Ductile Iron News-Issue 2, November 2011

WOW!!! What a great turn out, with 130 registrations, to our Fall Ductile Iron Society Technical and Operating meeting held in historical Gettysburg, PA. The first day was busy with committee meetings. We held our Research Meeting in the morning with a record 35 members in attendance. Even in the afternoon we had more than normal turnout for the operating committees. The DIS Board of Directors meeting was held at 3:00 pm and adjourned at 5:00 pm. If any of you out there that are members of the DIS would like to join, please check out our committee structure on the website and contact Jim Wood at jwood@ductile.org. The day concluded with an excellent reception in the evening.

On the second day, the attendees were presented with 10 quality talks. John Lewensky (Pure Power Technologies - Navistar) and chairman of the DIMG (Ductile Iron Marketing Group) and Jim Wood (DIS Executive Director) started off the day with a presentation on our first ever trade show booth and display at this year's Railroad Interchange in Minneapolis, MN. You can find that presentation with the other technical presentations through the links on the left hand side of the DI News website.

The day ended with our reception and banquet which was officiated by our DIS President, Scott Gledhill of ThyssenKrupp Waupaca.
Foundry. Scott then welcomed Donsco, Incorporated back as a member of the DIS and introduced 9 attendees from Donsco to our meeting. They were;

Bill Blechschmidt  Lizeth Medina
Chris Buck        Bach Phung
Sam Chatterjee    Mike Ruby
Harry Deverter    Jesse Fluck
Bernie Kyler

Our new DIS Members that joined since our Spring Meeting in Dallas are;

Grede Holdings, LLC Berlin Division
Bessemer Division
Biscoe Division & Trevor Beach

Brewton Division
Brewntown Division
Columbiana Division
CorporateOffices
Iron Mountain Division
Liberty Division
Marion Division
New Castle Division
Novocast, Mexico Division
Reedsburg Division
St.Cloud Division
Teknik, Mexico Division

Other new members that were introduced;

Foundry Member, Mid-City Foundry Company in Milwaukee, WI
Associate Member, Allied Mineral Products in Columbus, OH
Associate Member, MRO Resources LLC in Charleston, SC
Associate Member, S&B Industrial Minerals, North America in Cincinnati, OH

Scott then introduced our Chairman of our DIS College & University Relations Committee, Jim Csonka to introduce our guest students in attendance for this meeting.
Jim introduced Joe Hsieh of Drexel University and Dean Zawistowski of Kent State University. Both gentlemen presented what their respected programs are about and their own work experience to date. Both are looking for full time employment in the Spring 2012. Their resumes are available in the Features Tab in the links on the left hand side.

Thanks to Gene Muratore of Rio Tinto and Kathy Hayrynen of Applied Process for being our morning and afternoon technical chairpersons. Both were asked by Scott to present each of our speakers with a DIS token of appreciation for presenting at our technical session.

Next, Scott introduced Bill Juergens of T B Woods Foundry to give the group a short presentation on the history of the foundry [Click to view presentation] and what the group would see the next day on their tour.
Thanks to not only Bill, but Lew Crist (Belted Drives Business Unit Manager) Svetlana Dodik-Pelja (Technical Director) and many other folks who helped the tour through the foundry.

TB WOOD'S FOUNDRY TOUR PICTURES

This wrapped up the evening festivities and Scott closed with a reminder about our Spring 2012 Annual Meeting in Muskegon, MI with a tour of CWC Textron. For more information, please visit the DIS website. Make sure you connect to the link on the left side of the home page under Bulletin Board and not only will you find information on the Spring 2012 meeting but future DIS meetings.

Also coming soon, will be a new Member Services software program called NetForum, accessible from the DIS Website that will have many new features. Just to name a few are registering and paying for meetings, individual member and company search and finding out information on DIS committee activities.

Jim Wood
DIS Executive Director
Ductile Iron Society Tour of

TB Wood’s
Chambersburg, PA Plant

October 28, 2011
TB Wood’s - History

• T.B. Wood, a Philadelphia native, was a master mechanic journeyman. He moved to Chambersburg in 1847 as a machinist for the Franklin Railroad. In 1850 after CVRR acquired Franklin Railroad he was appointed master mechanic for the 52 mile line.

• Peter Housum was a millwright, a designer, and builder of machinery. He descended from an iron making family. His father and two uncles had built and operated Franklin Furnace, located in nearby Edenville, PA.
TB Wood’s - History

- In June of 1857 T.B. Wood joined with Peter Housum to take ownership of Franklin Foundry & Machine Shop after former owner C.F. Miller retired.
The plant built in 1840 was nearly 200 feet long and varied in width from 26 to 52 feet. It ran east-west perpendicular to the Franklin Railroad which is now Third Street.

The two partners and their 24 employees offered a variety of “job shop” work.
TB Wood’s - History

• In 1857, Franklin Foundry & Machine Shop offered “mill gearing,” the pulleys, gears, couplings, rope sheaves and flat belting which drove the mills and factories of the day.

• In 1859, John Brown moved to Chambersburg, taking a small room on King Street, half a block from Wood & Housum’s shop. The people of Chambersburg were unaware that Brown was receiving weapons within 100 yards of the shop and planning a raid on Harpers Ferry.

• The October raid failed, but it brought the nation another step closer to war.
The civil war began with the bombardment of Fort Sumter on April 11, 1861.

Peter Housum answered the call for volunteers immediately and became a militia captain in “Chambers Artillery”. Housum rose to become a Lt. Colonel and commander of the 77th Pennsylvania Regiment by October 1861.

Lt. Col. Housum was killed in the battle of Stones River, near Murfreesboro, TN, December 31, 1862. In was 39 years old.

The following year T.B. Wood bought his late partner’s interest in the business and became the sole owner.
TB Wood’s - History

- During the Civil War, the borough of Chambersburg saw the Confederate army three times.
- The first was October 1862 when Maj. Gen. J.E.B. Stuart raided Chambersburg.
- The second time was June 23, 1863 when Robert E. Lee and A.P. Hill met in the town square and made their decision to move the 50,000 man army east toward York. The advance ended in Gettysburg.
- In 1864 the Confederate Army demanded a ransom and burned the town when a ransom was not paid.
TB Wood’s - History

- In 1884, the firm named changed to T.B. Wood & Sons.
- The company remained a general supplier of iron goods, but concentrated on mill gearing, including water wheels. Unrelated products included bridges, feed troughs, stoves, and a corn cob crusher with the trade name “The Miller’s Friend”
- T.B. Wood retired in 1889 and his two sons continued the business under the name T.B. Wood’s Sons Company.
In 1903, C.O. Wood (the oldest son of George A. Wood) applied for a patent on a shafting hanger which provided a unique two-axis ball-and-socket mount for line shaft bearings. The design simplified line shaft installation and leveling.

The patent was not issued until 1906, but by then the “Universal Giant” hanger already was well established as a product line.
Spurred on by the success of the Universal Giant design, the hanger business had grown by 1905 to a point where a larger facility for their manufacture was justified.

The two-story hanger which had been built at Third Street between 1900 and 1903 already had been outgrown.

A plot along Fifth Ave was developed, and in 1906 the hanger and bearing department moved.

The new shop was the first building on the present site, and is still known as the hanger shop to most Wood’s people.
TB Wood’s - History
TB Wood’s - History
TB Wood’s History

- Starting in 1947, heavy jolt-squeeze Spo molding machines were installed, along with a large capacity, mechanized sand system.
- In 1948 new twin cupolas for melting were installed.
- The rapid move toward individual motors and drives for machinery increased V-belt drive sales while demand for line shaft products declined.
TB Wood’s is a 440,000 sq. ft. facility that produces product for their own product line and offers “value added” machining for their commercial casting business.

In December of 1986 C. O. Wood III sold the company to Tom Foley.

In April of 1990 TB Wood’s hourly work force went on strike. The strike lasted two and one half years at which time the union was decertified. TB Wood’s is currently a non union shop.

On February 8, 1996 TB Wood’s became a public company listed on the New Stock Exchange (NYSE).

In 1996, TB Wood’s received their ISO 9001 certificate. TB Wood’s quality management system is currently certified to ISO 9001:2008.

Altra Industrial Motion acquired TB Wood’s in April, 2007.
Power Transmission and Motion Control Products
TB Wood’s - TODAY

• Altra Industrial Motion was formed in 2004.
• Altra is home to 20 of industry’s leading power transmission brands.
• Headquartered in Braintree, Massachusetts.
• Sales of $600 million.
• 3,450 full time employees.
• Facilities in 13 nations across 5 continents.
• Over 1,000 direct OEM customers.
• Over 3,000 distribution outlets.
• Publicly traded NASDAQ: AIMC
History

October 2004
Acquired Kilian Manufacturing (1922)

November 2004
Acquired the Colfax Power Transmission Group
- Ameridrives Couplings (1928)
- Boston Gear (1877)
- Centric Clutch (1948)
- Delroyd Worm Gear (1922)
- Formsprag Clutch (1946)
- Industrial Clutch (1930)
- Marland Clutch (1931)
- Nuttall Gear (1897)
- Stieber Clutch (1944)
- Warner Electric (1927)
- Wichita Clutch (1954)

May 2006
Acquired Bear Linear (2001)

April 2007
Acquired TB Wood's (1857)

October 2007
Acquired All Power Transmission (1986)

December 2006:
Launched IPO: AIMC

February 2006
Acquired the Hay Hall Group
- Bibby Transmissions (1919)
- Huco Engineering (1965)
- Inertia Dynamics (1971)
- Matrix International (1939)
- Twiflex Limited (1946)
- Saftek Friction (1985)

(Indicates year founded)
The “Power Brands” in Power Transmission

Warner Electric  Ameridrives Couplings
TB Wood’s  Centric Clutch
Boston Gear  Delroyd Worm Gear
Warner Linear  Kilian Bearing
Formsprag Clutch  Inertia Dynamics
Stieber Clutch  Matrix Engineering
Marland Clutch  Bibby Transmissions
Wichita Clutch  Twiflex Limited
Industrial Clutch  Huco Dynatork
Nuttall Gear  Ameridrives Power Transmission
## Leading Market Share

**Strong Brands Lead to Strong Market Share**

<table>
<thead>
<tr>
<th>Category</th>
<th>Brand</th>
<th>Geography Served</th>
<th>Awareness Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overrunning Clutches</td>
<td>Formsprag, Marland, Stieber</td>
<td>Global</td>
<td>#1</td>
</tr>
<tr>
<td>QD Bushings</td>
<td>TB Wood’s</td>
<td>North America</td>
<td>#1</td>
</tr>
<tr>
<td>Integral HP Clutches &amp; Brakes</td>
<td>Warner, IDI, Matrix</td>
<td>Global</td>
<td>#1</td>
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<tr>
<td>Engineered Bearing Assemblies</td>
<td>Kilian</td>
<td>North America</td>
<td>#1</td>
</tr>
<tr>
<td>Large Sheaves</td>
<td>TB Wood’s</td>
<td>North America</td>
<td>#1</td>
</tr>
<tr>
<td>Electrically Released Brakes</td>
<td>Warner, IDI, Matrix</td>
<td>Global</td>
<td>#1</td>
</tr>
<tr>
<td>General Purpose Disc Couplings</td>
<td>TB Wood’s</td>
<td>North America</td>
<td>#2</td>
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<tr>
<td>Pneumatic Energy Brakes</td>
<td>Wichita Clutch</td>
<td>Global</td>
<td>#2</td>
</tr>
<tr>
<td>Diaphragm Couplings</td>
<td>Ameridrives</td>
<td>Global</td>
<td>#2</td>
</tr>
<tr>
<td>Worm Gear Reducers (1&quot; - 6&quot; CD)</td>
<td>Boston Gear</td>
<td>North America</td>
<td>#2</td>
</tr>
</tbody>
</table>

* Management Estimates
Broad and diverse product array

**Electro Magnetic Clutches & Brakes**
- Electrically Released
- Packaged
- Basic
- Turf & Garden
- Magnetic Particle
- Wrap Spring
- Tension Control

**Heavy Duty Clutches & Brakes**
- Water Cooled
- Pneumatic
- Hydraulic
- Caliper
- Fluid Couplings
- Tension Control
- Spring Set

**Overrunning Clutches**
- Back Stops
- Multi-Purpose Sprag
- Multi-Purpose Roller
- Ball Bearing Type
- Continuous Duty
- Cages and Retainers
- Bi-Directional

**Engineered Bearing Assemblies**
- Custom Bearing Assemblies
- Track Rollers
- Vehicular Assemblies
- Thrust Assemblies
- Polymer Assemblies
- Roller Assemblies
- Housed Units

**Couplings**
- Disc
- Elastomeric
- Diaphragm
- Gear
- Grid
- Jaw
- Universal Joints
- Mill Spindles
- Torque Limiters

**Gearing and PT Components**
- Worm Gear Speed Reducers
- Helical Gear Drives
- Open Gearing
- Linear Actuators
- Precision Couplings
- Adjustable Speed Drives
- AC and DC Motors

**Engineered Belted Drives**
- V-Belt Drives
- Synchronous Drives
- Made-to-Order Sheaves
- Belts
- Bushings
- Gray & Ductile Iron Castings

Sample Markets:
- Turf & Garden
- Forklift
- Elevator

Sample Markets:
- Aerospace
- Material Handling

Sample Markets:
- Automotive
- Petro/Chem

Sample Markets:
- Energy
- Metals

Sample Markets:
- HVAC
- Forklift

Sample Markets:
- Safety
- Marine

Altra Industrial Motion
A global footprint to support customers around the world

- Direct sales coverage in over 25 countries
- Total coverage in over 70 countries via extensive distributor network
- 28 manufacturing locations worldwide
- Over 250 sales and marketing personnel
- Aligned with Altra’s core competencies
- Large breadth of Altra products available for sale
- Global customer base
- Balanced cycles
- Opportunities to focus on collaborative new product development and competitive displacement
Diversified Revenue Base

Key End Markets

- Aerospace & Defense: 2%
- Specialty Machinery: 8%
- Construction: 3.6%
- Other: 22%
- PT & Motion Control: 10%
- Paper & Pulp, Forest: 4%
- Material Handling: 9%
- Transportation: 7%
- Turf, Garden, Agriculture: 9%
- Energy: 10%
- Metals & Mining: 5%
- Food Processing: 9%

Geography

- North America: 70%
- Europe: 22%
- Asia & Other: 8%

(1) 2007 pro forma for TB Wood’s
Belted Drive Products

V-belt Components

Synchronous Components

Variable Speed Drive

Sure Grip Bushing
TB Wood’s - TODAY

MELT CAPACITY

- TB Wood’s has four 40 ton channel furnaces, one 15 ton channel furnace, and two 3,000 lb. coreless furnaces.
Iron Capabilities

- Gray Iron (ASTM A 48)
  - Class 25, 30, 35, or 40
- Ductile Iron (ASTM A 536)
  - Class 60-40-18; 65-45-12; 80-55-06; 100-70-03

Nuttall Gear Housing
TB Wood’s - TODAY

MOLDING CAPABILITY & CAPACITY

• Three green sand molding centers
  – Herman line (MD2) – cope & drag
    • Flask size – 34” sq. w/10” over 10” height
    • Line speed – 60 molds per hr.
    • Maximum casting size – 350 lbs.
  – Sinto line (MD3) – cope & drag
    • Mold size – 20” x 24” w/8” over 8” height
    • Line speed – 80 molds per hr.
    • Maximum casting size – 80 lbs.

6,000 lb Casting
Molding Capability & Capacity (cont’d)

- Pulley/Slinger/Floor (MD1) – cope & drag molding
  - Work Centers P20, P36, P50, P60, HF
  - Mold size – 20” to 108” diameter
  - Maximum casting size – 108” diameter, 70” height, 10,000 lbs

- 2 NO-BAKE molding centers
  - MD4 – cope and drag molding
    - Maximum mold size – 60” x 96”
    - Line speed – 20 boards per hour
    - Maximum casting size – 50” height, 2,800 lbs.
Molding Capability & Capacity (cont’d)

- MD1 Floor molding
  - Maximum mold size – 120” x 120”
  - Molding speed – 3 molds per hour
  - Maximum casting size – 120” sq, 70” height, 10,000 lbs.
TB WOOD’S STRENGTHS

• Process Controls
  – Hartley controls on each muller monitors sand characteristics on each sand batch.
  – Lab Technician takes sand samples daily and monitors performance with SPC.

