensive Hazmat packaging is eliminated, as is the need to stock and dilute phosphoric acid on the shop floor. Time is saved and a source of potential errors and accidents is eliminated. Although the investment contains silica, as the other platinum investments do, it contains no other hazardous substance.

The new investment provides added flexibility in processing. Molds can be invested and cast the same day, or they can be invested, fired overnight and cast the next day, or invested and held overnight, then fired and cast the next day. This provides great flexibility in scheduling or adjusting to unforeseen events.

After casting, the investment can be mostly removed by quenching the hot mold in water as is done with gold investments. Alternatively, it can be removed by manual knockout or water blasting.

These advantages over the phosphoric acid investments are achieved with no loss in quality. In fact, in many cases the results are actually improved.

The new investment is covered by US Patent 6,746,528, recently issued to Robert A. Horton and Claude H. Watts, and assigned to

PMI.

Visit http://www.wattsworks.com for more information on investment casting materials including, premium solid mold investments, superior investment casting waxes and other investment casting materials for the industrial and jewelry investment casting trades.

Visit http://www.precisionmetalsmiths.com for more information on PMI.

Precision Metalsmiths, Inc. was founded in 1945 by Robert R. Miller. PMI's pioneering work in investment casting set the standard for its innovative approach to research and development. More than 200 U.S. and foreign patents have been issued to PMI on casting methods, materials, and processing equipment.

PMI is recognized throughout the world as a leader in the investment casting[1] process and in related technologies. PMI has both ferrous and non-ferrous capabilities at their facilities in Cleveland, Ohio and Markesan, Wisconsin with licensees worldwide. Proprietary methods allow PMI to create near net shape metal parts with lower cost and consistently better quality than traditional investment casting. PMI takes pride in their reputation for producing quality castings. At PMI every casting becomes a testimonial to their commitment to quality.

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[1]An Investment casting is a near net shape made by the "lost wax" process that features cast-in-detail, tight tolerances, and excellent surface finish. The term investment refers to the ceramic materials that are used to build a solid investment mold or hollow ceramic shell into which molten metal is poured to make the casting. Every casting requires a pattern which is wax welded onto a cylindrical shape. The patterns are dipped into a ceramic slurry and coated with a stucco of fine sand or surrounded with solid investment. The wax pattern is melted out and the void filled with molten metal. The metal castings are finished according to customer's specifications.

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Ductile Iron News
Ductile Iron Society
To Promote the production and application of ductile iron castings
Issue 3, 2004

Inductotherm Meeting Photos

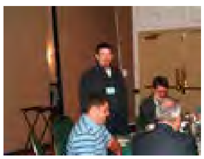
Click photo to enlarge

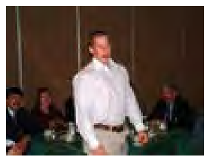
Meeting Photos

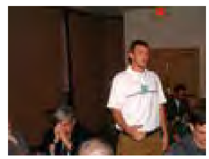
Tri State University Student Guests


James Bauman


Christopher Bixler


Ryan Canfield


Jon Edwards


Stephen Johnson

Speakers Are Thanked For Presentations by Jim Wood & Gene Muratore


Patricio Gill
Teknik Foundry


John Keough
Applied Process


Chad Moder
Neenah Foundry


Preston Scarber
University of Alabama


Charles Fink
Inductotherm Vice President of Sales


Jim Csonka
Hickman, WIlliams & Co.


Jim Wood Thanks Charles Fink For Invitation to Visit Inductotherm


Program Chairman Jim Wood
Hickman Williams & Co.

Plant Tour

View
Ductile Iron Related
Publications

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email:jwood@ductile.org

News Briefs

MEETINGS - BUSINESS

MEETINGS

The Ductile Iron Production Seminar will be held on February 22-23, 2005 at the Holiday Inn Rolling Meadows Illinois. Click here for more details and to register for this meeting.

