Ductile Iron Society Visits
QIT Sorel Plant of Rio Tinto

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Ductile Iron News
To Promote the production and application of ductile iron castings
Issue 2, 2004

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Ductile Iron Society Visits
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PR Gangasani of Wells Manufacturing presented results of a program which investigated the friction and wear behavior of various ductile irons under dry conditions over hardened 52100 disks using a 3 pads-on-disk method. In this study, the wear loss of the materials tested was found to be related only to the starting hardness. Grade 5 ADI and Q&T D5506 ductile iron exhibited the lowest wear rates, which were approximately 9% that of D4512 ductile iron.

A. Alagarsamy of Citation Corp suggested that scrap rates could be significantly reduced by employing a disciplined approach to understanding the nature of defects and the mechanism of defect formation as well as controlling key process variables. Casting defect codes from The International Atlas of Casting Defects Handbook were shown. It was contended that the use of these codes would enable foundry personnel to share and use data from one foundry to another, thus, disseminating the knowledge for solving casting defect problems.

The current state of worldwide standards for ductile iron were discussed by several members of the SAE Division 9 Iron and Steel Casting Standards Committee. Reviewing and updating these standards to keep them current in terms of materials properties is an on-going activity. It was emphasized that such activities are necessary for design engineers to consider ductile iron for applications.

C. Labrecque of Rio Tinto Iron & Titanium demonstrated that high purity pig iron generated the least amount of slag during the production of ductile iron when compared to other charge materials like ductile iron returns and steel scrap. The amounts of slag generated by the different charge materials expressed as the percentage of liquid bath weight are listed in Table 1.

<table>
<thead>
<tr>
<th>Material (% in charge)</th>
<th>Test Results % Slag</th>
<th>Corrected Results* % Slag</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPI (80%)</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>DI Returns (67%)</td>
<td>2.90</td>
<td>4.0</td>
</tr>
<tr>
<td>Bushelings (50%)</td>
<td>0.35</td>
<td>0.57</td>
</tr>
<tr>
<td>Selected Frad (50%)</td>
<td>0.79</td>
<td>1.43</td>
</tr>
</tbody>
</table>
The Ductile Iron News

Note: Corrected results are for a charge made of 100% of the material listed.

P. Scarber of the University of Alabama-Birmingham demonstrated the use of real time x-ray technology in the production of ductile cast iron. The flow of iron into the mold under different conditions was shown and correlations were made between the flow characteristics and the formation of defects.

T. Skaland of ELKEM Foundry Products compared Lanthanum and Cerium bearing treatment alloys. Experimental results revealed that La-bearing MgFeSi alloys when used in the ladle treatment process have advantages over using Ce-bearing alloys. Such advantages include: increased nodule counts (2 – 3 times), improved nodularity (10-20%), reduction of pearlite content of up to 50%, substantial lowering of the chilling tendency and the elimination of shrinkage porosity in a hot spot crossbar. The use of a 0.5% La-bearing alloy was found to minimize or eliminate the need for post inoculation, thus, providing a cost effective alternative for ladle treatment.

L. Björkegren of the Swedish Foundry Association described the challenges with machining Grade 500-7 ductile iron with a hardness range of HBW 170-230. A new alloy with a higher Si content was designed in order to narrow the hardness range to HBW 185-215, thus minimizing some of the machinability variations with the wider hardness range of conventional Grade 500-7 iron. Cost reductions of 10% for machining in addition to time reductions of 5-20% have been realized. A new designation of SS 0725 is recognized for this material in Sweden while the new ISO standard will refer to the material as GJS 500-10.

K. Hayrinen of Applied Process Technologies Division discussed the state of the ADI industry in 2003. The historical growth rates of ADI suggest that North American ADI production could approach 200,000 tons per year by the end of this decade and exceed 300,000 tons per year by 2020 as shown in Figure 1.

![Estimated Worldwide ADI Production (2002)](image)

Figure 1: Estimated Worldwide ADI Production

T. Tackaberry of Foseco described direct pouring on automatic horizontal molding machines using a specially designed insulating sleeve containing a reticulated ceramic foam filter. Users of this system were found to experience the production savings of high-volume molding, yield...
improvements, increased pattern productivity and reduced cleaning expenses. Overall increases in productivity and improved foundry profitability are also realized.

K. Taylor of Foseco presented a series of casting production case studies that illustrated how yield, quality and productivity were improved in leading European foundries. The use of ceramic foam filters was highlighted, not as an emergency solution only, but as a means of improving the quality of castings as a whole. In the broader global context, the use of ceramic foam filtration is now a state-of-the-art technique, which supports the manufacture of high quality automotive and engineering components at optimum cost.

I. Riposan of Politehnica University of Bucharest discussed the use of cooling and contraction curves to identify the influence of inoculants on the shrinkage behavior of hypereutectic ductile irons in green sand molds. Analysis was completed on several inoculated ductile irons. By using this method of analysis, a Ca-Ce-S-O-FeSi alloy was demonstrated to be a powerful inoculant without promoting shrinkage in ductile iron.

N Downes of Dana de Venezuela proposed ten steps for improving casting yield in ductile iron foundries. In the past, conventional attempts at reducing costs have focused on scrap reduction. While the importance of scrap reduction was recognized, it was suggested that yield improvement can be a more significant cost reduction tool. The ten steps highlighted included: use of ceramic foam filters, use of stable raw materials, use of trapezoidal gate cross-sections, optimizing pour times and pouring sequence, optimum gating/runner modulus to control temperature loss, use of risers to compensate expansion, placing risers at optimum locations, use of a riser for more than one casting (if feasible), use of top risers and use of hot risers.

W. Bauer of the Austrian Foundry Research Institute discussed the bending fatigue behavior of ductile iron with as-cast surfaces. In general, the bending fatigue behavior of as-cast surfaces does not necessarily correlate with tensile strength, as is the case with machined specimens. It was found to depend more on the frequency and size of the defect as well as on the intensity and uniformity of blast cleaning (i.e. level of residual compressive surface stresses), than on matrix structure or grade of ductile iron. The following ranges were determined for the bending fatigue limit with as-cast surfaces. (See Table 2.)

<table>
<thead>
<tr>
<th>Matrix Structure</th>
<th>Tensile Strength MPa</th>
<th>Fatigue Limit with As-cast Surface [MPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>not Blast Cleaned</td>
</tr>
<tr>
<td>predominantly ferritic</td>
<td>420-480</td>
<td>165-190</td>
</tr>
<tr>
<td>predominantly pearlitic</td>
<td>620-800</td>
<td>170-210</td>
</tr>
<tr>
<td>austempered</td>
<td>930-980</td>
<td>210-250</td>
</tr>
</tbody>
</table>

Table 2: Bending Fatigue Limit Ranges (50% failure probability)

R. Griffin of the University of Alabama presented results from a study on understanding ductile iron machinability. The effects of strength, hardness, matrix structure and minor alloy concentrations in both drilling and turning operations were investigated for varying amounts of Cu and Sn. The data suggests that at a given strength, tin would provide better machinability compare to copper, however, additional research is necessary to confirm these initial findings.

R. Voigt of Penn State University showed that the complex interaction between the matrix and the graphite in cast irons influences the deformation and fracture events taking place at a microstructural level ahead of and beneath the cutting tool during machining. The goal of ongoing research on machinability of ductile iron at PSU is to gain insight into lot-to-lot variations in machinability of production ductile irons and to identify production practices for insuring consistent high machinability. Machining video clips can be accessed and viewed at the following website: www.ie.psu.edu/mcg/default.htm.