• Melt Control
  – In-house spectrometer to monitor chemical characteristics.
  – In-house mechanical testing of test bars.

• In-house heat treatment capabilities (annealing and stress relief).
TB WOOD’S STRENGTHS (cont’d)

- In-house pattern shop
  - CNC pattern making
  - Pattern gating, PMs, and repairs
  - Journeyman patternmakers

- Value added machining
  - 13 CNC work centers
  - Turning, milling, drilling, hobbing, and shaping.
Thank You!
The brands of Altra Industrial Motion
Thursday, October 27, 2011 Morning Session

SPEAKER BIO'S

Dr. Prem Mohla

Prem graduated from IIT in Mumbai, India and obtained his PhD in Metallurgy from the University of Sheffield, England. He worked for Tata Motors in India prior to coming to the USA. Prem was previously employed by Ford Motor, Intermet Corporation and Globe Metallurgical. In 2003, Prem joined Hickman Williams & Company as a technical service representative.

Prem has devoted his 45 years of professional career towards the development, production and application of ductile iron in the industry. He has been a member of the AFS and DIS since 1972.

The DIS welcomes Prem who is here to talk about “Managing Intricacies of Ductile Iron Production – Part 1”

Al Alagarsamy

Al Alagarsamy has been involved with iron foundries for more than forty years and has worked with three major foundry groups in research and development functions. He continues to work as a consultant to foundries and casting users alike. He has served as a research committee chairman at AFS and DIS. He has authored and presented many papers at AFS casting congress meetings and DIS meetings. He has received the award of Scientific Merit from AFS and the distinguished service award from the DIS. He continues to write technical articles for the DIS. He has developed training materials for the iron foundries in areas of metallurgy, sand control, casting defects, etc. He has a patent for ductile iron treatment “Ladle Converter” for using Mg rich alloys. He has introduced stream inoculation for manual pouring in several foundries.

The DIS welcomes Al who is here to talk about “Managing Intricacies of Ductile Iron Production – Part 2”

Abhay Pande

Abhay graduated in Metallurgy and also received his MBA in International Business. He has been employed at Foseco for the last 15 years in the field of Molten Metal Transfer and Ferrous Metal Treatment products. Abhay is the product Manager for Ferrous Metal Treatment. His paper today describes a new metallurgical process for ductile iron foundries.

The DIS welcomes Abhay who is here to talk about “INITEK – The New Way to Make Ductile Iron” Part #1

Bill Simmons

Bill graduated in Metallurgical Engineering and is a Chartered Engineer. His career includes periods working in mass production iron foundries and at the British Cast Iron Research Association. Bill is the International Product Manager for Ferrous Metal Treatment products.
at Foseco, based in the UK. His paper today describes some of the results of Foseco’s current experience and new developments in iron foundry metal treatment.

The DIS welcomes Bill who is here to talk about INITEK – Part #2

Don Craig

Don graduated with his Bachelor of Science in 1980 from Mount Allison University. He then received his Bachelor of Engineering from the Technical University in Nova Scotia in 1982. He then received his Masters of Applied Science in Metallurgy a year later. Don was not finished yet, so he moved over to the University of Buffalo and received his Master of Business Administration in 1991. From 1983 to 1987, don worked as a metallurgist at Wabtec – Wallaceburg Foundry. He then moved on to Elkem Metals from 1987 to 1994 as a market development Engineer at the development center and then as a Quality Engineer at the Ashtabula Plant. He then moved on to NYCO Minerals as Director of Quality and Process Engineering from 1994 to 1998. In 1998, he went to Wheland – Warrenton Foundry as Technical director and then in 2001 he change companies and moved to Selee Corporation and is currently the Senior Metallurgist – Foundry Filtration Methods. Don is a past Director of the DIS and member of the DIS Research Committee. He is also a current member of the AFS 5H – Grey Iron Research.

The DIS welcomes Don who is here to talk about “Identification & Elimination of Inclusion Defects in Ductile Iron Castings”

David Roth

David graduated from the University of Missouri with his Bachelor of Science in Metallurgical Engineering. David has over 35 years of experience in the aluminum industry. He has worked for Alcoa and ARCO Aluminum as a metallurgist, process control manager and Director of technology. He then moved on the ALTEK for 25 years and was involved in dross handling projects, casting projects and furnace installations. As a principle and President of the company, David oversaw all aspects of ALTEK dross handling systems and engineering services. Currently the President of the new venture GPS Global Solutions, he is focused on processing various metal slags and drosses with the goal of total metal removal and ultimately zero land fill waste. This venture with Didion takes him into new areas of recovery of metal and oxide products from other metals including aluminum. David has over a dozen US and International patents, and has published numerous international articles.

The DIS welcomes David who is here to talk about “The Environmental Approach to Reduced Waste and Increased Metal Recovery by in House Slag Processing”
Thursday, October 27, 2011 Afternoon Session

Speaker Bios

Alex Pardo

Alex graduated from Penn State University in 2010 with a degree in Industrial Engineering, with a focus on manufacturing. At Penn State, he worked extensively at the Learning Factory and on the Penn State FSAE team. His hometown is Pottstown, PA, just outside of Philadelphia and is currently living in Painted Post, NY. Alex is currently the Process Engineer for Hitachi Metals Automotive components in Lawrenceville, PA.

The DIS welcomes Alex who is here to talk about “Implementation of Thermal Analysis to Reduce Shrinkage Defects in ductile Iron Castings”

Alan Wertz

Alan graduated from Pennsylvania College of Technology in 2006 with a Manufacturing Engineering Technology Degree. He started working at Benton Foundry Inc. in Benton, PA in July 2006. Responsibilities at the foundry include Foxalls, tooling and equipment designs, as well as many other projects throughout the foundry.

The DIS welcomes Alan who is here to talk about “Robotic Grinding Using ABB’s Force Control Technology”

Dileep Thatte

Dileep graduated with his Masters in Chemical Engineering and he also obtained his Master’s in Business Arts. Dileep has been a senior executive for many global corporations and has headed International Operations in the Asia-Pacific, Europe and Canada. He has presented papers at International Conferences on the subjects of International Business, Industrial Marketing and Water Treatment. He is currently working as a Program Manager at the National Institute of Standards and Technology (NIST) – Manufacturing Extension Partnership (MEP) group of the US Department of Commerce. The Manufacturing Extension Partnership (MEP) is a catalyst for strengthening American Manufacturing – accelerating its ongoing transformation into a more efficient and powerful engine of innovation driving economic growth and job creation.

The DIS welcomes Dileep who is here to talk about “Profitable Growth through Business Innovation”

Paul Jones

Paul graduated from Michigan Technological University in 1979 with his Bachelor of Science in Metallurgical Engineering and Bachelor of Science in Engineering Administration. He then moved on to the University of Michigan and graduated with his Master in Business Arts in 1986. Paul has over 31 years’ experience in the automotive and metal casting industry. He started with General Motors at the Central Foundry Division in Saginaw, MI serving in a variety of engineering and quality positions. He also worked at the GM Tech Center.
Advanced Engineering Staff and GM’s Saginaw Steering Gear Division. In 1994, Jones became part of the American Axle serving in leadership roles in Product Engineering, Advanced Product Quality Engineering, Supplier Development and Engineering Casting Development. In 2009, Paul began working for ThyssenKrupp Waupaca serving as Manager, Development and Launch for Detroit based customers. He is a member of AFS, ASM, ASQ, DIS and SAE.

The DIS welcomes Paul who is here to talk about “Castings as a Source of Competitive Advantage ….Their Job, or our Job”

Marc King

Marc graduated in 1996 from Michigan Technological University with a Bachelor of Science degree in Metallurgical Engineering. He has held metallurgical positions in several foundries. He has been the Metallurgist at Hiler Industries since 2006. Hiler Industries has two shell molding foundries that pour Ductile Iron, Carbidic Ductile Iron, White Iron, Ni-Hard, Gray Ni-Resist, Ductile Ni-Resist, Brass and Bronze. Marc has spoken in the past at DIS meetings. He is also an active member of the DIS Research Committee.

The DIS welcomes Marc who is here to talk about “Improved Process Techniques for Thin Sectioned Ductile Iron”
FEATURES

2011 FALL MEETING HIGHLIGHTS

- Managing Intricacies of Ductile Iron Production - Prem Mohla/Al Alagarsamy
- INITEK: The New Way to Make Ductile Iron - Abhay Pande/Bill Simmons
- Certification & Elimination of Inclusion Defects in Ductile Iron Castings - Don Craig
- The Environmental Approach to Reduced Waste and Increased Metal Recovery by in-House Slag Processing - David Roth
- Implementation of Thermal Analysis to Reduce Shrinkage Defects in Ductile Iron Castings - Alex Pardo
- Profitable Growth Through Business Innovation - Dileep Thatte
- Castings as a Source of Competitive Advantage, Their Job, or Our Job - Paul Jones
- Robotic Grinding Using ABB's Force Control Technology - Alan Wertz
- Improved Process Techniques for Thin Sectioned Ductile Iron - Marc King
- 2011 FEF Conference
- Joe Hsieh-Drexel Univ.- Resume
- Dean Zawistowski-Kent State Univ.- Resume

DEPARTMENTS

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- Back Issues
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Dr. Prem Mohla - Globe Metallurgical

Prem graduated from IIT in Mumbai, India and obtained his PhD in Metallurgy from the University of Sheffield, England. He worked for Tata Motors in India prior to coming to the USA. Prem was previously employed by Ford Motor, Internet Corporation and Globe Metallurgical. In 2003, Prem joined Hickman Williams & Company as a technical service representative.

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AND

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The DIS welcomes Al who is here to talk about “Managing Intricacies of Ductile Iron Production – Part B”
Managing Intricacies of Ductile Iron Production

- Prem Mohla
  Hickman Williams & Co
- Al Alagarsamy
  Free agent
Progress in Ductile Iron Technology

- Reduction in silicon from 3% down to 2%
- Reduction in Mg from over 0.05% to 0.03%
- Reduction in S, P, Cr, Mn levels
- Post inoculant from 1.0% to 0.2%
- As cast and high strength grades
- Improved efficiency and consistency
  - Alloy usage from above 2% to less than 1%
  - Driving the progress - customers, researchers, foundrymen, suppliers, AFS and of course DIS
Continuing the Progress

Realizing full potential of ductile iron

• Part A
• Processing of ductile iron
• Part B
• Achieving clean, sound castings with consistent properties
Nucleation & Solidification

• Opportunities for process optimization
  – Base melt, materials, procedure and conditioning
  – Treatment type, materials
  – Ladle inoculation, time, materials
  – Late inoculation, amount, method, materials

• Achieving clean, sound castings with consistent properties
  – Substrates
  – Graphite and austenite nucleation
  – Undercooling, recalescence
  – Segregation
Processing of Ductile Iron

- Melting
  - Preconditioning
- Treatment
  - Methods
- Alloys
  - Mg Alloys
  - Inoculants
- Mold filling

Hot topics issue 2 thru 5 -2010; Effect of process variables on metallurgical quality
Melting

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<th>Materials</th>
<th>Affecting</th>
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<tr>
<td>– Chemistry</td>
<td>– Nucleation</td>
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<tr>
<td>– Cleanliness</td>
<td>– Carbides</td>
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<tr>
<td>Melting</td>
<td>– Shrinkage</td>
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<tr>
<td>– Temperature</td>
<td>– Persistent oxidation</td>
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<tr>
<td>– Slagging</td>
<td>– Alloy consumption</td>
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<td>– Gas formation</td>
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</table>
Oxidation and Reduction Reactions during Melting

- Reactions occur simultaneously
- Depending on temperature and concentration, some reactions are favored over others
- Reactions may not go to completion in high productive melt shops

- Highly oxidized melt
  - Dirty charge materials - iron oxides - moisture
  - High turbulence during melting
  - Taping right after power turned off
  - Effect persists through solidification
Oxidation of melt caused by excessive turbulence during melting

Anthracite coal was used as carbon raiser
Melting - Preconditioning

• Steps/actions taken to prepare metal during melting so as to provide best and consistent properties in castings
• Materials
  – FeSi
  – Carburizers
  – Silicon carbide
  – Proprietary agents of different active elements
    • (Ba, Al, Zr, La, Mn, Ca)
Preconditioning

- Generates large quantity of stable nuclei
- Manages S and O activity
- Gives higher and consistent Mg recovery
- Reduces shrinkage and micro-porosity
- Makes slag separation and removal easy
- Improves lining life and reduce inclusions
- Rejuvenates superheated metal
- Applicable for both GI & DI
Added to the furnace after initial meltdown and heated quickly, slagged off after a delay of about 10 minutes, as per Bocardo Angelo

World foundry Congress, 1998
## Effect of Preconditioning on Tensile Properties

<table>
<thead>
<tr>
<th></th>
<th>Hardness</th>
<th>Tensile, Mpa</th>
<th>Average, Mpa</th>
<th>% reduction in tensile</th>
<th>Comment</th>
<th>T/H ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual casting</td>
<td>193</td>
<td>273.9</td>
<td>270.5</td>
<td>267.8</td>
<td>10.75</td>
<td>Classic inoculation 0.143</td>
</tr>
<tr>
<td>Automatic casting</td>
<td>197</td>
<td>236.7</td>
<td>221</td>
<td>291</td>
<td>16.6</td>
<td>Ladle inoculate + stream 0.105</td>
</tr>
<tr>
<td>Automatic casting</td>
<td>217</td>
<td>302.9</td>
<td>297.7</td>
<td>291</td>
<td>basis</td>
<td>Precondition + stream 0.143</td>
</tr>
</tbody>
</table>

Optimization of gray cast iron safety casting casted with automatic furnaces and importance of preconditioning of the melted iron, Bocardo Angelo, World foundry congress, 1998, Budapest, Hungary
Ductile Treatment

**Methods**
- Ladle
  - Open/Sandwich/Tundish
- Pure Mg
  - Converter, cored wire
- In-mold
- Treat and pour
- Etc.

**Variables**
- Treat temperature
- Mg content of alloy
- Ladle design
- Rate of fill
- Use of cover
- Ladle maintenance
- Etc.
Mg Vapor Pressure vs Temp

Vapor pressure in atmospheres

<table>
<thead>
<tr>
<th>Atmospheres</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment Temperature Celsius</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1200</td>
<td>1300</td>
<td>1400</td>
<td>1500</td>
<td>1600</td>
<td>1700</td>
<td></td>
<td></td>
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<tr>
<td>2372</td>
<td>2552</td>
<td>2732</td>
<td>2912</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9% Mg alloy

5% Mg alloy

3% Mg
MgFeSi Alloys for Ladle Treat

- Chemistry
  - Mg 2.8 - 10%
  - Ca 0.5 – 3%
  - TRE traces – 3%
  - Al 0.5 – 1.25%
  - Si 44 – 48%
  - Fe balance
  - Ba or La as requested

- Size
  - 1 ¼” x ¼” ( 30 x 6 mm )
  - ¾” x 10 mesh ( 20 x 2 mm )
  - 5/8” x 18 mesh ( 15 x 1 mm )

- Quality
  - Cleanliness
  - Consistency
  - Minimum Segregation
Treat and Pour in a single ladle

- Mg treatment and inoculation done as a single step
- Lower furnace tap temp by 75 – 100 F
- Special tall ladle not a necessity
- Lower production costs
- Greater productivity
- Generally higher nodule count
- 3% Mg alloy better suited
- Greater number of nodularity coupons
- One step treatment for ductile iron; E. Compomanes, AFS trans 1973
Micro Comparison
Tundish vs. Treat & Pour

Lower tap temperature
Higher nodule count
Lower fading rate
Better nucleation

Higher temperature
Faster fading
Temperature and Mg loss during transfer
MgFeSi Alloys for Ladle Treatment