The **Ductile Iron Society 2005 June Meeting** will be held in South Bend, Indiana on June 15-17, 2005. Click here for more details and to register for this meeting.

BUSINESS

Precision Metalsmiths, Inc. Receives Patent

Cleveland, Ohio and Markesan, Wisconsin June 2004 - Precision Metalsmiths, Inc. – ***PMI***, with corporate headquarters in Cleveland, OH announces it has been awarded a new patent for investment casting.

A totally new, solid mold investment specifically developed for investment casting platinum jewelry, but also suitable for other applications, and for other high melting alloys such as cobalt chromium, nickel chromium and steels including stainless.

Precision Metalsmiths, Inc., (supplying materials through its subsidiary Wattsworks), announces the availability of a unique new solid mold investment material for casting platinum jewelry and for other uses.

This totally new investment material provides significant advantages over all of the existing platinum investments, whether of the older magnesium phosphate type, or the dental investments which have been adapted to jewelry casting or of the phosphoric acid types which up to now have been preferred for the most demanding work.

Compared to magnesium phosphate jewelry investments of the older type or the more recent dental adaptations, the new investment provides superior finishes, while still providing the capability to be invested and cast the same day.

Compared to the phosphoric acid investments, it provides the great advantage of being used with water. No acid or other liquid are required. The need for the expensive Hazmat packaging is eliminated, as is the need to stock and dilute phosphoric acid on the shop floor. Time is saved and a source of potential errors and accidents is eliminated. Although the investment contains silica, as the other platinum investments do, it contains no other hazardous substance.

The new investment provides added flexibility in processing.

Molds can be invested and cast the same day, or they can be invested, fired overnight and cast the next day, or invested and held overnight, then fired and cast the next day. This provides great flexibility in scheduling or adjusting to unforeseen events.

After casting, the investment can be mostly removed by quenching the hot mold in water as is done with gold investments. Alternatively, it can be removed by manual knockout or water blasting.

These advantages over the phosphoric acid investments are achieved with no loss in quality. In fact, in many cases the results are actually improved.

The new investment is covered by US Patent 6,746,528, recently issued to Robert A. Horton and Claude H. Watts, and assigned to PMI.

Visit http://www.wattsworks.com for more information on investment casting materials including, premium solid mold investments, superior investment casting waxes and other investment casting materials for the industrial and jewelry investment casting trades.

Visit http://www.precisionmetalsmiths.com for more information on PMI.

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Precision Metalsmiths, Inc. acquires Eden333 Rapid Prototype Machine from Stratasys, Inc.

Cleveland, Ohio and Markesan, Wisconsin November 2004 - Precision Metalsmiths, Inc. – ***PMI***, with corporate headquarters in Cleveland, OH announces two new services related to rapid prototype metal parts and low volume quick tooling.

Two new services from Precision Metalsmiths, Inc.

PMI acquires Eden333 Rapid Prototype machine from Stratasys, Inc.

AVAILABLE NOW!

In-House rapid prototype service direct from your cad file or print. See your design in metal within days. Highest resolution, dimensional accuracy and repeatability propels PMI prototypes to a higher standard. PMI's proprietary methods allow us to use our newly acquired Eden333 rapid prototype machine to directly produce patterns for investment casting. Layer thickness of .0006 produce the highest resolutions available while still holding the investment casting standard of .005 inches per inch tolerance with exceptional surface finishes unrivaled by any other rapid prototype machine. Smoother finishes and tighter tolerances than SLA or Castformä patterns with zero warpage and no support structure defects. Metal prototypes available in any of 200 alloys, from stainless steels to aluminum to copper alloys.

AVAILABLE SOON!

In-House rapid tooling. Based on the above technology PMI can build short run, bridge or prototype tooling directly from prototype model material. PMI proprietary methods let us inject investment casting wax directly into a plastic tool built using the Eden333 rapid prototype machine. Your short run order completed from cad file to investment cast metal parts in weeks, not months. Best of all, PMI will create this tooling at minimal cost to you.