D. Gamble of St. Gobain Advanced Ceramics presented work on the effects of inclusion particles on the microstructure of unalloyed austempered ductile irons. Within the colony of a eutectic cell, inclusions that were deficient in Mg were surrounded by a ferrite ring while Mg-enriched inclusions were surrounded by acicular ferrite. Manganese segregation in the
intercellular regions was determined to affect the ability to form acicular ferrite near inclusions with formation only occurring near Mg-deficient inclusions.

H. Roedter of Rio Tinto Iron & Titanium reviewed the development history of the ductile iron wind power industry in Europe, which has accelerated, beginning in the 1990’s. Ferritic ductile iron (EN-GJS-400-18 LT) is the grade of choice for such applications. It is expected that the North American market for wind energy power plants will follow the same trend as the European market during the 2000-2010 decade.

J. Fourmann of Pechiney discussed the benefits of using Lanthanum to minimize the appearance of micro shrinkage in ductile iron. When La additions are made, an equiaxed solidification behavior is favored. This results in a reduction in the thickness of the columnar solidification zone which leaves larger free flowing passages for the remaining molten iron to travel and, thus, feed those casting areas in need of liquid iron.

ADDITIONAL INFORMATION

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One of the highlights of the year for metal casters is the annual FEF College Industry Conference. This year FEF will combine with AFS and the Human Resource Division to offer two excellent programs back to back.

The HR conference will precede the FEF conference with both being held at the historic Drake Hotel in Chicago. The HR program will include nationally known speakers who will discuss issues of concern – the rising cost of healthcare, motivating and keeping top performers, compensation trends, military leave obligations, workplace implications of same-sex marriages and managing the Hispanic worker.

Human Resource executives can then choose to participate in the FEF conference where they will have an opportunity to meet over 100 of the best metal casting students in North America. In addition, industry leaders who were once FEF scholars themselves, will present outstanding educational speeches. All paid participants with the AFS HR meeting will be eligible for a 25% reduction in FEF conference registration fees. In addition, all companies registering for the first time for the Industry Information Session, with 1 or more registered people, will have the industry table fee of $400 waived for this year.

The Keynote address for the FEF CIC will be given by Tom Prucha, Vice President, Technical Services of Intermet Corporation. The panelists will be Glenn Byczynski of Nemak, Steve Renz of Howmet Castings, and Daniel Twarog of North American Die Casting Association. All are former FEF students with each representing a different stage in work experience and outlook for the future of the industry. Earl Brooks, II, President of Tri-State University in Angola, Indiana, will be the Awards Breakfast speaker.

The FEF Annual Banquet will be held in the Gold Coast Room at the Drake Hotel in Chicago. We will enjoy a buffet of Drake specialties followed by a presentation by internationally recognized speaker Dan Clark. Dan is a New York Times best selling author and primary contributing author for Chicken Soup for the Soul and Chicken Soup for the College Soul; along with twenty other books. He is also an entertainer, songwriter/recording artist, and in 1982 was named Outstanding Young Man of America with the National Speakers Association. The student delegates will join the banquet...
for dessert and both industry people and college students will enjoy Dan’s highly charged and inspirational presentation. Dan Clark has been listed as one of the top ten speakers in the world.

The FEF College Industry Conference brochure will be mailed out in August. You can also check it out and register on the FEF website after August 1, 2004.

For more information contact the FEF Office at 847/705-8400; (fax) 847/705-8448; email info@feoffice.org; web page http://www.fefoffice.org. Registrations can be taken now; Drake Hotel reservations can be made at 312/787-2200
Research Committee Report on Spectrograph Set Up Standards

During the past two years the DIS Research Subcommittee on Process Control has been running a comparative study on powered metal set up standards (SUS) produced by ARMI (Analytical Reference Materials International). These standards are not certified for true composition, but since they are made from generally homogeneous powders the entire sample can be used. They should be used for drift correction not curve generation. Typical chemistries are shown in the two tables below.

The DIS tested these two standards at 11 different foundry labs and found them to be statistically acceptable for use. We plan to check with DIS foundry members to see if there are other chemistries needed for set up. If you wish further information or if you want to obtain these standards contact ARMI at www.armi.com.

The standards have the following numbers and chemistries:

<table>
<thead>
<tr>
<th></th>
<th>215A</th>
<th>216A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>0.037</td>
<td>0.06</td>
</tr>
<tr>
<td>Boron</td>
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<td></td>
</tr>
<tr>
<td>Carbon</td>
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<td>Cobalt</td>
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<tr>
<td>Chromium</td>
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<td>1.5</td>
</tr>
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<td>Copper</td>
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<td>0.08</td>
</tr>
<tr>
<td>Manganese</td>
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<td>0.3</td>
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<td>Sulfur</td>
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<td>0.03</td>
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<td>0.004</td>
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<td>Magnesium</td>
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<td>0.08</td>
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<tr>
<td>Antimony</td>
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</tr>
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<td>0.01</td>
</tr>
<tr>
<td>Zirconium</td>
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<td>0.05</td>
</tr>
</tbody>
</table>
Influencing Factors on the High Purity Pig Iron - Steel Scrap Optimum Ratio in Ductile Iron Production

I. Riposan*, M. Chisamere*, S. Stan*, N.Adam**
*Politehnica University of Bucharest, Romania
**Robinete Indestirale, Bacau, Romania

1. Introduction

Ductile irons show complex chemical composition, and therefore rigorous controls are required for the group of elements (Table 1) that are generally present. The important thing to note is that the elements during solidification process segregate inside the eutectic cells (FS<1.0: Si, Ni, Cu) or outside the intercellular regions (FS>1.0: Mo, Ti, V, Cr, Mn, P) [1].

To obtain ferritic ductile irons, most important are the elements that cause pearlite stabilization, having FP – Pearlite Promoting Effectiveness Factor at high values. Such elements are Sn, Mo, P, Cu, Mn, Ni, Sb and As [2]. In all cases, Antinodulizing Factor (FAN) must also be considered, for ensuring high nodularity as required for ductile iron (>80% NG, <20% C/VG, without LG). A lot of elements such as Bi, Pb, Sb, Ti, Sn, As and Al [3] are considered harmful to achieve high nodularity.

Along with the graphite deterioration the occurrence of intercellular lamellar graphite, which is also promoted by such elements as Bi, Pb, Sb, As, Cd, Al and Sn. Thick wall castings present a typical graphite morphology (Chunky Graphite) localized in the thermal center favored by Si, Ni, Ce and Ca. Carbides have a frequent occurrence in the ductile iron structure, as eutectic carbides (high degree of undercooling), inverse chill (Cr, Mn, P, Mg, Ti, As and Ce) and intercellular carbides (Mn, Cr, Mo and V) [1]. It is evident that the production of ductile iron requires a rigorous control of over 30 elements interacting and thus requiring a strict control over the selection of the metallic and non-metallic materials used.

For many foundries, steel scrap is an important component of their charge make-up, as it is a lower cost material. However, it is also a major contributor for trace elements. High purity pig iron, despite its higher cost, is very attractive as it is the lowest contributor of trace elements and has the potential to improve the metallurgical quality of the iron melt, especially for graphite nucleation. Although the ductile iron returns are the other component of the charge makeup, it is the steel scrap to high purity pig iron ratio, which is more important in order to minimize the melt cost and maximize the quality of castings. [4,5]

Laboratory experiments and plant trials were conducted to optimize the High Purity Pig Iron (HPPI) and the steel scrap additions for the various pearlitic/ferritic grades under different melting practices.