• Mg Content – 3% vs 5% performance
  – 3% Mg (84% recovery)
  – 5% Mg (65% recovery)

  Lower Mg alloys have:
  – Less tendency for carbides, shrink and inclusions
  – Less flare, smoke, slag and cleaner ladles

• Rare Earths – Ce, La or balanced
  – Cost and availability have become major issues
  – When and where to add
  – Which type is the best

• Special Addition – Ba, Ca
  – Effect of mg content of spheroidizer on chilling tendency of SG melt; H. Nagayoshi, AFS Trans 96 - lower Mg content better
Role of Rare Earths

- Desulfurization and deoxidization
- Neutralizing subversive elements
- Stable nuclei, lower fade
- Augmenting Mg in nodularizing
- Increase NC
- Possibility of using higher sulfur base iron

- Optimum levels and type in MgFeSi
  - Carbides, shrink, low nodularity, chunky and degenerated graphite, flotation
  - Section sensitive
- Pure Mg – before /after treatment
Proposed Strategy for Minimizing Rare Earths Use

- Reduce RE levels to 0.2 – 0.5% in the alloy for thin to medium sections
- Optimize the type of RE (Ce, La etc)
- Use of preconditioning to obtain greater degree of nucleation
- Use of Ba in the MgFeSi (0.2 -1.0%)}
- Use of stronger inoculants with RE and/or RE + Bi in the ladle and/or in the stream with low RE magnesium alloys, pure Mg
Potential Risks with Lower Rare Earths

- Greater fade of nodularity
- Lower nodule count
- Greater tendency for shrink
- Low nodularity
- Graphite shape control

- Use of thermal analysis for process control of ductile iron; Adrain Udriou, Italy, 2002 Novacast Conference
- Best alloy 9-3-3 (Mg, Ca, RE)
Effect of Rare Earths in MgFeSi on Shrink

<table>
<thead>
<tr>
<th>Location</th>
<th>Mass Pro (T-8)</th>
<th>Hic Wil C-3 (T-9)</th>
<th>Sss Mag Alloy (T-10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>J5</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>J4</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Shaft 4</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>J3</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Shaft 2</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>J2</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Shaft 1</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>J1</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Oil Seal</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Shrinkage Defect Size

- Mass Pro (T-8) (0.15% RE)
- Hic Wil C-3 (T-9) (0.001% RE)
- Sss Mag Alloy (T-10) (0.0% RE)

- F2 F1 R1 R2 F2 F1 R1 R2 F2 F1 R1 R2
- X X X X X X X X X X X X
- 4.0 5.5 4.7 13.4 14.4 16.0 17.2
Effect of Rare Earths in MgFeSi on Nodule Count

Front Total Nodule Count

<table>
<thead>
<tr>
<th>Mass Pro (0.015%)</th>
<th>C-3 (0.001%)</th>
<th>Sss (0.00%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T8 798</td>
<td>447</td>
<td>411</td>
</tr>
</tbody>
</table>

Rear Total Nodule Count

<table>
<thead>
<tr>
<th>Mass Pro (0.015%)</th>
<th>C-3 (0.001%)</th>
<th>Sss (0.00%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T8 777</td>
<td>511</td>
<td>310</td>
</tr>
</tbody>
</table>
Effect of Rare Earths Inoculants on Shrink

X Indicates Shrink Defect Was Uncovered.

Low Rare Earth Shrink Test

<table>
<thead>
<tr>
<th>Location</th>
<th>Mass Pro T-11</th>
<th>C3 w/ Foundry Grade (T-12)</th>
<th>C3 w/ FG Fe-Si &amp; Amerinoc (T-13)</th>
<th>C3 w/ Amerinoc (T-14)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F2</td>
<td>F1</td>
<td>R1</td>
<td>R2</td>
</tr>
<tr>
<td>J5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J4</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Shaft 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J3</td>
<td></td>
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</tr>
<tr>
<td>Shaft 2</td>
<td></td>
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</tr>
<tr>
<td>J2</td>
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</tr>
<tr>
<td>Shaft 1</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>J1</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Oil Seal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Shrinkage Defect Size

T-11 (0.15% RE) T-12 (0.001% RE) T-13 (0.002% RE) T-14 (0.003% RE)
Effect of Rare Earths Inoculant

Front Total Nodule Count

<table>
<thead>
<tr>
<th>T11</th>
<th>T12</th>
<th>T13</th>
<th>T14</th>
</tr>
</thead>
<tbody>
<tr>
<td>895</td>
<td>739</td>
<td>772</td>
<td>825</td>
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</tbody>
</table>

Rear Total Nodule Count

<table>
<thead>
<tr>
<th>T11</th>
<th>T12</th>
<th>T13</th>
<th>T14</th>
</tr>
</thead>
<tbody>
<tr>
<td>935</td>
<td>671</td>
<td>788</td>
<td>890</td>
</tr>
</tbody>
</table>
Inoculation for Quality Optimization

- Ladle inoculants for carbide prevention
- Special purpose inoculants for shrink
- Late stream and mold inoculants for nodule count maximization, etc.
- Higher nodule count
  - Good indicator of iron quality
  - Minimizes segregation (grain boundary carbides)
  - Better austemperability
  - Better mechanical properties
  - Better machinability
  - Inverse chill elimination
Inoculants - Compatibility with Process

• Active elements
  – Ca, Al.
  – Ba, Zr,
  – Bi, Rare earths

• Ladle, Stream, In the mold
  – Size, cleanliness, dissolution rate

• Where and when to add
  – Treatment alloy (MgFeSi)
  – Ladle / autopour
  – Pure Mg treatment
Mold Inoculation

- Powder
- Granular
- Lump
- Pressed
- Cast
- Typical 75% FeSi
- Trial with RE + Bi
- Pouring temp
- Proper gating
- Before filter
- Print / pocket
- Slag free
- Consistency
- Cold weather
Stream Inoculation

“The equalizer”

- At the left manual and fixed spout stream inoculators for manual pouring
- Late stream done correctly overcomes many process inconsistencies
- It should be matched with the rest of the process for amount, type of material
- Ensuring correct amount added during the entire mold filling is a must
Mold Filling

Dross - turbulence in gating and in mold filling

Surface graphite - chemistry, turbulence

Interior - graphite degeneration - sulfur reversal
Few of the many questions still out there

1. Why there is no general agreement on ductile iron solidification after more than 50 years of experience?
2. Why some practices work in some places and not in others?
3. Why there are differences in the solidification behavior even when the processes are seemingly controlled?
4. Why some jobs run successfully with low CE where as in other jobs, carbon needs to be higher
Managing Intricacies of Ductile Iron Production

Prem Mohla
Hickman Williams & Co
AI Alagarsamy
Free Agent

DIS T&O Meeting, October 26-28, 2011
Gettysburg, PA
Part B
Achieving clean, sound castings with consistent properties

Why do castings sometimes have shrink, pinholes, and dross defects when “we have not changed a thing for the past twenty years?”
Answer may depend on who you ask

- ‘Cornered’ Metallurgist may explain “on one hand ------- and on the other .......”
- ‘Steely’ Tooling guy says, “my tooling didn’t change, it is the ... melt...”
- ‘Religious’ Sand man says, “using natural materials and god has made them, so that can’t be it”
- ‘Overworked’ Foundryman might say “It is the change in the weather”
- Copout “Ductile iron does that some times”
The not so definite answer may be:

- Cast iron metallurgy is very complicated due to multi-component system.
- Nucleation and grain growth depends on many factors including time, kinetics, along with other normal suspects.
- Melting, treating and handling of metal is dynamic and measurements change with time.
- Melt in the mold cavity is not homogeneous.
- Variability in the raw materials purchased.
- Casting soundness and inclusion content depends also on casting design, gating and riser design practice and mold quality, which includes molding sand.
Answers to the questions become obvious when you Read

“21 Ways to Fail in Quality Control”
Kenneth M. Smith
Foundry consultant, Cleveland
August 1964, ‘Foundry’ magazine
Shared by
George Di Sylvestro
Nucleation and solidification affected by

- Base melt, materials, procedure and conditioning
- Treatment type, materials
- Ladle inoculation, time, materials method
- Late inoculation, amount, method, materials
  - These influence
- Substrates for graphite growth
- Graphite and austenite nucleation
- Degree of Undercooling, Recalcsence
- Segregation
Nucleation and growth

Austenite nucleation

Graphite can nucleate austenite but
Austenite is a poor nucleator of graphite

Need to nucleate Graphite

Substrates for nuclei

Oxides and sulfides of Mg, rare earths etc.

Driving force - undercooling

Austenite grain size

- In ductile iron austenite growth changes from columnar at surface to equi-axed at the interior
- Grain size decreases with increasing CE - from hypo to eutectic to hypereutectic
- Finer grain size:
  - Favors feeding
  - Reduces segregation

AFS Trans. 2003-159, R.E. Boeri et.al.
Research advances in Ductile iron solidification,
Austenite grain size

• ‘Spiking’ - Long dendrites
  - Low CE, super heated iron, (Monday morning iron) hypoeutectic, heredity
• Segregation
  - Large austenite grains increase segregation
  - Affects dynamic properties
• Feeding distance, thickness, shrinkage
• Mechanical properties
**Effect of Austenite ‘Spiking’**

**Nodule alignment, segregation**

Low tensile 76.7ksi (528MPa) for the hardness (207) and low elongation (4.8%) for the yield strength. 51.2ksi (353MPa) fracture follows ferrite and nodule orientation. TS/H=0.26 and YS/H=0.17 versus
Casting soundness affected by casting design

- Directionally solidified casting
  - Make the riser pipe
    - Riser and gate design
  - Chemistry - could be hypo eutectic
  - Why cast irons seem to be complex?
- Casting with isolated hot spots
- Iron self feeding
  - Chemistry, (Si, Mg, RE, carbide stabilizing elements)
  - Temperature
  - Inoculation
  - Slightly hyper eutectic

Effect of pouring temperature and composition on shrinkage cavity in Speheroidal graphite cast iron. AFS Trans – 2006 -084, T kanno et.al.
Riser design and location matters

Marginally designed risers, do not pipe, depending on process variables - what is the pressure causing feeding?

Even when the riser does not pipe, castings are sound.
Variability in process leading to variability in feeding, piping of risers and porosity in the casting

Temperature - time of gate freezing
Mold fill rate - effective cavity temperature
Inoculation - gate freezing, austenite grain size
Chemistry - CE, liquid shrinkage, sequence of phase development, Etc.
Casting cleanliness influenced by

- Melting and treatment practice
  - Materials
  - Melt practice
  - Alloys -elements
  - Time delay
  - Transfers
  - Temperature
- Mold filling
  - Pouring device -lip or stopper rod
  - Pour cup and runner system - filters
  - Gate placement and size - turbulence
  - Temperature drop
  - Mold metal reactions

Optimization of gray cast iron safety casting casted with automatic furnaces and importance of preconditioning of the melted iron, Bocardo angelo, World foundry congress, 1998, Budapest, Hungary
Does flake graphite mean ‘slag’ always?
Treatment slag - no mistake
Better quality ductile iron

1. Better dynamic properties
2. Casting soundness
3. Least impurities
4. Consistent properties
Variability in tensile properties

Y, blocks, keel blocks, modified round bars

Yield versus elongation-65-45-12 grades
Fatigue and other dynamic properties

• For the same microstructure and hardness fatigue endurance limit is lowered by:
  – Micro porosity and shrinkage cavities
  – Non-metallic Inclusions
    • reduced by better gating
  – Factors affecting fatigue properties in ductile iron
    D.Venugopalan, Al Alagarsamy, AFS Trans 1992-44 and other sources

• Impact properties affected by carbides, pearlite, inclusions - many sources

• As cast surface properties affected by graphite morphology, surface defects, shot blasting
Effect of poor gating practice on fatigue endurance, machined samples, as cast ductile iron, From previous reference

Matrix hardness – (HV)

Fatigue endurance limit, ksi

Optimized gating

Inclusions due to mold filling
Surface structure does matter

Green sand mold surface flake graphite resulted in fatigue failure

PUCB core mold graphite shape affected in area with close contact to core material
One picture is worth what?

If only we know how to listen to those words

Where is the casting whisperer when we need one?

Gases from mold explode through metal causing droplets

Ferrite band thickness and surface pearlite
Reported: Ductile iron change with time

- John Torrance - ATAS meeting
  - 5 minute delay improves GRF2 factor
- Vasko Popovski et.al. (Gregg Industries)
  - Better after five minutes of treat and inoculation
- Alagarsamy, Seaton - DIS project # 45 Also Keith Millis symposium 2008
  - Changes of surface and interior microstructure with holding time, Mg alloy and inoculation
- Dynamic and process dependent - Hence
  - Findings at different locations and practices could be different

Is ductile iron like a big mural, or a big jigsaw puzzle? And no one knows the entire picture, but only a small portion.
Did we already mention Ductile iron is complicated

• Combination of variables make it unique in every situation
  – It takes time even for established software system to make sense of existing conditions and make improvements - installation of sinter cast, ATAS for example)
  – Understanding basics helps
  – Process control in every step is very important
Micro shrinkage at cell boundaries - carbide forming elements
Lack of Nucleation during late stage solidification
Effect of pouring temperature and composition on shrinkage cavity in spheroidal graphite cast iron. AFS Trans -2006-084, T. Kanno, et.al.

Increasing temperature increases shrinkage, reduces nodule count, increases mushy freezing zone. Eutectic freezing has no shrinkage. Segregating elements increase shrinkage- cylindrical block casting no riser)

Increasing carbide forming elements (Mo), increase shrinkage propensity

Shrinkage volume

4.1 4.3 4.5 4.7
Carbon Equivalent (C+1/3Si)
Practical aspects of nodularity and its relationship to high casting yield in ductile iron, N. Rizzo, 2008 Keith Millis symposium

Shrinkage in diff carrier casting affected by graphite nodule size

Too much of a good thing?
Hot topic # 1 2004
Carbon and silicon control in ductile iron - for self feeding during eutectic solidification

Alloys without the benefit of graphite are made successfully, why then even with graphite expansion we struggle?

Directionally solidified casting

Figure 2. Carbon and silicon ranges for different section castings and irons
Testing For Process Control, Typical

- Chemistry Control
- Major and Trace Elements, spectrometer
- Cooling Curve Analysis of Base Iron (Data Cast, and others)
- Thermal Analysis of Final Iron (ATAS and others)
- Micro Coupons or Dip Sampling for Nodularity Verification
- Ultrasonic Testing of Coupons
Evaluating the process change - materials - mold filling - Filters, Placement etc. Test bars for as cast surface quality

Test bars that will be tested, top and bottom surface in bending – at three levels in Disa molds and lost foam. Cope and drag one level

Loose pieces that will be removed for testing the effect of flow offs on cope surface strength (quality) (other variations as applicable

Different mold materials can be used such as shell, cold box, warm box with different surface treatments for studying effects of different process variables
Four point bend test, quick and simple

Load span 3 to 5”
Support span 7.5”
Bar size 0.625”
deep and 1” wide,
8” long

Preferred
Pearlitic matrix
Stress relieved after shot blasting

Surface under maximum stress
Process Optimization - from floor tests

To learn about the effect of gating variables, and process variables on top surface quality

Gating variables

- bottom or top gated
- with and without flow offs
- metallostatic head pressure
- rate of vertical rise
- Use of filters, type and placement

Process variables

- Melt materials
- Treatment alloys and method
- Mold and core materials
- Temperature
- Chemistry
- Additives, slagging practice, etc

To establish and control Process variables for optimum Quality
Opportunities

• Improving mold yield (Is 50% good enough?) - Why not use the expansion of graphite to our advantage
  – gate feeding, riserless casting (Can you say 80%)
• Cleaner melt, better properties
• Mold fill - Quieter gating system
• Single mold treat and pouring system -
  – Approaching this idea: In-mold, over the mold, Holding pure Mg treated iron and delivering to mold
  – Will it reduce variation?
Riserless castings? Rudy’s recommendations?