For a quote or details on how we can help you with your metal parts needs, fax us your print (FAX 216-481-8903), email your cad file pmisales@precisionmetalsmiths.com or call us today at 216-481-8900.

How we do it. Starting with your print or cad file a 3D computer image is rendered of your part. PMI adds appropriate gating and sends the file to the Eden333 to be produced. The part is built, layer-by-layer, fully encapsulated inside a gel support structure, so there are no issues with overhangs, support generation or removal as with some other RP systems. The UV resin parts are removed from the machine fully cured to eliminate any warpage or shrinkage issues. Requiring only removal of the gel support material with a waterblast unit the parts are ready to be investment cast immediately. PMI's heavy investment in R&D over the last 60 years helped PMI develop the proprietary methods needed to directly use UV cured resin prototype models for direct investment casting. **Rapid tooling** works much the same way. Injection die blocks of your part cavities are rendered on the computer as a 3D image. The images are built on the Eden333, usually overnight, to produce a wax injection tooling made of rigid UV resin plastic. The die halves are cleaned up and used to make investment casting wax patterns via wax injection. **Investment casting** in general means to create a wax pattern in the image of the intended part, surround the wax pattern with solid investment or a ceramic slurry shell, melt out the wax pattern leaving behind a hollow ceramic shell, and pouring molten metal into the ceramic shell. The ceramic shell is removed and the resulting metal parts are finished according to customer requirements. **PMI** uses proprietary methods to create consistent, high quality investment castings. Our unique systems are tailored to small sizes (fractions of an ounce to 10 pounds) and small to medium quantity (<100 to 100,000+) production runs. Extra fine surface finishes and extreme detail holding abilities sets PMI apart from ordinary investment castings.

More information about Precision Metalsmiths, Inc. can be found at www.precisionmetalsmiths.com

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Ashland Announces Innovative Design Services Center

DUBLIN, Ohio (USA) – Ashland Casting Solutions, a business group within Ashland Specialty Chemical, a division of Ashland Inc. (NYSE:ASH), announces the opening of its Design Services Center at the company's headquarters in Dublin, Ohio. The center is a "one-stop shop" for the metal casting industry providing support from engineered drawings through casting and testing in Ashland's design-to-manufacture process.

An example of the total innovative solutions package available from Ashland, the Design Services Center is staffed with engineers dedicated to meeting the needs of the complex and diverse metal casting industry. The Center offers the latest technologies and technical support to help Ashland's customers optimize casting designs and processes to increase productivity and profitability.

Using Arena-flow1 software, Ashland can produce animated simulations of sand core blowing and gassing processes. With EXACTCALC® methoding software, Ashland determines the mold gating and risering required to optimize mold filling. And, with Novaflow & Solid2 software, Ashland can validate the casting design and predict and eliminate defects.

"Our Design Services Center team works to provide the total solution from concept to completion," said Mike Swartzlander, vice president, Ashland Specialty Chemical, and general manager, Ashland Casting Solutions. "Working with customers from engineered drawings through casting and testing, we have the unique ability to make their processes more productive and profitable while improving quality."

To contact the Design Services Center call 1.800.848.7485.

Ashland announces innovative Design Services Center -2

About Ashland

Ashland Casting Solutions, a business group of Ashland Specialty Chemical, is a leader in supplying products, processes and technologies to the global metal casting marketplace. The group has operations (including licensees and joint ventures) in 21 countries.

Ashland Specialty Chemical, a division of Ashland Inc., is a leading, worldwide supplier of specialty chemicals serving industries including adhesives, automotive, composites, metal casting, merchant marine, paint, paper, plastics, watercraft and water treatment. Visit www.ashspec.com to learn more about these operations.

Ashland Inc. (NYSE:ASH) is a Fortune 500 transportation construction, chemicals and petroleum company providing products, services and customer solutions throughout the world. To learn more about Ashland, visit www.ashland.com.

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