In laboratory experiments, the effect of SC/HPPI ratio on the solidification parameters was tested. In plant trials, as cast and heat treated ferritic ductile irons were obtained, by melting in the 50 Hz-Coreless Induction Furnace (CIF). High manganese gray iron, ductile iron returns and steel scrap were the starting materials and high purity pig iron was added to adjust the chemical and metallurgical behavior of the base iron melt. The possibility to use commercial steel scrap in Medium Frequency-Coreless Induction Furnace was also considered for different SC/HPPI/DIR ratios and metal matrix make-ups.

Finally, some representative graphs were recorded for various DI Returns/Premium Quality Steel Scrap/High Purity Pig Iron ratios for the representative ferritic and pearlitic ductile iron grades.
2. Influence of SC/HPPI Ratio on the Solidification Parameters

In the laboratory experiments, the influence of the SC/HPPI ratio on the solidification behavior was pointed out for the same final chemical composition of ductile irons. Two representative heats are presented in Table 2: for the same ductile iron returns rate of (40%) in, which the SC/HPPI ratio was changed from, 2:1 to 1:2. The final chemical composition of the two heats is very close (CE = 4.51 and 4.54%) as a result of alloying materials added into graphite crucible induction furnace (10 kg, 8000 Hz).

Tundish - Cover Mg – treatment was applied. According to the metallic charge make-up and SC/HPPI ratio, respectively:

- 2.2% FeSiCaMg 6 for SC: HPPI = 2:1 (L₁ heat)
- 2.0% FeSiCaMg 6 for SC: HPPI = 1:2 (L₂ heat)

Ladle inoculation was used as 0.35% FeSi75 addition.

The specific samples were cast in dry sand molds, under identical conditions of temperature and holding time:

- 25 mm Y- Block, for microstructure and mechanical properties evaluation;
- Wedge Test (W₄) and Chill Test (4C) (metallic plate, ASTM A 367-94);
- Quick-cup, Electronite type – Cooling Curve Analysis;
- Cone Sample (f’80 x 65 mm, V=110 cm³), for Shrinkage evaluation.

Metallographic analysis pointed out the same characteristics in the both variants as 80-90% Graphite Nodularity and metal matrix (Ferrite: Pearlite 1:1) despite the lower Mg – treatment alloy consumption in the second heat (SC/HPPI = 1:2).

Figure 1 illustrates the solidification parameters and mechanical properties of the ductile irons with the similar final chemical composition. According to SC/HPPI ratio decreasing:

- No different mechanical properties resulted
- Beneficial influence on the solidification was recorded:
  - lower eutectic undercooling degree;
  - chilling tendency (clear chill) markedly lower:
    - *Wedge Test: 11 to 2 mm
    - *Chill Test: 25 to 12 mm
  - shrinkage level visibly lower.

3. Gray and Ductile Iron Productions with High Mn Metallic Charge

3.1. Molten Cupola Iron "Heel" in 50 Hz – CIF Operation

A cast iron foundry operates both an acid cupola (1100 mm inner diameter) and an acid lined coreless induction furnace - CIF (6.3 t, 50 Hz) exclusively as a duplex system. Ductile iron is melted in induction furnace either with gray iron (200-300 grades) from the cupola or with proper charge melting in the induction furnace.
Frequently when it is necessary to change from gray to ductile iron production, the iron received from cupola is at high sulfur content (>0.15%), manganese (0.6-1.0%), phosphorus (>0.08%) and trace elements. On other times commercial steel scrap is usually used with excessive Mn content. In order to obtain ferritic ductile iron grades high purity pig iron (HPPI) is used to adjust the base iron for chemical and metallurgical control.

Low frequency coreless induction furnace (6.3 t) was used to produce as-cast 400-15 and 400-12 ferritic ductile iron grades and short annealed 400-18 grade from the base of 9-10% cupolas molten iron "heel" (0.18% S, 0.66% Mn), 26-51% DI Returns (0.33% Mn) and 18-28% Steel Scrap (0.3 and 1.15% Mn), by addition of 37-44% HPPI (0.002% Mn, 0.005% S) (Table 3-5, A….E heats) [4].

High purity pig iron (HPPI) had a high contribution in carbon (1.45-1.75%) but very low in silicon (0.06-0.07%), phosphorus (0.0007-0.0009%), sulfur (0.0019-0.0022%) and trace elements (<0.015% Cu, Cr and 0.03-0.04% Ni), without significant changes in manganese. In these conditions the manganese content in the charge is mainly due to the cupola iron "heel" (0.06-0.07% Mn), the contribution of ductile iron returns (0.08-0.16% Mn) and the steel scrap (0.08-0.2% Mn) but it was kept less than 0.3% by HPPI contribution.

Average level of silicon in the included charge was usually in the 0.9-1.0% Si range, even with the highest rate of returns (51%). Molten cupola iron "heel" gave the highest sulfur (0.016-0.018%), despite it being no more than 10% in the charge.

Sandwich technique was used for Mg – treatment (1.9-2.0% FeSiCaCeMg) and ladle inoculation with Ba containing FeSi. General characteristics of the microstructure were as follows: more than 90% Nodular Graphite, more than 120 Nodules/mm², less then 60m m nodule diameter, less than 2% carbides. High Ultimate Tensile Strength (UTS) and Elongation (A) were obtained, with 0.30% Mn (D and E heats). In the last case, more than 550 N/mm² Ultimate Tensile Strength was obtained at UTS/BH = 3.0 ratio with no more than 40% pearlite in the structure and very good nodular graphite phase. Brinell Hardness (BH) level was according to metal matrix make-up.

3.2. 50 Hz – CIF Operation without "Heel"

In order to obtain high elongation ductile irons (400-15 and especially 400-18) in the above foundry (after gray iron processing in the induction furnace) the other alternative was also tried: 100% solid charge (without "heel"), DI returns at relatively high Mn content (0.33% Mn), steel scrap (0.28% Mn) and HPPI (0.002% Mn).

Tables 4-5 (F, G-heats) show the test results. In the as-cast state, predominantly ferritic structure was obtained, at more than 90% Nodular Graphite, more than 100 Nodules/mm² (mainly less than 60m m size). 400-15 DI Grade resulted in an as-cast state, while a short annealing cycle led to 400-18 DI Grade. The absence of the "heel" in the 50 Hz-CIF led to difficulties in the start of the charge melting, so the first tested variant, (gray iron melt "heel") appears to be more efficient to start ductile iron production.

4. Commercial Steel Scrap – High Purity Pig Iron Ratio in MF- CIF

As was mentioned before, the ductile iron production needs to be closely monitored to prevent segregation within intercellular regions (especially lamellar graphite promoters), and factors that promote antinodulizing, chunky-graphite, pearlite and/or carbides.

New generation medium frequency Coreless Induction Furnaces - MF- CIF (200-800 Hz) are more often used in foundries for ductile iron production especially, without the necessity to use liquid "heel" for the next melting operation (only solid charge). In this melting shop, the metallic charge in the ductile iron production should be considered as made up of two major parts:

- Ductile iron returns (DIR) at maximum utilization;
Steel scrap (SC) and High Purity Pig Iron (HPPI) in properties determined by the ductile iron type (ferritic, ferritic/pearlitic or pearlitic), iron grade, casting characteristics, heat treatment restrictions, graphite condition, etc.