- Near Eutectic- solidification
- Relatively small sections
- Liquid shrinkage fed from gates
- Low pouring temperature
- Hard molds
- Low levels of segregating elements

**Concerns**
- Gating
- Dross formation
- Expansion- exudation-feed back- mold strength

Super heat in cast irons versus steel and other alloys
To get superior ductile iron castings

• The entire system should be matched
  – Raw materials, melting, treating, inoculation, gating, casting design, mold filling, sand system and testing and inspection methods and philosophy

• Process control in every step
• Understanding the basics
• Do not violate physics
• Wouldn’t you like if you do not have to write any more 8-Ds?
Are you confounded yet?

If yes,
• We have done our job

If not
• Ask away
For additional information, please contact:

- **Name**: Al Alagarsamy
- **Address**: Birmingham, AL
- **Phone**: 205 919 6203
- **Email**: alagarsamy15@gmail.com
The DIS welcomes Abhay who is here to talk about “INITEK – The new Way to Make Ductile Iron” Part #1

AND

The DIS welcomes Bill who is here to talk about INITEK – Part #2

Abhay Pande - Foseco

Abhay graduated in Metallurgy and also received his MBA in International Business. He has been employed at Foseco for the last 15 years in the field of Molten Metal Transfer and Ferrous Metal Treatment products. Abhay is the product Manager for Ferrous Metal Treatment. His paper today describes a new metallurgical process for ductile iron foundries.

Bill Simmons - Foseco

Bill graduated in Metallurgical Engineering and is a Chartered Engineer. His career includes periods working in mass production iron foundries and at the British Cast Iron Research Association. Bill is the International Product Manager for Ferrous Metal Treatment products at Foseco, based in the UK. His paper today describes some of the results of Foseco’s current experience and new developments in iron foundry metal treatment.

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email:jwood@ductile.org
INITEK – The new way to make ductile iron

By

Abhay Pande - Foseco NorAm
Bill Simmons - Foseco International Limited, UK
SYNOPSIS

The newly developed 'INITEK' process consists of:

1. A specially designed ‘convertor’ ladle which has a high thermal efficiency, reducing temperature losses and increasing the recovery of magnesium;
2. ‘Initialising’ treatment of the iron with a barium alloy which has the effect of neutralising the oxygen before the addition of magnesium;
3. Treatment with magnesium;
4. Controlled timing of all the process steps to ensure that reactions go to completion;
5. Late inoculation to make a final adjustment of the metallurgy, if needed;

The efficiency of the process results in magnesium recovery of around 90%, meaning that lower Mg-additions are needed and the inoculation step is reduced. The economics of the process are greatly improved.

The problems resulting from magnesium use, of carbide tendency, risk of shrinkage, non-metallic inclusions and high cost are much less and the metal produced by this process has exceptional mechanical properties, with a greater tendency to ferrite and high elongation values. Foundries can then use raw materials which are less pure and still get the specified properties. They can work with lower amounts of pig iron and cheaper grades of steel scrap; ‘pre-conditioning’ with silicon carbide is no longer needed.

Five foundries around the world, in France, Italy, India and Australia have now adopted the process and are producing 100% of their ductile iron castings in this way. As well as considerable cost saving, the new process is robust and consistent giving less variability and tighter process limits.

LIMITATIONS OF THE CURRENT SANDWICH AND TUNDISH COVER TREATMENT PROCESSES

The ‘tundish cover process’ for the magnesium treatment of ductile iron was developed in the late 1970s, and was an improvement on the even older ‘sandwich’ process. The tundish cover process was based on the principle that by covering the ‘sandwich’ treatment ladle, the amount of available oxygen was limited during the reaction of the iron with magnesium, and thus, there would be significantly less Mg fume created, and a more economical reaction with higher and more consistent Mg-recovery. The cost of achieving these benefits was small in terms of capital expenditure and the costs could be recovered in a short time. Nevertheless, even though the tundish cover practice was simple and effective many foundries still continue to use the open ladle sandwich process.
There have been no further significant developments in the magnesium treatment operation since the development of tundish cover systems and there are many metallurgical limitations arising from the use of magnesium, which foundries have to tolerate and work around. The evolution of ladle treatment with magnesium is shown in figure 1, illustrating the changing profile of treatment vessels and the resultant recovery of magnesium.

![Image of magnesium recovery diagram]

**Figure 1. The evolution of ductile iron treatment process**

The principal problems with nodulising using magnesium are a result of:

1. Magnesium is a carbide and pearlite promoter
2. The presence of non-metallic magnesium compounds in the melt - the analysed Mg-content is ‘total magnesium’, i.e. the sum of dissolved (useful) magnesium and combined magnesium in the form of oxides and sulphides
3. Excessive Mg adversely increases shrinkage tendency
4. Economics – even with recoveries of approximately 60% the cost of Mg treatment is high
5. Variability of the process – the initial oxygen content is not measured or controlled so that magnesium going into solution varies; the non-optimum designs of ladles also create inconsistency especially during filling.
Promotion of carbides and pearlite

The carbide-promoting tendency of magnesium compels the foundryman to inoculate heavily, with an addition, which is much greater than needed for grey iron. Since inoculants are silicon-based, this can lead to higher cost for the silicon in the castings as a result of the use of expensive silicon in the inoculant instead of cheaper charge silicon, or (even cheaper) silicon in return scrap.

The pearlite promoting effect also imposes costs and technical constraints on the producers of ferritic grades of ductile iron; to compensate for the Mg-effect it is necessary to manage the content of other pearlite promoting elements (such as Mn, Ni, Cu, Sn) and use a higher silicon content, which must be done by using expensive, purer melting charges, with high-purity pig iron or a greater content of higher quality, expensive steel scrap. The manganese level is controlled as follows in as-cast grades, showing how the producers of ferritic ductile iron with high elongation are driven to use low-Mn charge materials:

<table>
<thead>
<tr>
<th>Casting section</th>
<th>800/2, 700/2, 600/3</th>
<th>500/7</th>
<th>420/12</th>
<th>370/17</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;13mm</td>
<td>0.5</td>
<td>0.30</td>
<td>0.20</td>
<td>0.10</td>
</tr>
<tr>
<td>13 – 25mm</td>
<td>0.6</td>
<td>0.35</td>
<td>0.25</td>
<td>0.15</td>
</tr>
<tr>
<td>25 – 50mm</td>
<td>0.7</td>
<td>0.40</td>
<td>0.30</td>
<td>0.15 – 0.20</td>
</tr>
<tr>
<td>50 – 100mm</td>
<td>0.8</td>
<td>0.50</td>
<td>0.35</td>
<td>0.20</td>
</tr>
<tr>
<td>&gt;100mm</td>
<td>0.8</td>
<td>0.60</td>
<td>0.40</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Table 1: Maximum recommended manganese level in different grades of as-cast ductile iron

Specifications for mechanical properties are written around the iron that is produced by the existing processes, and a new process that overcomes the limitations imposed by use of excess magnesium will allow new ranges of properties to be achieved.

Inoculant fade means that treated iron has to be poured within a short time, and this influences the treatment cycle and the layout of the foundry, meaning smaller treatments must be done.
**Non-metallic magnesium compounds**

The dissolved Mg level required for complete conversion of graphite into nodules is approximately 0.030% (figure 2) \(^3\); foundries usually work with a target Mg content of 0.035 – 0.045% and it is very common to find much higher Mg levels. The Mg above this value that is found by chemical analysis is present as magnesium oxides and sulphides and as excess dissolved Mg.

The dissolved silicates, oxides and sulphides of magnesium are large non-metallic inclusions, which form dross and slag and have to be removed by de-slagging or by filtering in the mould. They also reduce the fluidity (i.e. the ability of the iron to fill thin sections of castings). The formation of dross is governed by the oxygen content, which in turn varies according to turbulence and the cycle time of the foundry.

![Figure 2. Relationship between Mg content and graphite form](image)

The excess of dissolved magnesium promotes carbides and pearlite, and as a result excessive inoculation is needed.
Shrinkage tendency

There is a further effect in that excess Mg above 0.045% increases the tendency to shrinkage (figure 3). Many foundries have incidents when the Mg level spikes at 0.060% or even higher and this is probably the cause of occurrences of scrap from carbides, inclusions or shrinkage. Variability in Mg recovery means that consistent shrinkage behaviour cannot be guaranteed, so foundries must design the casting methods with an added safety margin. This, plus the extra scrap means that overall foundry yields are lower than they should be.

Figure 3. The effect of magnesium content on the freezing range of ductile iron
Economics

The cost of magnesium has risen sharply, and in the past half-year the cost of rare earths has multiplied by a factor of six times. Even with a good magnesium yield of 60% in the tundish cover process, plus a similar or lower yield in the production of FeSiMg, the process is costly; the current price of magnesium ingot on European metal markets is about $3,000 per tonne, meaning that foundries are paying the equivalent of $8,000 per tonne for the magnesium contained in ductile iron castings.

However the major cost penalties are found in the necessity to use low-Mn charge materials for ferritic grades and in the lower foundry yield that results from the variability of the Mg-process.

VARIABILITY OF THE MAGNESIUM TREATMENT PROCESS

Foundries measure the sulphur content of iron, and calculate the magnesium addition, using the time-honoured formula:

$$\text{Mg Recovery} \% = \frac{\% \text{Mg}_R + 0.76(\% \text{S}_I - \% \text{S}_F)}{\% \text{Mg}_{\text{Alloy}} \times \% \text{Alloy}} \times 100\%$$

where:
- $\% \text{Mg}_R$ = Residual, analysed Mg content of the iron
- $\% \text{S}_I$ = Initial % sulphur
- $\% \text{S}_F$ = Final % sulphur
- $\% \text{Mg}_{\text{Alloy}}$ = % Mg in the treatment alloy

This can be rewritten as:

$$\text{Addition} \% = \frac{\% \text{Mg}_R + 0.76(\% \text{S}_I - \% \text{S}_F)}{\% \text{Mg}_{\text{Alloy}} \times \% \text{Recovery}} \times 10,000$$

This simple calculation takes no account of the other major variable in the base iron, - the oxygen content, which is almost never measured, because of the difficulty and cost of measurement. However oxygen reacts with Mg and rare earths in the nodulariser. Oxygen is absorbed into the iron from exposure to atmosphere, from rusty charge materials, from moisture and from ferroalloys. The spectrometer analysis of magnesium content includes:

- Mg–oxides and silicates and sulphides which have not yet floated into the slag
- Dissolved Mg which is available to transform the graphite from flakes to spheroids
- Excess dissolved magnesium
It is the variability of oxygen content, which can cause variation in the amount of dissolved Mg, thus affecting nodularisation and nucleation.

Attempts have been made to minimise this variability by a variety of techniques, known as ‘pre-conditioning’, including adding silicon carbide in the furnace, adding Ba-inoculants at the same time as the magnesium alloy, adding Al-containing inoculants etc, however all of these techniques give inconsistent results.

FOSECO’S NEW INITEK PROCESS

The new ‘INITEK’ process, developed by Foseco, and now in regular use in a number of foundries around the world addresses all these deficiencies by a 5-part process:

1. Use the specially-designed Foseco convertor (figure 4) which increases magnesium-recovery and reduces temperature loss
2. INITIALISE the iron with INODEX alloy to neutralise the oxygen and ensure that the oxides are present in the form of micro-inclusions, rather than in the form of dross
3. Magnesium treatment at the correct time after initialising
4. A small late stream inoculation, using MSI 900 or MSI+DC for final trimming if necessary

5. All controlled on the foundry floor with ITACA thermal analysis software

Figure 4. The Foseco Convertor, for the INITEK process
The benefits of this process are:

- Magnesium recovery in the range of 75 – 98%, depending on convertor size
- The variable oxygen in the base melt no longer combines with magnesium to form dross, but becomes suspended micro-inclusions of oxide which have a powerful inoculating effect. The magnesium addition can be much lower because it is no longer wasted as a de-oxidiser, and because the oxygen variable has been neutralised by INODEX it is no longer necessary to add a safety margin of excess magnesium
- The freedom from excess dissolved magnesium results in a 'soft' iron with very high elongation. To achieve the same properties foundries do not need to reduce the manganese content, and can use less pig iron with cheaper, less pure steel scrap
- The thermally efficient design of the convertor allows lower tapping and treatment temperatures
- Very high fluidity results from the absence of dross and so pouring temperatures can be lowered, which can reduce the cost of shot-blasting and fettling.

The Convertor

The Convertor is a prism shaped treatment vessel with carefully calculated ratios of dimensions (patent applied for). The features of this shape are that in the horizontal position the surface area which is losing heat to atmosphere is smaller than in a cylindrical vessel (figure 5), and when in the upright position the metallostatic head is greater, which increases the recovery of magnesium. The Convertor is lined with KALTEK ISO insulating refractory for maximum insulation and reduced heat loss.

INODEX

INODEX is a newly developed alloy that was specially designed for the Initialising process (patent applied for); the composition is given in table 2:

<table>
<thead>
<tr>
<th>Silicon %</th>
<th>Barium %</th>
<th>Manganese %</th>
<th>Zirconium %</th>
<th>Aluminium %</th>
<th>Calcium %</th>
<th>Grain size distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>46 - 50</td>
<td>7 - 11</td>
<td>1.5 – 2.5</td>
<td>1.5 – 2.5</td>
<td>&lt;1</td>
<td>1.2 – 1.8</td>
<td>0.5 – 25mm</td>
</tr>
</tbody>
</table>

Table 2: composition of INODEX alloy

The alloy is a powerful de-oxidiser and contains other elements to lower the melting point and neutralise nitrogen in iron.
NODULANT

NODULANT 016 or NODULANT 116 are used in the INITEK process. Their compositions are given in table 3:

<table>
<thead>
<tr>
<th></th>
<th>Mg%</th>
<th>Si%</th>
<th>Ca%</th>
<th>Al %</th>
<th>Rare Earths %</th>
<th>Grain size distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>NODULANT 016</td>
<td>5.5-6.5</td>
<td>42-50</td>
<td>0.8– 1.6</td>
<td>&lt;1</td>
<td>&lt;0.25</td>
<td>4 – 10</td>
</tr>
<tr>
<td>NODULANT 116</td>
<td>5.5-6.5</td>
<td>42-50</td>
<td>0.8– 1.6</td>
<td>&lt;1</td>
<td>0.4 – 0.7</td>
<td>4 -10</td>
</tr>
</tbody>
</table>

Table 3: compositions of NODULANT for the INITEK process

OPERATION OF THE PROCESS (figure 5)

The process begins with a light preheat of the convertor, then it is moved to the furnace, in its horizontal position, with the pocket charged with NODULANT and INODEX placed in the body. Cover steel is not required in the INITEK process. Iron is tapped into the convertor while it is still in the horizontal orientation, dissolving the INODEX into solution.

Figure 5. The characteristics of the Foseco Convertor, compared to a cylindrical treatment ladle
There is then a carefully measured time delay to allow the deoxidation reaction to take place before the convertor is rapidly rotated to vertical for the magnesium reaction to take place. Close the lid of the convertor during the time delay. After completion of the Mg-reaction the slag can be removed before transferring the iron to the pouring furnace or going directly to pouring the iron into the moulds – it is not necessary to transfer the iron into pouring ladles.

Practical benefits are that:
- Tapping temperatures can be 30 - 100ºC lower because of the thermal efficiency of the convertor and the low addition rate of magnesium alloy
- Magnesium recovery is in the range of 75 – 98%
- No covering material, such as steel punchings is required
- The inoculation step after nodularising is usually eliminated. Occasionally a light final late stream inoculation is used
- The reaction is quiet and there is very little fume escaping to atmosphere
- A very dry ‘pop-corn’ slag is created which is easy to remove, and compared to normal ductile iron's sticky viscous slag, very little iron is pulled off with the slag
- Pouring temperatures are greatly reduced due to the freedom from dross which means the iron is very fluid

COST SAVINGS FROM THE INITEK PROCESS:

Cost savings can add up to as much as €75/tonne of liquid metal – made up of:

Reduced metal treatment alloy costs

Less magnesium alloy is used, inoculation is lower, cover steel is eliminated, and less slag coagulant is needed

Reduced energy consumption

Reductions of 30 – 40º in tapping temperature for superheating the iron save electricity costs and give longer lining life in the furnaces. The convertor needs very little preheating with gas torches.

Reduced costs in the fettling shop

Low pouring temperatures lead to shot blasting and cleaning costs being cut in half, because mould-metal reactions are greatly reduced
Lower costs for melting stock

Charge and alloying costs are much lower because the INITEK process produces a very soft, ferritic iron with very high elongations. This means that foundries can adjust the elongation properties back down to the specification by replacing pig iron and pure steel scrap with cheaper steel scrap, which contains higher levels of manganese. Sometimes it is necessary to add extra ferromanganese in the furnace charge.

Lower scrap rates

Because of the effect shown in figure 2, scrap caused by shrinkage is lower. The dry nature of the slag and the ease and effectiveness of de-slagging reduces inclusion scrap. Hardness problems are less frequent because of the ferritic structure as described above.

A more consistent process

The INITEK process has very little variability because the treatment with INODEX before the magnesium step means that oxygen is no longer a variable when tapping induction furnaces it is common for the time to cover the Mg alloy with iron to be variable – this effect is eliminated because the convertor rotates rapidly from horizontal to vertical in a consistent manner; and temperature losses during metal transfers are less.
CASE STUDY 1 – Australian foundry making Grade 500/7 ductile iron

The Problem

Inconsistent and poor quality steel scrap which compelled the foundry to monitor and test every treatment, make constant adjustments and there was a high number of rejected treatments. A high addition rate of FeSiMg was used in order to overtreat for the worst case situation, which led to high residual Mg levels and high pearlite in the microstructure – castings then had to be annealed.

The Solution

The INITEK process was installed in the foundry with a 700kg capacity convertor (figure 6) using 0.4% of INODEX; the results are:

FeSiMg addition reduced from 1.7% to 1.1%, recovery increased and cover material removed
Ladle inoculation eliminated
Environmental improvement in the foundry due to less MgO fume during treatment
Casting quality improved and consistent – consistent nodularity, and improved physical properties
Heat treatment eliminated on some castings.

Figure 6. 700 kg Convertor in use
CASE STUDY 2 – French foundry making a range of grades of ductile iron

The Problem
This foundry makes a range of jobbing castings up to weights around 2 tonnes; many of these are, for example, for the windmill industry, where properties and quality are highly specified. The foundry required a consistent process which would give good metallurgical results.

The Solution
The INITEK process was implemented in the foundry using convertors of 1 tonne and 2 tonne capacity, and an INODEX addition of 0.4%. The savings can be summarised as follows in Table 4:

<table>
<thead>
<tr>
<th>Cost changes</th>
<th>VALUE € per tonne of liquid iron</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nodularising and inoculation costs</td>
<td>-7.8</td>
</tr>
<tr>
<td>Refractories</td>
<td>+2.8</td>
</tr>
<tr>
<td>Energy</td>
<td>-8</td>
</tr>
<tr>
<td>Metallic charge – pig iron and steel scrap</td>
<td>-31</td>
</tr>
<tr>
<td>Casting cleaning, shot-blasting &amp; grinding</td>
<td>-30</td>
</tr>
<tr>
<td>TOTAL</td>
<td>74</td>
</tr>
</tbody>
</table>
Case study 2: cost savings from the INITEK process

The processes used before and after, including the mechanical properties achieved in this foundry for grade 350-22-LT ductile iron are shown in Table 5. The elongation and low temperature impact properties are significantly improved when switching from tundish cover process to INITEK process, even though the charge, with less pig iron and more steel scrap is cheaper and would be considered as low grade. The Mn content is higher and the Si content is reduced, which would normally reduce the elongation properties.

<table>
<thead>
<tr>
<th>Furnace charge &amp; metal treatment:</th>
<th>Previous Tundish cover process</th>
<th>INITEK process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pig iron</td>
<td>80%</td>
<td>40%</td>
</tr>
<tr>
<td>Steel</td>
<td>15%</td>
<td>55%</td>
</tr>
<tr>
<td>FeSiMg</td>
<td>1.775%</td>
<td>1.00%</td>
</tr>
<tr>
<td>INODEX</td>
<td>0</td>
<td>0.4%</td>
</tr>
<tr>
<td>Tap temperature ºC</td>
<td>1520</td>
<td>1450</td>
</tr>
<tr>
<td>Composition %</td>
<td>C 3.45, Si 1.99, S 0.003, Mn 0.10, Mg 0.043</td>
<td>C 3.64, Si 1.78, S 0.010, Mn 0.23, Mg 0.039</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanical properties specification and achieved:</th>
<th>Previous Tundish cover process</th>
<th>INITEK process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rm, Mpa</td>
<td>350</td>
<td>415</td>
</tr>
<tr>
<td>Rp 0.2</td>
<td>220</td>
<td>260</td>
</tr>
<tr>
<td>A %</td>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td>KV -40ºC</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>HB</td>
<td>150 max.</td>
<td>155</td>
</tr>
</tbody>
</table>

Table 5: comparison of tundish cover process and INITEK process in case study 2
CONCLUSIONS

The INITEK process is a major advance in ductile iron treatment practice; it gives the foundry:

1. Significant cost savings, up to €70 per liquid tonne, coming from:
   a. Reduced cost of treatment alloys
   b. Reduced energy consumption
   c. Lower metal temperatures
   d. Cheaper materials for melting, i.e. less pig iron and cheaper steel scrap
   e. Lower scrap rates
   f. Reduced shotblasting and cleaning of castings
2. Improved mechanical properties, principally elongation, but also low temperature impact properties
3. Improved process consistency with less variability of results
4. At the time of writing the INITEK process has been fully adopted by 6 foundries around the world and is in trials in a further 16.

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Don Craig - Selee Corporation

Don graduated with his Bachelor of Science in 1980 from Mount Allison University. He then received his Bachelor of Engineering from the Technical University in Nova Scotia in 1982. He then received his Masters of Applied Science in Metallurgy a year later. Don was not finished yet, so he moved over to the University of Buffalo and received his Master of Business Administration in 1991. From 1983 to 1987, don worked as a metallurgist at Wabtec – Wallaceburg Foundry. He then moved on to Elkem Metals from 1987 to 1994 as a market development Engineer at the development center and then as a Quality Engineer at the Ashtabula Plant. He then moved on to NYCO Minerals as Director of Quality and Process Engineering from 1994 to 1998. In 1998, he went to Wheland – Warrenton Foundry as Technical director and then in 2001 he change companies and moved to Selee Corporation and is currently the Senior Metallurgist – Foundry Filtration Methods. Don is a past Director of the DIS and member of the DIS Research Committee. He is also a current member of the AFS 5H – Grey Iron Research.

The DIS welcomes Don who is here to talk about “Identification & Elimination of Inclusion Defects in Ductile Iron Castings”
Identification and Elimination of Inclusion Defects in Ductile Iron Castings

Don Craig
Selee Corporation
Typical Inclusions that occur in Ductile Iron

- Slag
- Dross
- Sand
- Gas
Classification of Inclusions

• Inclusions in metals are classified into one of two categories depending on their source of origin:
  – Exogenous
  – Indigenous
Exogenous Inclusions

• Exogenous inclusions originate from foreign materials that the molten metal contact and entrain during melting, handling and pouring of the metal.

• Examples are:
  – eroded refractories
  – eroded mold sand and core materials
  – Slag from Melting Process
  – Un-dissolved Inoculants
Indigenous Inclusions

• Indigenous inclusions form as the result of precipitation reactions within the molten metal

• Two Sub-Types
  – *Primary Indigenous*: Formation occurs before solidification
    – *Ex*: MgS  *Dross in nodular iron*
  – *Secondary Indigenous*: Formation occurs during or after the onset of solidification,
    – *Ex*: Gas bubble
Frequent Primary Indigenous Inclusions in Ductile Cast Iron

• One major source of dross and slag in Ductile iron is the result of the addition of magnesium or magnesium alloys.
  
  • XRD analysis of dross indicates it is comprised of MgO, SiO₂, Mg₂SiO₄, MgSiO₃, MgS, Al₂O₃, Fe₂SiO₄, silicides and amorphous silicates.

• Second Major source of dross and slag in Ductile iron is the result of re-oxidation of the metal due to turbulence within the flow of metal.
Frequent Secondary Indigenous Inclusion in Ductile Iron

Oxides entrained in the liquid iron will react with carbon during the solidification of the ductile iron:

\[
\text{FeO}(l) + C = \text{Fe}(l) + \text{CO} \text{ (g)}
\]

\[
\text{SiO}_2(s) + 2C = \text{Si}(l) + 2\text{CO}(g)
\]
Case Studies for Identification and Elimination of Inclusion defects
Case 1

Inclusion Defect on a Cast surface
Key Features
(Gas void + Slag + Flake Graphite)

Highlighted Area
Defect Identification

CO gas + Metal oxide slags

Iron Oxide

MgO*SiO2*FeO
Defect Analysis

• Observations
  • CO gas void – Metal oxide slags

• Root Cause
  • Excessive turbulence within the metal flow during the filling of the mold

• Corrective Action
  • Flow Modification using foam filters
Case 2
Inclusion Defect on a machined surface
Key Features
(Gas void + Sand)
Defect Identification
CO gas + Sand + Clay + Metal oxide slags

Sand
Clay
FeO

DIS T&O Meeting, October 26 -28, 2011
Gettysburg, PA
Defect Analysis

• Observations
  • CO gas void + Sand + Clay + Metal oxide slag

• Root Cause
  • Mold Erosion due to turbulence of metal during filling of mold

• Corrective Action
  • Flow Modification using foam filters
Case 3

Inclusion Defect on a Cast surface
Key Features
(Gas void + Slag + Iron Droplets)
Defect Identification
CO gas + Metal oxide slags + Droplets

MgO-SiO$_2$-CaO-Al$_2$O$_3$-MnO

MgO-SiO$_2$-CaO-Al$_2$O$_3$

Iron Droplets
Defect Analysis

- Observations
  - CO gas void – Metal oxide slags – Iron droplets

- Root Cause
  - Turbulence within the metal flow during filling causing re-oxidation of the liquid metal

- Corrective Action
  - Flow Modification using foam filters
Case 4
Identification of Inclusion Defects on a machined surface
Case 4
Identification of Inclusion Defects
on a machined surface
Case 4
Identification of Inclusion Defects on a machined surface
Key Features
(Gas void + Dross + Sand)
Defect Identification
CO gas + Metal oxide Dross + Sand

SiO$_2$ *CaO *MgO

Sand Grains
Case 4
Identification of Inclusion Defects on a machined surface
Key Features
(Gas void + Dross + Sand)
Defect Identification
Gas Void + Dross + Sand

SiO₂ *CaO *MgO
Defect Analysis

• Observations
  - CO gas void – Metal oxide Dross – Sand

• Root Cause
  - Dross Entrainment in liquid metal and turbulence of metal during filling of the mold

• Corrective Action
  - Correct selection and placement of foam filters
Case 5
Inclusion Defects on a Cast surface
Key Features
(Gas void + Slag + Sand)
Defect Identification
Gas Void + Metal Oxide Slag + Sand

Sand Grains

Bentonite Clay

$\text{SiO}_2 \cdot \text{Al}_2\text{O}_3 \cdot \text{MgO} \cdot \text{Ce}_2\text{O}_3 \cdot \text{MnO}$
Defect Analysis

• Observations
  • CO gas void – Metal oxide Slag – Sand

• Root Cause
  • Erosion of mold due to excessive turbulence of the metal during filling of the mold

• Corrective Action
  • Correct selection and placement of foam filters
Case 6
Inclusion Defects on a Cast surface
Key Features
(Gas void + Metal oxide Slag + Sand)

Highlighted Area

500μm

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Gettysburg, PA
Defect Identification
Gas Void + Metal Oxide Slag + Sand
Defect Analysis

• Observations
  - CO gas void – Metal oxide Slag – Sand

• Root Cause
  - Erosion of mold due to excessive turbulence of the metal during filling of mold

• Corrective Action
  - Correct selection and placement of foam filters
Case 7
Inclusion Defects on a machined surface
Key Features
(Gas void + Metal oxide Slag + Iron Droplets)
Defect Identification
Gas Void + Metal Oxide Slag + Iron droplets

SiO$_2$ - MgO - Ce$_2$O$_3$
Defect Analysis

• Observations
  • CO gas void – Metal oxide Slag – Iron droplets

• Root Cause
  • Slag Entrainment in liquid metal due to excessive turbulence of metal during filling of the mold

• Corrective Action
  • Correct selection and placement of foam filters
Case 8
Inclusion Defects on a machined surface
Key Features
(Gas void + Metal oxide Slag + Sand)

Highlighted Areas

DIS T&O Meeting, October 26-28, 2011
Gettysburg, PA
Defect Identification
Gas Void + Metal Oxide Slag + Sand

DIS T&O Meeting, October 26-28, 2011
Gettysburg, PA
Defect Analysis

• Observations
  • CO gas void – Metal oxide slag – Sand

• Root Cause
  • Erosion of mold due to excessive turbulence of metal during filling of the mold

• Corrective Action
  • Correct selection and placement of foam filters
Case 9
Inclusion Defects on a cast surface
Key Features
(Gas void + Metal oxide Slag + Sand)
Defect Identification
Gas Void + Metal Oxide Slag + Sand + inoculant

SiO$_2$ - MgO
FeO
FeSi
CaO - Al$_2$O$_3$

DIS T&O Meeting, October 26-28, 2011
Gettysburg, PA
Defect Analysis

• Observations
  
  • CO gas void – Metal oxide slag – Sand - Inoculant

• Root Cause
  
  • Slag and Inoculant entrainment in liquid metal plus erosion of the mold due to excessive turbulence of metal during filling of the mold

• Corrective Action
  
  • Correct selection and placement of foam filters
Case 10

Inclusion Defects on a machined surface
Key Features
(Gas void + Smooth Surface + Graphite Layer)

Highlighted Area
Defect Identification
Gas Void + Graphite layer + Decarburized area

Graphite Layer
Decarburized
Defect Analysis

• Observations
  • Hydrogen gas void – Decarburized zone – Smooth Surface

• Root Cause
  • Absorption of hydrogen by the molten iron from a source of excess moisture in the casting process

• Corrective Action
  • Locate and eliminate source of excess moisture in metal handling and pouring process
Case 11
Inclusion Defects on a machined surface
Key Features
(Gas void + Smooth Surface + Graphite Layer)
Defect Identification
Gas Void + Graphite layer + Decarburized area
Defect Analysis

• Observations
  • Hydrogen gas void – Decarburized zone – Smooth Surface

• Root Cause
  • Absorption of hydrogen by the molten iron from a source of excess moisture in the casting process

• Corrective Action
  • Locate and eliminate source of excess moisture in metal handling and pouring process
Summary

• Sample preparation is critical – Recommend vacuum impregnation for edge retention

• Examine external surface and polished cross section of defect to generate clues

• Utilize clues to understand the physics that control the formation of the inclusion material

• Develop hypothesis for the defect’s root cause

• Test corrective action to reduce or eliminate defect formation in casting
For additional information, please contact:

- Don Craig
- SELEE Corporation
- 700 Shepherd Street,
- Hendersonville, NC 28732
- 828-606-2532
- dcraig@selee.com
- www.selee.com
PRESENTATION: The Environmental Approach to Reduced Waste and Increased Metal Recovery by In-House Slag Processing

David Roth - GPS Global Solutions

David graduated from the University of Missouri with his Bachelor of Science in Metallurgical Engineering. David has over 35 years of experience in the aluminum industry. He has worked for Alcoa and ARCO Aluminum as a metallurgist, process control manager and Director of technology. He then moved on the ALTEK for 25 years and was involved in dross handling projects, casting projects and furnace installations. As a principle and President of the company, David oversaw all aspects of ALTEK dross handling systems and engineering services. Currently the President of the new venture GPS Global Solutions, he is focused on processing various metal slags and drosses with the goal of total metal removal and ultimately zero land fill waste. This venture with Didion takes him into new areas of recovery of metal and oxide products from other metals including aluminum. David has over a dozen US and International patents, and has published numerous international articles.