Mn, Cr and Cu are among the most important elements in ductile iron production that control pearlite and carbide formation and stability. In this respect premium quality steel scrap is usually used especially in ferritic ductile iron grades. At continuous increasing price it is usually represented by high quality stamped sheet steel. Much cheaper and more accessible is the plain carbon steel scrap, but generally not favored by the high content of Mn (0.4-0.8%), P (0.03-0.05%) and trace elements (Cr, Cu, Mo, etc).

Taking into account the high dilution of the unfavorable elements in the iron melt and to increase its metallurgical activity (especially as graphitizing potential), HPPI can be an important factor in determining the use of commercial steel scrap.

Figure 2 shows the representative level of Mn, Cu and Cr for the metallic charge including 30-55% Ductile Iron Returns of different types (from ferritic, ferritic-pearlitic and pearlitic DI grades production), 20-70% Commercial Steel Scrap and 15-70% High Purity Pig Iron. Depending on the availability and the type of the returns (DIR), the amount of HPPI necessary in the metallic charge will vary: the lower DIR rate and/or more ferrite, the higher HPPI needed.

5. Representative High Purity Pig Iron Ranges for Premium Quality Steel Scrap Use

Controlled laboratory and foundry experiments and technical literature review pointed out the multiple beneficial effects of high purity pig iron on the quality of ductile iron castings:

- Mn, P, S and trace element levels are limited in the base iron;
- C, Si and P content stabilization, especially in mass production;
- Metallurgical quality of the iron melt is improved, giving:
  - lower carbides tendency;
  - higher eutectic cell count and lower intercellular segregation intensity;
  - higher ferrite amount;
- Stabilization of the mechanical properties;
- Lower incidence of the shrinkage defects;

The beneficial action of HPPI in ductile iron contributes not only the virgin material in the charge but also as that is contained in the return scrap. On the base of previous obtained data in this field [1] and general evaluation of the specific conditions for ferritic and pearlitic/ferritic ductile iron, the graph shown in Figure 3 was recorded. Elongation was used as a representative to express the microstructure formation, from chemistry, graphite nucleation and growth and metal matrix conditions.

Lower ductile iron returns require, higher high purity pig iron additions especially for ferritic grades and superior level of elongation (ductility). For the lower quality steel scrap, more addition of HPPI is necessary, especially to obtain ferritic grades. If high purity pig iron is typically used in ferritic ductile iron production, low amount of this special material is also required in pearlitic grades. In both cases, various other influencing factors interact, so representative ranges could be considered for different ductile iron returns and ductile iron grades (Fig. 4).

6. Conclusions

The quality of ductile iron castings is highly process-sensitive and is influenced by the chemical
composition. Over 30 elements determine the quality of this iron, which is affected by segregation factors, pearlite promotion elements, antinodulizing action, chunky-graphite, intercellular flake graphite and carbide presence. On the other hand, physical characteristics of the iron melt; especially graphite nucleation is based on the heredity phenomena and the charge materials, respectively.

In laboratory experiments, it was found that for the same ductile iron return addition rate (DIR = 40%) and the same final chemical composition (CE = 4.5%), the ratio of the Steel Scrap (SC) / High Purity Pig Iron (HPPI) from 2:1 to 1:2 leads to the decreasing of eutectic undercooling, chill and shrinkage with a 10% lower Mg consumption and with no effect on structure or mechanical properties.

In a foundry practice, successive gray and ductile iron production is recorded, in a 50 Hz – Coreless Induction Furnace. A cupola iron "heel" and higher Mn – content charge materials (Steel Scrap, Returns) are modified by a HPPI addition to adjust chemistry and metallurgical quality of the base iron, especially in ferritic ductile iron production.

For the Medium Frequency – Coreless Induction Furnaces operation different commercial steel scrap / high purity pig iron/returns ratios are considered as Mn, Cr, Cu in the charge has an influence to obtain ferritic, ferritic- pearlitic and pearlitic ductile irons; the lower DIR rate and/or more ferrite, the higher HPPI share.

Representative HPPI ranges together with premium quality steel scrap and specific DIR usage were identified for different elongation level and ISO Ductile Iron Grades.

It was illustrated that the main influencing factors on the HPPI in the common metallic charge are as follows:

- Metal Matrix: 15-40% HPPI for Ferritic vs. 5-20% for Pearlitic / Ferritic.
- DI Returns (DIR): lower DIR, higher HPPI necessary
- Elongation (A): higher A, higher HPPI addition
- Steel Scrap (SC): lower SC quality, higher HPPI amount.

REFERENCES

1. DI Techniques. SORELMETAL – Suggestions for Ductile Iron Production. Published by RIO TINTO IRON & TITANIUM Inc., Canada

Table 1 The Specific Group of Elements in Ductile Iron
### Table 2 Chemical Composition of Experimental Irons

<table>
<thead>
<tr>
<th>Heat</th>
<th>Charge</th>
<th>Final Chemical Composition, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C</td>
</tr>
<tr>
<td>L1</td>
<td>40 % DIR, 40 % SC, 20 % HPPI</td>
<td>3.76</td>
</tr>
<tr>
<td>L2</td>
<td>40 % DIR, 20 % SC, 40 % HPPI</td>
<td>3.73</td>
</tr>
</tbody>
</table>

### Table 3 Chemistry of the Metallic Charge Materials

<table>
<thead>
<tr>
<th>No.</th>
<th>Metallic Material</th>
<th>Chemical Composition, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C</td>
</tr>
<tr>
<td>1</td>
<td>Cupola Iron</td>
<td>3.19</td>
</tr>
<tr>
<td>2</td>
<td>DIR</td>
<td>3.58</td>
</tr>
<tr>
<td>3</td>
<td>SC - I</td>
<td>0.26</td>
</tr>
<tr>
<td>3</td>
<td>SC - II</td>
<td>0.24</td>
</tr>
<tr>
<td>4</td>
<td>HPPI</td>
<td>3.98</td>
</tr>
</tbody>
</table>

### Table 4 Metallic Charge and Final Chemical Composition (6.3t CIF, 50 Hz)
A...E: Liquid Cupola Iron Heel; F, G: Without Heel (solid charge)

Table 5 Mechanical Properties of Ductile Iron Casting

<table>
<thead>
<tr>
<th>Heat</th>
<th>UTS [N/mm²]</th>
<th>YS [N/mm²]</th>
<th>A [%]</th>
<th>BH</th>
<th>UTS / BH</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>454</td>
<td>310</td>
<td>17.3</td>
<td>177</td>
<td>2.56</td>
</tr>
<tr>
<td>B</td>
<td>461</td>
<td>286</td>
<td>17.6</td>
<td>172</td>
<td>2.88</td>
</tr>
<tr>
<td>C</td>
<td>517</td>
<td>347</td>
<td>15.6</td>
<td>190</td>
<td>2.72</td>
</tr>
<tr>
<td>D</td>
<td>562</td>
<td>350</td>
<td>12.8</td>
<td>184</td>
<td>3.05</td>
</tr>
<tr>
<td>E</td>
<td>462</td>
<td>276</td>
<td>19.2</td>
<td>172</td>
<td>2.89</td>
</tr>
<tr>
<td>F</td>
<td>473</td>
<td>331</td>
<td>16.8</td>
<td>179</td>
<td>2.64</td>
</tr>
<tr>
<td>G</td>
<td>469</td>
<td>324</td>
<td>17.8</td>
<td>177</td>
<td>2.65</td>
</tr>
</tbody>
</table>