The DIS welcomes David who is here to talk about “The Environmental Approach to Reduced Waste and Increased Metal Recovery by In House Slag Processing”
History of Mechanical Slag Processing

David J. Roth
President – GPS Global Solutions
Maximizing Slag Values & Reduction of Land Fill Materials

- Financial Opportunities
- History Mechanical of Dross Processing
- RT/ TUMBLER Processing
- Environmental Opportunities
Financial Opportunities

Chart 1: North American Hot-Rolled Coil Prices vs Benchmark Scrap Prices (to Feb)

Source: FactSet, IHS Global Insight, UBS estimates
History of Mechanical Dross Processing

- Ball Mill Processing System
- Roller Crusher Processing System
- Hammer Mill Systems
- Horizontal and Vertical Shaft Impactors
- RT/TUMBLER Crushing/Cleaning Systems
Ball Mill Processing System

- Pre Crushing Required
- Input Size Restriction
- Expendable Media
- Product Screening

- Al Fines Generation
- Fe Contamination
- Oxide Roll In
Roller Mill Processing Systems

- Pre Crushing Required
- Input Size Restriction
- Product Screening
Hammer Mill Processing Systems

- Pre Crushing Required
- Input Size Restriction
- Artificial Size reduction
- Product Screening

- Al Fines Generation
- Fractured Oxide Content
- Secondary Impacting

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Gettysburg, PA
Horizontal/Vertical Shaft Impactors

- Pre Crushing Required
- Input Size Restriction
- Product Screening

- Shear Particle Reduction
- Secondary Crushing
- Tertiary Crushing
Charging of Slag
RT Model 84 - 2100 System
THE DIDION ROTARY TUMBLER/METAL RECLAIMER

ADVANTAGES AND FEATURES:
- PATENTED DESIGN CRUSHES, CLEANS, SEPARATES, SCREENS AND AIR WASHES TO RECLAIM VALUABLE METALLICS.
- LESS EQUIPMENT, FLOOR SPACE, AND INSTALLATION COST.
- LOWEST MAINTENANCE COST PER TON WORLDWIDE.
- AUTOMATIC MUSCLE AND AUTOMATIC RECONDITIONING ENSURES MAXIMUM SEPARATION AND CLEAN METALLICS.
- BATCH OR CONTINUOUS PROCESS, WITH NO OPERATOR REQUIRED.

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Gettysburg, PA
Benefits of the RT/TUMBLER Processing

- Accept Large Feed Materials
- Separates Metallics from Slag – Mechanically
- Dust Free System for Slag for Processing
- Sizes Fractions for Potential By Products Sales
- Low Maintenance and Operating cost
- Simple Compact System
Autogenous Crushing
RT /TUMBLER Feed Material
Final Products Range
RT/TUMBLER Processing Products

- Scrap for Steel Industry
- Recycled Flux And Slag Conditioners
- Aggregates for Road Fill
- Cement Industry Raw materials
- More compact land fill package

DIS T&O Meeting, October 26-28, 2011
Gettysburg, PA
Raw Steel Slag
Summary - RT / TUMBLER Processing

- A RT/TUMBLER System is simple and straightforward to operate without skilled labor within the slag generating facility.

- A RT/TUMBLER System is low in operating and maintenance cost for slag generating facilities.

- A RT/TUMBLER System can recycle slag in an environmentally efficient way preserving metal units and generating potential by product steams.

- A RT/TUMBLER will process slag for Significantly more Financial and Environmental Benefit than land filling.

- Typical Payback is less than 1 year.
Thank you!

For additional information, please contact:

- David Roth
- GPS – Global Solutions
- 610 – 476 - 0275
- david.roth@global-solutions.us.com
- www.didion.COM
Alex Pardo - Hitachi Metals Automotive Components

Alex graduated from Penn State University in 2010 with a degree in Industrial Engineering, with a focus on manufacturing. At Penn State, he worked extensively at the Learning Factory and on the Penn State FSAE team. His hometown is Pottstown, PA, just outside of Philadelphia and is currently living in Painted Post, NY. Alex is currently the Process Engineer for Hitachi Metals Automotive Components in Lawrenceville, PA.

The DIS welcomes Alex who is here to talk about “Implementation of Thermal Analysis to Reduce Shrinkage Defects in Ductile Iron Castings”
Around this time last year, I was a fresh out of college engineer who had no idea what they were doing in a foundry. I had just gotten my degree in Industrial Engineering from Penn State a few months before that, and with some luck and skill, I was hired by Hitachi Metals Automotive Components as a process engineer. I was excited for the opportunity, but I had no idea what to expect. I figured I would get some smaller jobs that no one would notice if I messed up, on the way to bigger and more important ones if I was able to show competency and a good work ethic.

Needless to say, I was quite surprised when my first project I was given was the keys to a very expensive thermal analysis system, and I was given the task of reducing the scrap fallout at our machine shops of a part that we made several thousand sets of a month. I didn’t know a lot about the theory behind the whole system at first. Sure, I had my college education and I recognized a lot of the words that were thrown around in the context of this system, but I didn’t have much to go on beyond that. But I saw this as a terrific opportunity, and I always knew that if there was something I didn’t understand there were plenty of people around me who had the answers I was looking for.

Fortunately, my role in the implementation of this ATAS (adaptive thermal analysis system) was mostly on the physical installation of the testing units and data collection, both of which I was very familiar with. I spent most of my college years working on Penn State’s Formula SAE team, which is a club where a bunch of sleep deprived college kids build a racecar from scratch with little to no faculty supervision. The bulk of my college classes dealt with how to collect data and analyze it properly, so I was well suited to tackle the task ahead of me.

The first thing you need to understand in why we went with ATAS is how our facility is set up. HMAC Lawrenceville (located in Lawrenceville, PA) makes small to medium ductile iron castings for the automotive industry. For the most part, we make knuckles and control arms, and a few brackets as well. We have two 10 ton electric induction melt furnaces, which is where all of the scrap steel, sprue and pig iron are melted down. At this stage, the operator adds carbon alloy to the melt, which is the only spot in our whole process where carbon is added. When the charge is complete, the furnace is tapped over into our 60 ton electric induction holding furnace. Here, the iron is poured into individual transfer ladles, which is also where the rest of our alloy (copper, silicon and magnesium) are added. The transfer ladle then is taken by overhead crane to one of our two Meka pouring units, one of which sits over a Disamatic 2013 molding machine and the other over a Disamatic 2070 molding machine.

We control our carbon content by keeping the holding furnace at a target carbon value. So if the holding furnace is a little low, we will deliberately add more carbon to the melt furnace we are tapping over from to bring the holding furnace into specification. Likewise, if the holding furnace carbon level is too high, we will tap over a melt furnace charge that has a little lower carbon value.
The reason we decided to implement a thermal analysis system was due to shrinkage problems we were having with a rear trailing arm that we make. A lot of the parts we make have complex geometries, and this part was no different. Due to the nature of how the part sits in the pattern, feeding a riser to the isolated boss that was causing the problem wasn’t possible. Even with a lack of risers, you can still avoid some shrinkage issues as long as your chemistry is within a very tight range. The customer specifications were very broad, so we had some runs with very little shrinkage defects, and others with a lot of shrinkage problems. Further exacerbating the problem was we couldn’t see the defect until after we machined it, so there was a lot of wasted part movement and tooling used up at our machine shops. We would be anywhere from 3%-10% scrap at the machine shop, so this was a serious problem.
I won’t spend too long going into what thermal analysis is. Essentially, you can control your carbon by analyzing the cooling curve (specifically the active carbon equivalent) of a sample of iron. Everyone is familiar with carbon equivalent, and everyone is also familiar with the fact that the accepted equation changes rather often. From a process control standpoint, controlling ACEL is much easier than trying to control the CE. When you add up the variation in all of the individual elements, you end up with a very large range where your CE could actually be. Since ACEL looks almost exclusively at the Liquidus temperature of the iron, there is only one factor that needs to be controlled, which greatly reduces variation.

My role in this wasn’t the theory of how the system works, it was implementing it in a way that was simple and repeatable for our employees. After Novacast did their initial training and dropped off the equipment we needed to take samples, I began the process of teaching the employees how to use the new hardware we received, getting their input on how to make the testing better, and at the same time trying to figure out how the software worked and the theory behind all of it. A lot of the initial improvements came right from the employees on the floor, such as mounting the test stands for the quick cups in an ergonomic position, creating funnels to capture the loose sand from pouring the samples, and installing lights to inform the operators when the system was sampling and when it was done. I used this opportunity to glean some knowledge from the employees on the floor. A lot of them had been working in a foundry since I had been in diapers, so it was good to get another perspective on how to run this operation.

After a lot of data collection and process improvements, it was time to crunch the data. Ideally, you will always hit the eutectic point of solidification in your iron, where iron and graphite are forming at the same time. For parts with simple geometry, hitting the eutectic point with your chemistry isn’t that critical, you just need to get close enough. The part in question for us though, had very complex geometry and as such we had to hit a very tight range near the eutectic point to prevent shrinkage defects. We never had any problems with hyper eutectic iron (that is, iron with too much carbon in it. The graphite precipitates first, forming large exploded nodules that robs the liquid iron of graphite to fill up space). We mostly had problems with hypoeutectic iron, or iron without enough carbon in it. Without graphite nodules forming to take up volume in the cavity of the casting, there wasn’t enough liquid iron left to feed the solidifying outer layers, resulting in a liquid-solid shrink defect.

When we looked at the data, and we could see that some of our runs showed eutectic solidification (when we were at the upper end of our carbon limit) and other runs showed hypoeutectic solidification. When we collected the scrap data from our machine shops, it was clear what the common denominator was. Production runs with low (<4.26) ACEL values had a lot of shrinkage scrap at the machine shop, while runs with ACEL values around 4.28 to 4.3 had almost no shrinkage fallout. Once we had the data that proved ACEL values around 4.3 were optimal for this part, we created a way to make sure that the melt operators could use this software to consistently hit a very tight ACEL range.
The date that gave our best scrap levels was actually a day where the operator experimented with the carbon addition function on the Novacast software itself. He added the amount of carbon that the program said was needed, and as a result, hundreds of parts had to be quarantined because they were out of specification. When we X-Rayed them, there wasn’t even the slightest amount of shrinkage visible (even on other good runs there was always a little bit of shrinkage). Needless to say, we altered the acceptable range and then went about devising a plan to control the carbon at the melt furnaces.

The only downside of the Novacast carbon addition system is that it isn’t particularly suited for how we control our iron at HMAC. Like I mentioned before, we always try to keep our holding furnace at a specific target, and we alter the melt furnaces to make that happen. We created a simple spreadsheet that allowed the operator to plug in the ACEL values he got at the holding furnace and melt furnace, and based off of that number, we would be able to add enough carbon to the melt to keep the holding furnace within its ACEL specifications. As I had done throughout this process, I made sure I stayed on all 3 shifts at some point during the week to make sure that the operators understood the system and knew how to use the software and the spreadsheet to determine carbon addition.

In the end, the thermal analysis system helped us a lot. We went from 3%-10% scrap at the machine shops to less than 0.5% scrap for this part. There are still a lot of features that the thermal analysis system offers that we are going to try to take advantage of, and in due time we will be able to use the entire software package to help us create quality castings as efficiently as possible.

Presentation:  Profitable Growth Through Business Innovation

Dileep Thatte - NIST

Dileep Thatte graduated with his Masters in Chemical Engineering and he also obtained his Master’s in Business Arts. Dileep has been a senior executive for many global corporations and has headed International Operations in the Asia-Pacific, Europe and Canada. He has presented papers at International Conferences on the subjects of International Business, Industrial Marketing and Water Treatment. He is currently working as a Program Manager at the National Institute of Standards and Technology (NIST) – Manufacturing Extension Partnership (MEP) group of the US Department of Commerce. The Manufacturing Extension Partnership (MEP) is a catalyst for strengthening American Manufacturing – accelerating its ongoing transformation into a more efficient and powerful engine of innovation driving economic growth and job creation.

The DIS welcomes Dileep who is here to talk about “Profitable Growth through Business Innovation”
Purpose of this Session

How to use Innovation in increasing sales and profits

NIST-MEP’s Innovation Engineering Process

Learning “How to Innovate”

Make More Money through Innovation and Have Fun!
Vision
MEP is a catalyst for strengthening American manufacturing – accelerating its ongoing transformation into a more efficient and powerful engine of innovation driving economic growth and job creation.

Mission
To act as a strategic advisor to promote business growth and connect manufacturers to public and private resources essential for increased competitiveness and profitability.
GET GOOD

Lean Systems
Quality Systems
On-time, All-the-time

GET $

New Products
New Markets
New Technologies
New Ways to Talk to Customers
### Client Impacts Resulting from MEP Services FY2009

<table>
<thead>
<tr>
<th>Impact</th>
<th>Impact</th>
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</thead>
<tbody>
<tr>
<td>New Sales</td>
<td>$3.5 Billion</td>
</tr>
<tr>
<td>Retained Sales</td>
<td>$4.9 Billion</td>
</tr>
<tr>
<td>Capital Investment</td>
<td>$1.9 Billion</td>
</tr>
<tr>
<td>Cost Savings</td>
<td>$1.3 Billion</td>
</tr>
<tr>
<td>Jobs Created and Retained</td>
<td>72,075</td>
</tr>
</tbody>
</table>
Manufacturing Extension Partnership
Innovative Services Initiative

Assist small- and medium-sized manufacturers in...

Reducing energy usage, greenhouse gas emissions, and environmental waste to improve profitability

Accelerating the domestic commercialization of new product technologies

Identifying and diversifying into new markets
Next Generation MEP Strategy

Next Generation Strategies (NGS) 5 key areas:

• Continuous Improvement
• Technology Acceleration
• Supply Chain
• Sustainability
• Workforce

• Increasing manufacturers’ capacity for innovation resulting in profitable sales growth is the overarching strategy for the MEP.

• The approach is to provide a framework for manufacturers that:
  – Reduces operating expenses through lean, quality, & other programs targeting plant efficiencies – which frees up capacity for business growth.
  – Adds to top line sales through business growth services focused on the development of new sales, new markets, and new products.
Innovation is The Engine for Profitable Growth
USA National Innovation Marketplace
Building USA Innovation Supply Chains
to INCREASE Innovation Speed and DECREASE Risk

Need
Sales?

Search $1.2 Billion in Innovation Buying Requests

Companies will pay you a premium if you can manufacture a solution to their Very Important Problems and Opportunities.

Need
Marketing Help?

Get Instant Credibility
List your company on the USA Manufacturing & Expertise Registry

Listing your company creates a free web site with higher credibility & search visibility. It tells what makes you great & links to your site.

Need
Inventions?

Search $105 Billion in Invention Business Opportunities

Painlessly find Inventions translated into Business Opportunities with Documented Sales Forecasts.
USA National Innovation Marketplace

http://www.youtube.com/watch?v=QnM2HCkL_aw
USA Innovation Connections accelerated by the 1,500 Member NIST MEP NETWORK

America’s #1 Growth Team

Across the USA - MEP Clients Report

$6.2 Billion In Increased Sales
Management System
Developed by
The USA’s #1 Growth Experts

Across the world Eureka! clients quantified
over $2.5 Billion
in “new ideas” &
improved “existing ideas”

Delivered by
The USA’s #1 Growth Network

Nationwide MEP clients reported
over $10.4 Billion
in sales increases from supply chain,
marketing, exporting & Eureka! projects
Companies on the LEFT Side of Curve are 84% of the total, indicating a strong sales growth over the past 3 years. Only 4% fall on the RIGHT Side of Curve. Companies wishing to grow sales should pursue "INNOVATION as their primary growth strategy."
COMPANIES wishing to GROW PROFIT MARGINS should pursue “INNOVATION as their primary growth strategy”
What prevents Innovation?
As Companies AGE the are MORE LIKELY to become reactive

*We find that Older Companies often “Don’t Know How or Can’t Envision Possibilities”*
All Companies follow a Curve

CONFRONT REALITY

Growth
- 27% of Time
- Spent Proactive

Cost Cutting
- 19% of Time
- Spent Proactive

Momentum
- 37% of Time
- Spent Proactive

Decline
- 12% of Time
- Spent Proactive
CONFRONT REALITY

Where is your organization on this curve?