*ISO 1083 and ASTM A536

Fig.1 Influence of SC/HPPI ratio on the solidification parameters and mechanical properties

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Fig. 2 Maximum Mn, Cr and Cu in the charge, at different DI Returns – Commercial Steel Scrap – High Purity Pig Iron ratios
(a) Ferritic Ductile Iron Returns; b) F/P Ductile Iron Returns; c) Pearlitic Ductile Iron Returns
Fig. 3 High Purity Pig Iron (HPPI) – Ductile Iron Returns (DIR) relationship for different elongation level in Ferritic and Pearlitic/Ferritic Ductile Irons

Fig. 4 Representative ranges of High Purity Pig Iron (HPPI) for different Ductile Iron Grades and Ductile Iron Returns (DIR) in the charge
Fig. 5
Producing Quality Ductile at Reduced Cost

Annual General Meeting of Ductile Iron Society, Montreal, Canada
June 24, 2004

P.E. Dhole, Maxil Marketing, Pune, India

Good afternoon and welcome! I am P.E. Dhole from Maxil Marketing, Pune, India. Today we are going to see how to produce quality Ductile Iron at reduced cost. The idea of cost reduction in my paper, is a conclusion drawn after 30 years of practical observations and constant experimentation done on Optimization of MgFeSi Alloy. This year, most of the time, the process of Optimization of an alloy has been carried out with Self-manufactured MgFeSi Alloy by our highly professional team. As a result, Optimization process became rapid and easier.

Achieving High Quality

As we know, MgFeSi alloy is most commonly used spheroidizer for making Ductile Iron. It is a fact that Magnesium present in an Alloy is required only for Spheroidization. Excess retained Magnesium is always Undesirable. It is Undesirable because:

- It reacts with most of the foundry materials, resulting into various casting defects, such as blow holes, pinholes, inclusions, etc.
- It creates Dross.
- It forms Carbides
- It hampers Inoculation.
- It adds to Pollution.

Hence Optimization of an alloy is essential by which level of Undesirable Magnesium is minimized to produce better quality Ductile Iron.

Reducing Cost

Optimization of an alloy not only produces better quality Ductile Iron but also reduces the cost effectively. Through Optimization treatment cost can be cut down to even up to 50% or maybe more! Optimization of an alloy helps Inoculant to act more effectively and thus reduces the cost of Inoculation. Optimization of an alloy also reduces dross and minimizes waste disposal problems. Optimization of an alloy ensures better life of Treatment Ladle resulting in reduction of ladle lining and associated costs. Due to reduced inventory of an alloy more storage space can be made available resulting in better inventory management. Optimization of an alloy also reduces pollution levels and ensures the Cleaner and Greener environment to the society. Different foundries worldwide produce Ductile Iron by using any one of the many formulations of MgFeSi alloy available. They are constantly trying to Optimize an Alloy to achieve better quality Ductile Iron at reduced treatment cost. The following graph shows reduction in an addition of an alloy which is an Optimization process and subsequent approximate
reduction in treatment cost achieve in last 30 years.

Approximate cost per tone of MgFeSi Alloy in 1974 was $1000 and that now is $1250.

We have seen that optimization process of an alloy is one of the basic ideas to produce quality Ductile Iron at reduced cost.

Foundry has to continue with the process of **Optimization** of an alloy till the **Lowest Retained Magnesium** level in Ductile Iron is achieved.

**Lowest Retained Magnesium** - Level which is just enough for an acceptable Ductile Iron casting. No matter what grade of MgFeSi alloy they use to achieve this goal.

*Is further optimization and drastic reduction in treatment cost possible?*
Approximate cost per tone new formulation of self-manufactured alloy is between $1650 and $1750.

YES! It is possible for the foundries to gear up or to accelerate the process of Optimization of an alloy and to Reduce the Treatment Cost drastically if they learn how to produce MgFeSi Alloy.

They can try any permutation and combination of MgFeSi alloy themselves to produce better Ductile Iron and can make use of this art as a tool for research and development of their products. After learning this technique, the foundry has always an option whether to manufacture MgFeSi Alloy in house.

- The process of manufacturing MgFeSi Alloy is safe and easy.
- It does not practically require any capital investment.
- Foundry should have specific Induction Furnace.

**Our Latest Findings**

Latest experiments on **Optimization** of an alloy with a new formulation of self-manufactured MgFeSi Alloy were carried out under following conditions:

- Treatment quantity - 500 kilos
- Total metal treated - 50 tones
- BathS % - 0.015 to 0.018
- Tapping Temp - 1520°C - 1530°C
- MgFeSi Alloy Addition - 0.4%
- Pouring time - < 7 minutes

Quality of Ductile Iron produced was better in all aspects than that produced with normal alloy. **Treatment cost $7 per tone.**

**Thanks to the Ductile Iron Society for giving me an opportunity to present this paper.**

P.E. Dhole  
Maxil Marketing  
10 A Yashodeep  
Rambaug Colony, Sadashiv Peth  
Pune 411 030, India.  
Tel: +91 20 2432 9617  
Telefax: +91 20 2432 9618
Ductile Treatment with Wire

Mike Doskocil
Casting Service
LaPorte, Ill

Plant Overview

- Gray Iron/Ductile Iron
- Machining Capability
- Casting weights from 50 lbs. to 200,000 lbs.
- Daily pour capacity up to 420,000 lbs.
- Melt Dept. includes 5 VCF’s
- Two (2) Wire Treatment Stations
- 125 T Overhead Crane Capacity

Melt Deck

Plant Overview Cont’d

- Full Metallurgical Lab
- Magma Simulation
- Charpy Impact Testing
- Air Set Molding: Largest flask size is 144” x 264”.
- Pit molding available
- Multiple Cores and Capabilities
- Markets Served include:
  - Wind Energy
  - Locomotive Frames
  - Forging Dies
  - Pumps

Products
Wire Treatment

- Two Treatment Stations
- Nodulizing with 9mm wire, varying between one or two wires.
- Treatment capacity between 6,000 and 65,000 lbs. per treatment.
- Two stations offer flexibility.
- Wire contains elemental Mg
- Recovery is typically 40% at 0.015% base iron sulfur.
- Better recovery in small ladles.
- Have successfully treated 0.025% sulfur iron.
- Can treat less than ladle capacity.
- Generally treat 6000 lbs. minimum.
- Have use wire for 7 years.

Treatment Room

Wire Coils

Control Panel
Inoculation

- Wire inoculation is performed in same containment room as nodulizing.
- 13mm wire used for inoculation.
- In Mold Inoculation also performed.

Reasons for Using Wire

- Previously treated in an open/sandwich ladle.
- Wire offered a more consistent treatment.
- Wire offered a more environmentally acceptable treatment.

Information

- Mike Doskocil, Casting Service, LaPort, Ill 219-362-1000 x 217
- mdoskocil@castingservice.com
The following is a list of equipment that our FEF Accredited Schools are in need of. If you can help, please contact the Key Professor directly. Click here for suggested policies for donating equipment.

Click here to go to the web page with professor phone numbers and emails.