Are your profit margins nearly the same or declining?

Would you buy your company if it was available?
Innovation Can **RESTART** A Profitable Future

61 Innovations in 61 Years

**Bottom Line**

Innovation is why Tide still makes a premium profit margin selling an old product “detergent” even in Wal-Mart!

**RESTART**

Every Year They Discontinue The #1 Selling MP3 Player

**Bottom Line**

Innovation is why Apple makes a premium profit margin in consumer electronics one of the most price driven marketplaces on earth.
The Solution
A Reliable Innovation SYSTEM that Increases SPEED up to 6x and Decreases RISK 30/80%
“94% of failures are due to the SYSTEM
6% are due to the worker”
What’s your **SYSTEM** for…

**DISCOVERING & DEVELOPING**

- More profitable **Customers & Markets**
- More profitable **Services & Products**
- More profitable **Processes**
Innovation is MEANINGFUL UNIQUENESS
If you’re not Unique
you better be Cheap

 Meaningfully
Creating Ideas
“Operating System”

Meaningfully Unique ideas

Explore Stimulus
ie. “homework”

Drive out Fear

\[ MU = \frac{S^D}{F} \]

Leverage Diversity
Meaningfully Unique Ideas

Leverage Diversity

Explore Stimulus

CREATE

Drive out Fear

COMMUNICATE

COMMERCIALIZE

MU = \frac{S^D}{F}
CREATE

COMMUNICATE

COMMERCIALIZATE
Step 1: Explore Stimulus

Twice as many practical ideas are generated when you explore stimulus.

<table>
<thead>
<tr>
<th>Stimulus Available</th>
<th># of practical ideas invented</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Stimulus</td>
<td>22</td>
</tr>
<tr>
<td>Medium Stimulus</td>
<td>38</td>
</tr>
<tr>
<td>High Stimulus</td>
<td>47</td>
</tr>
</tbody>
</table>
Where To Go On Vacation?

- More Stimulus = More Ideas
  (Quantity & QUALITY)
Leverage Diversity

Diversity multiplies the impact of stimulus.

TODAY: *Diverse Brains in the room*

<table>
<thead>
<tr>
<th>Diversity of Thinking</th>
<th># of practical ideas invented</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Diversity</td>
<td>19</td>
</tr>
<tr>
<td>Medium Diversity</td>
<td>30</td>
</tr>
<tr>
<td>High Diversity</td>
<td>46</td>
</tr>
</tbody>
</table>
Diversity Is Your:

- Frame of reference
- Point of view

Diversity is Influenced by…

- Life Experiences
- Functional Job Area
- Optimism/Pessimism
- Personal Thinking Style
- Education Experiences

THE MORE YOU HAVE, THE MORE YOU HAVE.
# Exercise: Thinking Styles

Please rate yourself on the following dimensions by choosing a number that best describes how you think.

<table>
<thead>
<tr>
<th>Idea Realist</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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</thead>
<tbody>
<tr>
<td>Rational</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Process Oriented</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Neat and Organized</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Trust the Facts</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Predictable</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<td>Logical</td>
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<td>4</td>
<td>5</td>
<td>6</td>
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</table>

<table>
<thead>
<tr>
<th>Idea Builder</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<td>Emotional</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
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<td>People Oriented</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
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<tr>
<td>Messy and Chaotic</td>
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<td>2</td>
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<tr>
<td>Trust Gut Instincts</td>
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<td>Spontaneous</td>
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<td>Visionary</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>
Diversification of Thinking

CREATE

Out of the Box INVENTING

Industrial Strength INVENTING

Linear CREATIVITY

Classic CREATIVITY

Genrich Altshuller  Doug Hall  Edward DeBono  George Prince

Andy VanGundy  Alex Osborn  Tony Buzan
It is About Cross Training your Brain

The Herrmann Whole Brain Model

The Whole Brain® Model

A
LOGICAL
ANALYTICAL
FACT BASED
QUANTITATIVE

B
ORGANIZED
SEQUENTIAL
PLANNED
DETAILED

C
INTERPERSONAL
FEELING BASED
KINESTHETIC
EMOTIONAL

D
HOLISTIC
INTUITIVE
INTEGRATING
SYNTHESIZING

# of Quality Ideas Created In One Hour

38
37
36
35
34
33
32
31
30
29

Left Brain
Right Brain
Whole Brain
When you give words to your ideas, they become real.

If you can’t clearly articulate your idea in writing then you have virtually NO CHANCE of success.

Success Rate (PDMA Research)

Source: American Marketing Association
Clarity!

Think Deeper on Each Dimension

<table>
<thead>
<tr>
<th>Customer &amp; their PROBLEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit PROMISE</td>
</tr>
<tr>
<td>Product/Service &amp; PROOF</td>
</tr>
</tbody>
</table>

- Meaningfully Unique
- Meaningfully Unique
120% Improvement in Marketing Effectiveness when you communicate a Meaningfully Unique Benefit Promise
Features are not Benefit Promises

Features are the

- Facts
- Figures
- Technology
- Details

That make up your offering
feature stabilization control

benefit PROMISE reduces rollover risk
feature
Contains Benzocaine 7.5%

benefit
Fast Teething Pain Relief
<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slippery Peel</td>
<td>“So What”</td>
</tr>
<tr>
<td>Soft &amp; Mush</td>
<td>“So What”</td>
</tr>
<tr>
<td>Potassium</td>
<td>“So What”</td>
</tr>
<tr>
<td></td>
<td>Creates great laughs</td>
</tr>
<tr>
<td></td>
<td>Great for kids to eat</td>
</tr>
<tr>
<td></td>
<td>Reduce cramping</td>
</tr>
</tbody>
</table>
Guarantee

Wright State University

College of Engineering and Computer Science

EMPLOYMENT GUARANTEE

“We’re so confident that we have outstanding engineering and computer science programs, that we’ll guarantee you employment in a degree-related career field after you graduate OR the opportunity to pursue an engineering or computer science master’s degree tuition free!”

Bar Z. Jang, Dean, College of Engineering and Computer Science

As a graduate of the College of Engineering and Computer Science at Wright State University with a Bachelor of Science degree, you are covered by our employment guarantee. This warranty applies if (1) you graduate from our college with a grade point average of 3.0 or above, (2) you are unable to find employment in your field of study after making a bona fide effort to secure such employment for a minimum of three months after graduation, (3) the request for the warranty is made within 12 months of graduation, and (4) you have regular admission status to the master’s program as a full-time student and remain in good academic standing with an average grade of “B” or better in all graduate work until completion of the degree or two years, whichever comes first.

We stand behind our programs and our students 100% – GUARANTEED

For more information, call (937) 775-5001 or email cecs-dean@wright.edu
Testimonial

EXPERT Testimonial

Laser Vision Correction

Testimonials from DOCTORS who have used this DOCTOR for Eye Surgery
Demonstration

Is Your Pool Cover This Safe?
117% Improvement in Marketing Effectiveness when you communicate a Meaningfully Unique Product/Service PROOF
Effective Marketing is SIMPLE

Tell the TRUTH & Nothing But The Truth
Creating Ideas
“Operating System”

Meaningfully Unique ideas

Explore Stimulus
*ie. “homework”*

Drive out Fear

\[ MU = \frac{S^D}{F} \]
Meaningfully Unique Ideas = Explore Stimulus

- Create
- Communicate
- Commericalize

Drive out Fear

Leverage Diversity
High Confidence in Innovation System DOUBLES Odds of High Profitability

Innovation System Confidence
Make Higher Profit Margins

% Above Average Profit Margins

Low confidence  Medium Confidence  High Confidence

Confidence in Innovation System
“94% of failures are due to the SYSTEM
6% are due to the worker”
The Value of Innovation is Obvious
So What’s the Problem?

Self Reported Primary Company Strategy

% Profit Margin
(Return on Sales)

Low Cost Quick Delivery Voice of Customer High Quality Innovation
CHANGE Sparks FEAR
Options for Making Unknown Known

“Proper & Mature” Business Innovation System
Expensive & Slow

Fail FAST - Fail CHEAP
Dissolve Risks with Small Steps
Fail FAST Fail CHEAP

Dissolve Risks with Small Steps

1. Plan
2. Do
3. Study
4. Act

Dig for TRUTHS
Just TRY IT
Do the NUMBERS
Ask for ADVICE

The Deming Cycle

COMMERCIALIZ$E
Continuous Learning Mindset

Fail FAST Fail CHEAP

1. Plan
What Death Threat?

2. Do
Learn

3. Study
What learned?

4. Act
Apply Revise Stop

Maximum Cycle Time = 7 Days

World Class = 24 Hour Cycles
Focus on Biggest Threats First

Turn KILLER Threats Into Manageable Threats

KILLER Death Threat

1. Plan
   What Death Threat?

2. Do
   Learn

3. Study
   What learned?

4. Act
   Apply
   Revise
   Stop

Manageable Threat
Fail Fast Fail Cheap Development System

Dissolve Risks with Small Steps

Focus

Disciplined Focus on the...
- Death Threats
- Killer Issues
- Big Rocks

Small Steps

Kaizen

“Solve Big Problems with Small Steps of Continuous Learning”

1. Plan
2. Do
3. Study
4. Act

“Fail Fast Fail Cheap”

Leadership

- Leadership Structure
- Simultaneous Engineering
- Meeting Rhythm

FAILS

Focus

Dig for Truth

Make it Real

Do the Numbers

Ask for Advice
Simultaneous Engineering

PROFIT Formula

Customer PROMISE

Project Leader Loves the Idea

PRODUCT Reality

MANAGEMENT Coach

PROCESS Coach
GOAL: A Continuous Flow of Innovations

Define
- Clarity on Raw Concept

Discover
- Fail FAST
- Fail CHEAP on Key DEATH Threats

Develop
- Make it REAL

Deliver
- Go to Market
Perpetual Profit Cycle

NEW Customers & Markets

ADAPT

CURRENT Customers

IMPROVE

CURRENT Capabilities

LEAD

NEW Products & Services
Fail FAST Fail CHEAP Actions

Dig for TRUTHS
• Data Dig - Patent Dig
• Search Academic Research
• Run Controlled Experiment

Just TRY IT
• Experience the Problem
• Fast Functional Demo
• Fast Marketing Demo

Math Game Plan
• Get & Estimate the Numbers
• Forecast Impact
• Do Math for You & for Customers

Ask for ADVICE
• Your Supply Chain
• Tech Expert Inventors
• Customers/Lead Users
To Win

Replace

Declare & Defend

with

Learn & Revise
Great success will be when you embrace 3 simple things...

1. I Don’t Know
   - “Learn More” Mining

2. I Need Help
   - Looking inside and outside

3. I Love Fail FAST Fail Cheap
   - Love active learning
Richard Branson’s 5 Favorite Words

“Screw it, Let’s Do It!”

His Next 3 Favorite Words...

“Protect the Downside”
Paul Jones - ThyssenKrupp Waupaca

Paul graduated from Michigan Technological University in 1979 with his Bachelor of Science in Metallurgical Engineering and Bachelor of Science in Engineering Administration. He then moved on to the University of Michigan and graduated with his Master in Business Arts in 1986. Paul has over 31 years’ experience in the automotive and metal casting industry. He started with General Motors at the Central Foundry Division in Saginaw, MI serving in a variety of engineering and quality positions. He also worked at the GM Tech Center, Advanced Engineering Staff and GM’s Saginaw Steering Gear Division. In 1994, Jones became part of the American Axle serving in leadership roles in Product Engineering, Advanced Product Quality Engineering, Supplier Development and Engineering Casting Development. In 2009, Paul began working for ThyssenKrupp Waupaca serving as Manager, Development and Launch for Detroit based customers. He is a member of AFS, ASM, ASQ, DIS and SAE.

The DIS welcomes Paul who is here to talk about “Castings as a Source of Competitive Advantage ….Their Job, or our Job”
Castings Done Right…. …for Competitive Advantage

Paul Jones
ThyssenKrupp Waupaca
Metal Casting Influencers –
My Experiences….
Not unlike others…

Castings are Great - MTU (76 – 79)
• Rundmann
• Mg/S Ratio and Effect Upon Graphite Morphology
Metal Casting Influencers

• **Passion for Castings** - CFD and GM (79 – 91)
  – Great Heritage & $2.0 Billion in Sales
  – Manufacturing is King, Safety and Metallurgical Intensity
  – Product and Process Development
    – Crankshafts, Con Rods, Steering Knuckles, ADI Ring and Pinions,.... Product Testing
    – RMIP’s, SMI Melt System, Lost Foam, Simulation……
Metal Casting Influencers

- Liquids Flow Better than Solids
  - University of Michigan (1985)
Metal Casting Influencers

“You Guys are STUPID…”
Hans Heine  DWAFS November 16, 1989

“…….half the foundries have been shut down in the last 10 years. Cooperate on basic research, compete on how well you execute!”
Metal Casting Influencers

Technical Guys are not Stupid......

Pittsburgh AFS - April 2000

But they are still closing foundries....!
Metal Casting Influencers

Technical Guys are still not Stupid……
Orlando AFS - April 2010

But foundries are either bankrupt or on the verge of bankruptcy....!
Metal Casting
2011

Still....

Castings are Great
Passion for Castings
Liquids Flow Better than Solids
Don’t be Stupid
Technical Guys are not Stupid......
Impact of the Influencers? 2011

So, how are we doing in making great castings with passion and technology for casting user and casting producer profits?

In general, how are our castings?
How we doing?
Good or NOT SO GOOD?

It seems to me.....

• There should be far fewer casting problems.
• We and our customers should be benefitting far more from our collective casting knowledge.
How we doing?
Good or NOT SO GOOD?

It seems to me.....

- Casting Designs and Customer Practices are inhibiting the benefits of the casting process....not so good.

Or, from another perspective....
How we doing?

Good or NOT SO GOOD

Decades of foundry closures and bankruptcies driving actions...

Passion, technology and capabilities for great castings…, and we still experience:

- Many Casting “Issues”
- Last minute sourcing
- Frozen non-manufacturing friendly designs
- Unrealistic acceptance criteria
- Adversarial Customer Plants
- Zero Defects and Zero PPM……..just push harder!!!!
- Combative Relationships
Not So Good is Not So Good!

Why?

Who is at fault?
Why? Who is at fault?

IT’S THE CUSTOMER!

The designs are bad, the specifications unrealistic and the customers are unreasonable.

They are the problem?
Why? Who is at fault? What does it matter?

The power has shifted...

• We can say “NO!” &
• “You’ve got to pay more!”
What?

And the power has shifted…

• We can say NO!
• You’ve got to pay more!

But is this sustainable?
I think I forgot Business Influencer!
Business Influencer

The Customer is always right… RIGHT?!!!!!!!!!!!!

So, What’s the Problem…?

The Customer is not the problem!¹

¹They might contribute to the problem, but they are certainly part of the solution.
So, What’s the Problem…?

PRIMARY PROBLEMS
• High customer or internal scrap
• Excessive costs
So, What’s the Problem…?

PRIMARY PROBLEMS
• High customer and/or internal scrap
• Excessive costs

Secondary Problems:
• Poor Delivery
• Added Inspection Costs
• Added Third Party Costs
• Resources tied up reacting to problem
• Combative meetings and conference calls
• Financials have prevented desired maintenance and upgrades?
**So, What’s the Problem…?**

**Primary Problems**
- High scrap
- Excessive costs

**Secondary Problems:**
- Poor Delivery
- Added Inspection Costs
- Added Third Party Costs
- Resources tied up reacting to problem
- Combative meetings and conference calls

**Bigger Problems?**
- Not working together on future products
- Not taking full advantage of casting technologies and capabilities.
- Reduced Casting Producer sales and profits?
- Casting Users not achieving Competitive Advantage through Castings!!
What’s the Root Cause?