**Schools’ Equipment Needs List – 3/04**

1. Cal Poly Pomona—non-destructive testing-any type/rapid prototyping/small investment casting press/sand testing-moisture, compactability scale/snap flasks & jackets (12”x12”, 12”x18”)

2. Cal State Chico—induction furnace/investment casting equipment

3. Central Washington—50 lb/min. Resin-bond Continuous mixer (Carver – Maxi-Mul. MM-50 SA)/Small 10-20# crucible – Swing type Induction Pedestal only/Heat treat-temper ovens, gas or electric

4. Kent State—investment casting/sand testing

5. Kettering—2nd jolt squeeze machine

6. Missouri Rolla—new induction furnace/sand testing equip/better investment capability

7. Mississippi State—rapid prototyping/small induction furnace/green strength & permeability testers/small jolt-squeeze molding machine/green strength and permeability determinators, plus a set of screens with a shaker

8. Mohawk College—x-ray spectrometer

9. Ohio State—high speed resin-bonded mold mixer and blower system

10. Penn State—small vibratory tumbler for finishing castings/1000 lb copper base alloy ingots/metallographic, image analysis system

11. Purdue Indianapolis—AFS Solids or Magmasoft/slightly larger furnaces

12. Tennessee Tech—complete sand lab and metal lab

13. Texas State—image scanning/macroscopic inspection/more appropriate shell mold system

14. Western Michigan—100-150 KW induction furnace/nondestructive testing/Magma Flux

15. Windsor—automated hardness tester
16. Wisconsin Milwaukee—ultrasonic equip to characterize castings

17. Wisconsin Platteville—sand blowing system to move new sand to hopper/jolt squeeze machine/mold rollers/image analysis/spectrometer/flasks/ Al XXL pouring jackets
Montreal Meeting Photos

Click on picture to see enlarged view

Speakers

David Knapp
Lenny Basaj
P.E. Dhole
Manfred Jonuleit
Iulian Riposan
Chantal LaBrecque
Vasko Popovski
Christof Heisser
Al Alagarsamy
Efren Huerta
Gene Muratore
Retiring Directors

Gene Muratore
Mike Hotchkiss
Laura Strohmayer
Lenny Basaj

Banquet

 Speakers

Banquet
Jim Wood

Tim Eilers

Pete Guidi and Bob K.

Located in Strongsville, Ohio, USA
15400 Pearl Road, Suite 234; Strongsville, Ohio 44136
Billing Address: 2802 Fisher Road, Columbus, Ohio 43204
Phone (440) 665-3686; Fax (440) 878-0070
email:jwood@ductile.org
AFS to Host 2004 International Lost Foam Casting Conference & Tabletop Exhibit

FOR IMMEDIATE RELEASE
Contact: Joe Santner, AFS; jss@afsinc.org
July 8, 2004 800/537-2437


Themed “Lost Foam Casting: That Was Then, This Is Now,” the conference will feature presentations on the steps that have been taken over the last five years to enhance the viability of the lost foam casting process. The conference also will present how the value-added lost foam casting process can add to your business and help you against “price-only” buying trends. Topics will include:

- current state-of-the-art technology implemented as a result of the U.S. Dept. of Energy Industrial Technology Program-AFS Lost Foam Casting Div. consortium programs;
- how the added value of lost foam casting can enhance your metalcasting facility’s capabilities;
- how lost foam cast products can benefit your customers, who are now utilizing other metalcasting processes for their components.

All attendees of the conference are eligible to participate (subject to space limitations) in tours of the lost foam casting area of the General Motors Powertrain, Defiance, Ohio, plant.

For more information on the AFS 2004 International Lost Foam Casting Conference and Tabletop Exhibit, contact Joe Santner, AFS, at jss@afsinc.org or 800/537-4237.

Headquartered in Des Plaines, Ill., 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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FOR IMMEDIATE RELEASE  
Contact: Kristy Glass; kglass@afsinc.org  
July 6, 2004 800/537-4237 x 224

Rosemont, Ill…More than 1,450 metalcasters gathered June 12-15 in Rosemont, Ill., for the 108th Metalcasting Congress co-sponsored by the American Foundry Society Inc. (AFS) and the North American Die Casting Association (NADCA). The show featured 153 exhibits and more than 50 technical and management sessions covering the latest advances in the industry.

The AFS Marketing Div. and Engineered Casting Solutions displayed the 11 honorees from the fourth annual casting competition. This year’s Casting of the Year award went to Alcoa Automotive Castings’ hollow rear lower control arm for BMW.

George M. Goodrich, Professional Metallurgical Services, delivered the Charles Edgar Hoyt Memorial Lecture. His presentation, “The Absence of Perfection,” detailed the necessity of the metalcasting industry to take advantage of new capabilities and push more forcibly into world markets, thus calling for a successful unification of engineers, managers and scientists to accomplish this task.

During the AFS Annual Banquet, Rodney L. Naro, ASI International Ltd., and J. Michael Williams, General Motors Powertrain (retired), received the industry’s highest honors in the Joseph S. Seaman Gold Medal and the William H. McFadden Gold Medal.

The Congress concluded with the President’s Luncheon and Annual Business Meeting. Oleg S. Fishman, Inductotherm Corp.; Daniel Groteke, Q.C. Designs Inc.; and Kathy L. Hayrynen, Applied Process Inc., received AFS Awards of Scientific Merit. Further, the AFS Service Citations were awarded to D.J. Couture, General Motors Powertrain; Sara Joyce, Badger Mining Corp.; Charles A. Ruud, Carondelet Foundry Co. (MetalTek International); and Daniel J. Torzewski, Indianapolis Casting Corp. David C. Williams, Allied Mineral Products Inc., received the CMI Directors’ Award.

For more information, contact Kristy Glass, AFS, at kglass@afsinc.org or 800/537-4237 x224.

Headquartered in Des Plaines, Ill., 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.
At the 108th Metalcasting Congress, Rodney L. Naro (l) received the Joseph S. Seaman Gold Medal and J. Michael Williams received the William H. McFadden Gold Medal.

American Foundry Society
505 State St.
Des Plaines, Ill. 60016
www.afsinc.org

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Optimizing the Mechanical Properties of Thin Wall Ductile Iron Castings by Controlling the Cooling Rate

by: C. Labrecque *, M. Gagné * and A. Javaid **
* Rio Tinto Iron & Titanium Inc., Montreal
** CANMET, Ottawa

1. INTRODUCTION
The request for improved fuel consumption has driven the automotive industry to re-evaluate all mechanical components with the objective of weight reduction. A competitive analysis of various structural materials, based primarily on weight, was carried out and, as a result, many Ductile Iron components have been challenged by aluminum alloys, powder metal steels or others. However, if the yield stress/cost ratio of the various materials is considered as-cast Ductile Iron is most of the time the winner!

The use of Ductile Iron for light weight automotive components has been limited in the past by the capability of the foundries to produce as-cast, carbide free, thin wall (3 mm and less) parts. For almost a decade, the Ductile Iron industry has invested significant amounts of money and time in the development of a technology that would allow the manufacture of such castings. Rio Tinto and CANMET joined their effort to investigate the problems related to the fabrication of thin wall Ductile Iron castings. The most recent results obtained in this study were presented at the DIS T&O meeting in Montreal and are summarized in this article.

2. TEST MATRIX
The details of the experimental procedures (melting, Mg treatment, pouring, pattern plate...) were presented in a previous Ductile Iron News article and can also be found in references 1 and 2. From previous work(1, 2), it has been concluded that 2 - 3 mm thick Ductile Iron castings can be produced carbide free but the mechanical properties are mostly controlled by the nodule count which has to be maintained in the order of 500 – 700 N/mm². This is obtained by controlling the heat extraction at the mould/metal interface (cooling rate of the casting) and the inoculation process. As shown in Table 1, the heat exchange (and cooling rate) was modified by admixing Low Density Alumina Silicate Ceramic (LDASC) (0 to 100 %) (~ 2 – 5 cm thick) to the silica sand in contact with the liquid metal. Description of LDASC can be found elsewhere (3). Three late inoculation levels were investigated : 0.1, 0.2 and 0.5% Bi bearing ferrosilicon commercial inoculant; note that the metal was also inoculated with 0.75% inoculating grade FeSi75 during the transfer to the pouring ladle. In addition to these two variables, the effect of silicon content (i.e. 2.6% vs 2.3% prior to in-stream inoculation) was included as a process variable.

TABLE 1 Test Matrix

TABLE 1A
TABLE 1B

<table>
<thead>
<tr>
<th>Mould #</th>
<th>Melt B 3.61% C, 0.029 % Mg</th>
<th>Sand</th>
<th>Inoc.</th>
<th>% Si</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100% Silica</td>
<td>0.2%</td>
<td></td>
<td>2.63</td>
</tr>
<tr>
<td>2</td>
<td>80/20 Blend</td>
<td>0.2%</td>
<td></td>
<td>2.63</td>
</tr>
<tr>
<td>3</td>
<td>60/40 Blend</td>
<td>0.2%</td>
<td></td>
<td>2.63</td>
</tr>
<tr>
<td>4</td>
<td>40/60 Blend</td>
<td>0.2%</td>
<td></td>
<td>2.63</td>
</tr>
<tr>
<td>5</td>
<td>20/80 Blend</td>
<td>0.2%</td>
<td></td>
<td>2.63</td>
</tr>
<tr>
<td>6</td>
<td>100% LDASC</td>
<td>0.2%</td>
<td></td>
<td>2.63</td>
</tr>
</tbody>
</table>

3. SELECTION OF INOCULATION PRACTICE

In previous work (1, 2), the liquid iron was strongly late-inoculated in order to ensure high nodule count and avoidance of as-cast carbides. However, as previously indicated, the resulting high nodule count (>1000 Nod/mm²) significantly impaired the mechanical properties of the parts. Reducing the level of late inoculation to reach the appropriate nodule count range (500 – 700 Nod/mm²) reduces but does not prevent the formation of carbides. However, when using LDASC, this level could be reached without formation of carbides. In order to determine the level of inoculation required, three levels of late inoculation (0.1, 0.2 and 0.5% Bi bearing FeSi) were tested for parts produced in moulds faced with a mixture 50% silica – 50% LDASC.

As shown in Figure 1, the use of LDASC allows to reduce the amount of inoculant in order to obtain the appropriate nodule count while avoiding the formation of as-cast carbides. Based on these results, a 0.2% late inoculation was selected as the base case for this study.
Figure 1. Effect of Late Inoculation on the 3 mm Plates Cast in 50 % Silica / 50 % LDASC Moulds

4. EFFECT OF LDASC

The effect of the addition of LDASC on the cooling rate of 3, 6 and 10mm plates is presented in Table 2. As LDASC content increases, the time to reach 900°C in the plate increases.

**TABLE 2**

Effect of LDASC on Cooling of Test Castings

<table>
<thead>
<tr>
<th>Moulding Material</th>
<th>Plate Thickness</th>
<th>Time to Reach 900°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Silica % LDASC</td>
<td>mm</td>
</tr>
<tr>
<td>100 0</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>0 100</td>
<td>6</td>
<td>70</td>
</tr>
<tr>
<td>100 0</td>
<td>10</td>
<td>150</td>
</tr>
<tr>
<td>100 0</td>
<td>3</td>
<td>250-400*</td>
</tr>
<tr>
<td>0 100</td>
<td>3</td>
<td>&gt;400</td>
</tr>
<tr>
<td>100 0</td>
<td>10</td>
<td>&gt;400</td>
</tr>
<tr>
<td>80 20</td>
<td>3</td>
<td>70</td>
</tr>
<tr>
<td>40 60</td>
<td>3</td>
<td>140</td>
</tr>
<tr>
<td>0 100</td>
<td>3</td>
<td>250-400*</td>
</tr>
</tbody>
</table>

* Range measured for different tests

As expected the decrease in cooling rate has a significant effect on the microstructure of the castings, i.e. on the nodule count and matrix composition. As shown in Figure 2, increasing the fraction of LDASC in the moulding sand decreases the nodule count and under the conditions used in this study, it appears that about 50% LDASC in the moulding sand gives the desired range of nodule count.

While a high nodule count is usually synonymous of a more ferritic matrix in Ductile Iron castings, this is not observed in thin wall castings. In spite of a very high nodule count, a mostly pearlitic matrix is obtained, as seen in Figure 3, for 100 % silica sand moulds. In such a case, the cooling rate between the end of solidification and 700°C is too high to allow the diffusion of carbon atoms to the graphite nodules. As seen in Figure 3, using LDASC also allows to control the matrix structure; with 100% LDASC, a fully ferritic matrix is achievable in 3 mm thick Ductile Iron plates.
Figure 2. Nodule Count Distribution along the Vertical Central Axis of 3mm Thick Plates as a Function of the LDASC Content (0.2% late inoculation)

Figure 3. Typical Microstructure in 3mm Thick Plates as a Function of the LDASC Content (0.2% late inoculation)

The effect of the amount of LDASC in the moulding sand on the tensile properties is listed in Table 3. All specimens were taken at about 2/3 of the extremity of the plates.

**TABLE 3**

Effect of % LDASC on the Tensile Properties of 3mm Plates (2.67% Si before 0.2% late inoculation)

<table>
<thead>
<tr>
<th>% LDASC</th>
<th>Tensile Strength MPa (ksi)</th>
<th>Yield Strength MPa (ksi)</th>
<th>Elongation %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>660 (94.3)</td>
<td>440 (62.8)</td>
<td>4</td>
</tr>
<tr>
<td>20</td>
<td>590 (84.3)</td>
<td>400 (57.1)</td>
<td>14</td>
</tr>
<tr>
<td>40</td>
<td>505 (72.1)</td>
<td>335 (47.9)</td>
<td>17</td>
</tr>
<tr>
<td>60</td>
<td>495 (70.7)</td>
<td>325 (46.4)</td>
<td>19</td>
</tr>
<tr>
<td>80</td>
<td>450 (64.3)</td>
<td>300 (42.9)</td>
<td>20</td>
</tr>
<tr>
<td>100</td>
<td>445 (63.6)</td>
<td>295 (42.1)</td>
<td>20</td>
</tr>
</tbody>
</table>

The measured tensile properties are in line with the observed microstructure. Under the test conditions used, a mixture of 60% silica sand / 40% LDASC results in 3 mm thick Ductile Iron castings meeting the ASTM 60-40-18 specification. Because in thin wall Ductile Iron castings the mechanical properties are very strongly influenced by the nodule count, the primary role of LDASC is to control it within the targeted range. Therefore, the matrix should be controlled via alloying, either by reducing the silicon content or adding copper, for example.

5. EFFECT OF SILICON CONTENT

Typically, thin wall Ductile Iron castings are produced with relatively high silicon content (2.8 % Si). However, because of the reduced and controlled cooling rate achievable with LDASC, the production of parts with lower silicon content may be considered.
specially for parts not requiring a fully ferritic matrix. Therefore tests comparing two base silicon contents (high and low) and inoculated at different levels were carried out. Table 4 shows the composition. Note that the final % Si varies due to the different inoculation practices.

**TABLE 4**  
**Silicon Content of Test Castings**  
*(50 % LDASC Moulds)*

<table>
<thead>
<tr>
<th>Base Iron</th>
<th>Late Inoculation</th>
<th>0.1% Inoc.</th>
<th>0.2% Inco.</th>
<th>0.5% Inco.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low % Si</td>
<td>2.29% Si</td>
<td>2.34% Si</td>
<td>2.56% Si</td>
<td></td>
</tr>
<tr>
<td>High % Si</td>
<td>2.61% Si</td>
<td>2.63% Si</td>
<td>2.83% Si</td>
<td></td>
</tr>
</tbody>
</table>

As seen in Figure 4, for a given inoculation process, a higher silicon content results in a higher nodule count. However, the nodule count achieved in the low silicon content is sufficient to avoid the formation of carbides at the center of 3 mm plates when cast in moulds containing 50 % LDASC. As expected, a larger pearlite content was found in the low silicon parts.

**Figure 4. Effect of Base Silicon Content and Late Inoculation Process on the Microstructure of 3 mm Plates (center position)**

Table 5 compares the mechanical properties of low and high silicon 3 mm plates late inoculated with 0.2 % Bi bearing FeSi. The opposite effects of increased nodule count in high silicon material and increased pearlite fraction in low silicon material result in mechanical properties that are comparable under the test parameters used. However, maintaining a lower nodule count would be favourable to fatigue strength. It is worth noting that the low Si material meets the 65-45-12 specification.

**Table 5**  
**Effect of Silicon Content on Tensile Properties**  
*(50 % LDASC, 0.2 % late inoculation)*

<table>
<thead>
<tr>
<th>Silicon Content</th>
<th>Nod/mm²</th>
<th>F</th>
<th>Nod/mm²</th>
<th>F</th>
<th>Nod/mm²</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.29% Si</td>
<td>458</td>
<td>47%</td>
<td>491</td>
<td>47%</td>
<td>613</td>
<td>52%</td>
</tr>
<tr>
<td>2.34% Si</td>
<td>648</td>
<td>40%</td>
<td>715</td>
<td>52%</td>
<td>1083</td>
<td>62%</td>
</tr>
<tr>
<td>2.56% Si</td>
<td>0.1% IPB</td>
<td>0.2%</td>
<td>0.5% IPB</td>
<td>0.5%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6. CONCLUSION
Within the limits of this investigation and under the conditions used during the test program, the following conclusions can be drawn.

1. Reducing the heat extraction capacity of the moulding material, for example by adding LDASC to silica sand, allows to produce 2 – 3 mm thick carbide free, Ductile Iron castings with as-cast microstructure and mechanical properties meeting ASTM specifications.
2. Three mm plates cast in a mixture containing 60% LDASC exhibit as-cast properties as follows: UTS: 495 MPa, YS: 325 MPa, Elong: 19%.
3. The following inoculation process was found to be efficient to produce carbide free 3 mm plates with an acceptable nodule count (sand mixture: 50% LDASC): 0.75% inoculating FeSi75 + 0.2% Bi bearing FeSi late inoculant.
4. Using 50% insulating sand in the moulding material makes possible to produce as-cast carbide free 3 mm plates containing 3.6% C and 2.35% Si (final).

7. ACKNOWLEDGEMENTS
The authors thank R. Showman and R. Afterheide (Ashland Chemicals) for supplying the LDASC material and for discussion.

8. REFERENCES

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Located in Strongsville, Ohio, USA
15400 Pearl Road, Suite 234, Strongsville, Ohio 44136
Billing Address: 2802 Fisher Road, Columbus, Ohio 43204
Phone (440) 665-3686; Fax (440) 878-0070
e-mail:jwood@ductile.org
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MEETINGS

The Ductile Iron Society 2004 Fall Meeting will be held in Rancocas, New Jersey on October 13-15, 2004. Click here for more details and to register for this meeting.

BUSINESS

Intermet names President and CEO Gary F. Ruff as chairman and CEO; John Doddridge retires.

Troy, Mich., July 15, 2004 - INTERMET Corporation (Nasdaq: INMT), one of the world's leading manufacturers of cast-metal automotive components, today announced that the company's Board of Directors has unanimously elected President and CEO Gary F. Ruff, 52, to Chairman of the Board and CEO, effective immediately. Ruff succeeds John Doddridge, 63, who joined INTERMET as Chairman and CEO in 1994, and is retiring as Chairman effective July 2004. John Doddridge will continue to serve on the Board of Directors. Doddridge stepped down as CEO in July of 2003.

Ruff has been President of INTERMET since December 2002 and was named CEO a year ago. He joined the company in 1999 as Vice President of Technical Services.

"With Gary's solid business strategy and over 150 years of tradition on which to build, INTERMET has the foundation for a successful future," said Doddridge. "He has put the right people in place who are working with the most advanced casting technologies to help improve performance for our investors and to continue the company's focus on quality and service to its customers."

Commenting on his appointment, Ruff said, "It is an honor and a privilege to take on this new responsibility with this great company. I look forward to the challenges, and most importantly, to continue working with the talented employees of INTERMET and their Board of Directors."

"John Doddridge is a highly respected automotive executive and has guided INTERMET through some demanding times," said Ruff. "We appreciate his dedication and the leadership he has shown through his years of service and wish him well in retirement."

Mitsunobu (Tony) Takeuchi Elected to INTERMET Board of Directors

Troy, Mich., July 15, 2004 - INTERMET Corporation (Nasdaq: INMT), one of the world's leading manufacturers of cast-metal automotive components, today announced that Mitsunobu (Tony) Takeuchi has been elected to its board of directors, effective today. Mr. Takeuchi fills a board vacancy created by the departure of Richard J. Peters, who is stepping down due to an increasingly demanding schedule.

Mr. Takeuchi is Chairman Emeritus of DENSO International America, Inc., the North American headquarters for Japan-based DENSO Corporation, and Honorary Advisor to the Board of Directors, DENSO Corporation. Previously he was Chair and Chief Executive Officer of the Southfield,
Mich.-based global supplier of advanced automotive systems and components.

"INTERMET Chairman and CEO Gary F. Ruff said, "Mr. Takeuchi's global experience and perspective will assist INTERMET as we further develop our relationships with the company's growing customer base overseas, particularly in Asia. We welcome him to our board and look forward to his counsel and insights."

Mr. Takeuchi's 40-year career with DENSO included serving as President and CEO of DENSO International America, overseeing operations in Canada, U.S. and Mexico. Prior to this he was General Manager of International Sales and Marketing for North America, South America, Europe and Asia/Oceania. He was elected to DENSO Corporation's Board of Directors in 1995. He began his career in 1964 with the firm's parent company, DENSO Corporation (formerly Nippondenso Company Ltd.).

Tony Takeuchi is a member and past president of the Japan Business society of Detroit and serves on boards of the National Association of Manufacturers (NAM), Original Equipment Suppliers Association (OESA), Motor Equipment Manufacturers Association (MEMA), and the Economic Club of Detroit. He holds a degree in international trading from Kanagawa University in Yokohama, Japan.