• Late Releases
• Non-manufacturing friendly casting designs
• Lack of Knowledge
  – Casting Producer
  – Casting User
• Combative Relationships
  – Within Casting User
  – Within Casting Producer
  – Between Casting Users & Producers
• Who Knows???????
What’s the Solution?

- What is to be done to allow Casting Users to achieve competitive advantage through castings?
Who is to Take the Lead?

- Casting Users
- Suppliers to the Casting Industry
- Casting Producers
Casting Users Leading

- To achieve competitive advantage through castings they should lead!

but,.............
Casting Users

Relative to applying and designing castings,

Three types of Casting Users:

1. They don’t know what they don’t know…..
2. They think they know what they don’t know……
3. They know what they don’t know!
Casting Users Leading

Outcomes of “What You Know”:

1. They don’t know what they don’t know…
   Can’t lead the effort successfully.

2. They think they know what they don’t know…
   Can’t lead the effort successfully.

3. They know what they don’t know!
   They are already successfully leading or leveraging those that know castings.
Suppliers to the Casting Industry – Can they fix it?

- Direct Materials – Some problems?
  - Pig Iron
  - Steel Scrap
  - Rare Earths

...It must be Global Competition
Suppliers to the Casting Industry – Can they fix it?

Indirect Materials – More problems

- Sand
- Energy

....It must be the Government

Maybe the Government can also fix

Global Competition!

....may not be sustainable, advisable or conceivable and certainly not appropriate!
Suppliers to the Casting Industry – Can they fix it?

• The Schools (Elementary through Universities)

Very Important contributors,…. part of the solution… but not the driver of the solution.
Technical Societies – Can they fix it?

AFS, ASM, ASNT, DIS, FEF, SAE, SME...

Not the drivers….but contributors.

How can contributions be maximized? Are we doing so?

Why we exist, meet and act.
Who is to lead?

- It is not the Casting Users
- It is not the Suppliers to the Casting Industry.
Casting Producers – What do we do?

1. We want to blame somebody else.
2. “If we continue to do what we have always done….”
3. Would Hans Heine suggest that, “We have we been STUCK ON STUPID?”
4. Bashing the customer doesn’t help.
5. If it’s to be, it’s up to we….The Casting Producers!
Casting Producers Must Lead

Casting issues on four continents over 32 years.....seems the solution is simple:

1. Manufacturable designs
2. Realistic Acceptance Criteria consistently administered.
Casting Producers Must Lead

1. Manufacturable designs
2. Realistic Acceptance Criteria consistently administered.

Something prevents it from being so simple......There are interactions of people.....Relationships are the KEY!
How to Manage the Relationships?

• A survey of 100 metallurgists was amazingly clear....

• When asked, What are the appropriate actions relative to relationships, 100 metallurgists said.....
How to Manage the Relationships?

“IT DEPENDS”.
It Depends on What?

1. Casting Producer Specific
2. Customer Specific
3. Customer Plant Specific
4. Part Specific
5. Suppliers, Communities, Schools
6. Supporting Technical Societies
Castings Done Right

Casting producers taking the lead to build customer relations to achieve manufacturable designs with realistic acceptance criteria consistently administered.
Castings Done Right – Within Casting Producers

• Ensure capabilities to make manufacturable designs.
• Ensure capabilities to know manufacturable designs and realistic acceptance criteria
• Have a customer relations strategy to persistently, passionately, patiently and professionally manage the customer.
• Customer Relations philosophies, policies, processes, procedures and practices….a culture of how you deal with the customer across your company to achieve manufacturable designs.
Castings Done Right – at the Customer

Customer Relations - Build and Maintain

• Face to face and electronically
• Across all disciplines ...bridge the gaps
• Corporate and at Plants
• Consistent and Unified within Casting Company

Customer Relations – Trust but DOCUMENT

• Partnership & Scrap Agreements...
• Acceptance Criteria...signed with lots of objective evidence

Customer Relations – Persistently, Passionately, Patiently and Professionally... A Culture
Castings Done Right – With our Suppliers

• Leverage the right “value stream partners” to optimize internal competencies and results and the mutual benefits of the partners.

• Support and Serve Technical Societies
  • Help with Customer Education
  • Utilize and leverage the full breadth of Technical Societies
    • AFS, DIS, FEF, NADCA leverage the strengths, avoid redundancies, collaborate.....
    • Build mutually beneficial relationships with SME, ASNT, SAE,.....
Casting producers taking the lead to build customer relations to achieve manufacturable designs with realistic acceptance criteria consistently administered.
Castings Done Right

• In closing, we must take the lead and “JUST DO IT”

• Apply wwbd!
What do we need to do....?
Thank You!
PRESENTATION: Robotic Grinding Using ABB’s Force Control Technology

Word Version

Alan Wertz

Alan graduated from Pennsylvania College of Technology in 2006 with a Manufacturing Engineering Technology Degree. He started working at Benton Foundry Inc. in Benton, PA in July 2006. Responsibilities at the foundry include Foxalls, tooling and equipment designs, as well as many other projects throughout the foundry.

The DIS welcomes Alan who is here to talk about “Robotic Grinding Using ABB’s Force Control Technology”
Robotic Grinding using ABB’s Force Control Technology
Alan J. Wertz
Manufacturing Engineer
Benton Foundry Inc

The concept of force control and its uses have been around for years within the robotics industry, though recently it has become a fully integrated part of ABB robotic systems. In the past “Force Control” may have been a compliant device that was able to recognize excess tool pressure through an external computing device (computer/PLC). At this point the computer/PLC would tell the robot to abort path, or return to a given point in the program and try again. With today’s force control technology built directly into the control the robot it is making all of its decisions. The robot can do many things with force control resulting in, constant pressure applications allowing the robot to vary from programmed path, but apply constant pressure to a work piece. Speed Change will allow the robot to slow down/speed up as contact forces rise/fall. Or recover rules can be applied to send the robot to a particular subprogram to remove additional material before moving forward with its standard program. Decreased cycle time and increases in part quality are some of the reasons force control is of interest in the foundry.

ABB’s robot system consists of the IRC5 robot controller with Robotware Machining FC, ATI Omega 160 IP65 Force Torque Sensor, DAQ Card on the Axis Computer, necessary cabling and Test signal viewer. All of these components make it possible for the robot to “feel” its path. Before force control and compliant devices, robots were purely position controlled devices. They would go from point to point at a given speed with no concern of, or reaction to, contact forces. Now we can give the robot the ability to “Feel” its way along, around, or through a part. It can, with the correct information, adjust its path or speed as necessary to accomplish the programmers desired results. ABB’s force control package can also be used for programming as well as program optimization.

FC Pressure makes it possible for the robot programmer to take a finished part and let the robot feel its way, generating its own program points as needed. In the past you as the programmer were responsible to tell the robot every point in which it needed to pass through to get your desired results. Now you still give the robot guidance as to where you would like to travel through, but the robot will record points as needed around the part to be able to replicate your original part.

Running a program with FC Pressure is good for grinding/polishing applications. It allows for like parts to vary in size within a given range, but still achieve a uniform finish. You must tell the robot in which direction you want it to apply pressure, and how much pressure to apply. The robot will, at that point, start to follow your programmed path applying pressure “X”. As long as the robot is applying pressure “X”, it will move in relation to your actual path. It will not necessarily reach your programmed points but it will apply constant pressure along the path while trying to do so. This is dependant on having the correct direction of loading programmed into the robot. This allows parts to
vary slightly in size, but still get uniform results. This is best suited for polishing type applications.

Running a program with FC Speed Change is good for deburring and material removal applications. It allows you to program for a more optimum part. Before force control you had to give the robot every point that you wanted it to pass through, and give a speed that it could give you the desired results even in worst cases. Now with force control speed change, you can program your parts for the best of both worlds. You program your speeds for your best parts and worst parts at the same time. If you have some parts with more flash or a heavier than normal contact area you tell the robot once you go over “X” force slow down as needed to minimum speed “Y”. At this point the robot will run at optimum speeds, slow down as needed, and speed back up when it can resulting in as much as a 30% cycle reduction over conventional point to point programming. You will find that with force control, cycles vary from cycle to cycle, because the robot is making the decisions as to when it needs to slow down. This is unlike previous programming with out force control, where you had a very consistent cycle time from part to part, but not necessarily a consistent finished product.

ABB’s force control is very nicely integrated in the robot RAPID programming language. You can turn FC on and off as necessary between programmed points. You can change your control contact force at any point in the program and as often as needed. We have used/changed our force limit as many as 9 times within the same program depending on whether we are using a wheel to remove a parting line, ingates, or riser contacts or a burr for parting line/core flash. Program contact forces vary from 125N to 450N depending on the tool and the application.

When using FC in a robot program there are several things to consider. They are:
- Is it worth taking the 6-8 seconds to calibrate the tool? (As this must be done every time the tool is changed, or that the robot reorients(changes position)).
- What tool am I using? (Burrs tend to need lower programmed forces)
- What am I trying to remove?
  - With parting lines, you tend to use a lower force so that if there is a sticker or flash, it will react quickly enough to clean it up
  - With ingates and riser contacts, you use much higher forces so that when you are further from the casting where they brake off inconsistently your not slowing down until you are to the point where all are the same.
- What program speed can I run best case/worst case in a particular area?
- What is my desired result, high quality/high speed?….there is a fine balance

The graph as seen below is a result of ABB’s test signal viewer software, an aid in optimizing the robot program and its reactions. The Red line on the graph represents the force limit for a given point in the program. The Blue line is the actual robot applied force at a given time within the program. The Green line is the percent of programmed speed that the robot is currently running. This chart shows the robot running between 30 and 100% of programmed speed. When the (Blue) actual force surpasses the (Red) programmed limit the robot will slow down its programmed speed (Green) in a controlled
and predictable manner based off of program speed and applied force. The robot will also speed back up under another set of pre-established instances when the (Blue) actual force is below the programmed limit by a particular value and time. This software allows the robot programmer to better understand what forces the robot is seeing, and allows the programmer to better control how the robot reacts and when.

Of the many advantages available through Force Control two are most apparent and they are cycle time savings and consistent quality finishes. Since purchasing our new Foxall (Foxall 2) we have been not only adding new work, but also transferring work from our older Foxall (Foxall 1). In many instances we have been able to reduce our cycle times as well as our need for manual touchup work. Below is an example of job than we have moved from Foxall 1 to Foxall 2. We have proven an average cycle time savings of 30% reducing our cycle time from 247 seconds to an average of 174 seconds with a cycle time range of 208-160 seconds. With the old cell cycle times are very consistent because the robot moves through the programs at its programmed speed every time. With Foxall 2 and force control we are allowing the robot to make decisions as to when it needs to slow down or speed up. The example shows 1 particular riser contact that has broken of 4 different ways. One close to the casting, one further from the casting face, one broke of to one side, and one broke of the other side. One also has some parting line flash on the center hub. With Foxall 1 we had to program this particular job for the worst case riser contact height and the occasional parting line flash. This means staring high with the contact grinding slow the entire time. This resulted in our 247 second cycle time. With Foxall 2, we programmed the robot to start at the same distance from the casting face as
with Foxall 1, but with force control active we can program this part with a higher speed. When wheel contact forces start to climb as the robot is in contact with more of the casting it will slow down as needed. This results in high speeds during air time and slower speeds where they are needed when in contact with casting. The robot can feel that it is in contact with air only or casting material and it make its decisions on whether to speed up or slow down.

We have had similar results from other jobs that we have transferred from Foxall 1 to Foxall 2. Another example was a 244 second cycle time being reduced to an average of 170 seconds with a range of 206-132 seconds. With this second job, we had instances where there was some touchup work for the Foxall operator where they were not able to keep up with the touchup work after coming out of the cell and keep up with the machine despite the 4 minute cycle. Now with force control and the reduced cycle time, if there is any touchup for the operator, they have plenty of time to do it, and still keep up with the machine. So, we are not only processing castings faster, but more consistently.

Not all jobs have had a 30% cycle time reduction, but all cycle times have been reduced or matched with little or no touch up work necessary as before.

With force control not only have we been able to maximize our production on our new Foxall, but we have also been able to increase our production on our original machine. After hours of watching our new machine run at elevated speeds as compared to our old we were able to change how we program our old machine as well. If we have a contact that is not always consistent as the previous example instead of programming that contact as one item we do it as two. The first is to start at maximum height but at a slightly higher speed than before. We use this to get the contact to the point were we know that will be in casting contact the whole time and move to the contact 2 program so that we can slow the robot down to perform the job necessary. Not nearly the time savings that we are getting with force control but a savings none the less.

Not every job is a great job to use force control on because as stated before it does cost you cycle time. So if your goal is to save time, then you have to have more time to save than it takes to calibrate.

<table>
<thead>
<tr>
<th>Use FC when you have:</th>
<th>Don’t Use FC when you have:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Large parts with complex work</td>
<td>• Simple geometry</td>
</tr>
<tr>
<td>• Varying Riser Contacts or Ingates</td>
<td>• Small Consistent Riser Contacts/ or Ingates</td>
</tr>
<tr>
<td>• Tight Grinding Tolerances</td>
<td>• Large Grinding Tolerances</td>
</tr>
<tr>
<td>• Cosmetic Grinding</td>
<td></td>
</tr>
<tr>
<td>• Burr work</td>
<td></td>
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</table>
Advantages of FC
- As much as a 30% Reduction in cycle time
- Improved Quality and consistency of finished product
- Can turn FC on and off as needed
- Grinding “AIR” is greatly reduced on contacts and in gates
- Can program for best/worse case castings in one program
- Reduced Manual touchup
- Operators at times could not keep up with extended cycles on Foxall 1 without FC, but now can keep with the much shorter cycles on our Foxall 2 w/FC

Disadvantages of FC
- High initial setup cost
- Calibration
  - Sensor is to be calibrated offsite once every 1-2 yrs
  - Each tool and tool orientation must be calibrated every cycle
- Abrasive life is reduced.
  - Removing more material in less time generates more heat
Marc King - Hiler Industries

Marc graduated in 1996 from Michigan Technological University with a Bachelor of Science degree in Metallurgical Engineering. He has held metallurgical positions in several foundries. He has been the Metallurgist at Hiler Industries since 2006. Hiler Industries has two shell molding foundries that pour Ductile Iron, Carbidic Ductile Iron, White Iron, Ni-Hard, Gray Ni-Resist, Ductile Ni-Resist, Brass and Bronze. Marc has spoken in the past at DIS meetings. He is also an active member of the DIS Research Committee.

The DIS welcomes Marc who is here to talk about “Improved Process Techniques for Thin Sectioned Ductile Iron”
Thin Sectioned Ductile Iron Process Techniques

October 27, 2011

Mr. Marc King
Hiler Industries
Hiler Industries: Kingsbury Castings Division Kingsbury, IN

Shell molding foundry producing Pearlitic, Ferritic, and Carbidic Ductile Cast Iron

Shell sand molds work well with detailed, thin sectioned work having complex parting lines. Thin knife gates are used to allow the parts to break off easily and cleanly. Many parts < ¼ in section size.

Melting and pouring department –
2 6000 lb medium freq. Batch Coreless Furnaces,
1 1,200 lb open tundish treatment ladle
2 600 lb teapot pouring ladles
1 Shell Mold Pouring Line (Power and Free)
Chemical Analysis Equipment:
Spectro Max CCD Spectrometer
LECO CS 300 Carbon and Sulfur Analyzer

Metallographic Analysis:
Laboratory Analysis:
Olympus PME3 with digital camera and IA32 Analysis Software.

Shop Floor Analysis: %Nodularity (Every Ladle Poured): Olympus GX51 with digital camera and IA32 Analysis Software.
**Purpose of the Study:**
Modify metal chemistry and inoculation practice to optimize graphite nucleation and eliminate carbide formation in thin-wall DI castings.

**Standard Magnesium Treatment:** Tundish Ladle, 1200 lb Base Iron, 19 – 20 lbs 6% MgFeSi, 1 lb. 60 Mesh X 20 Mesh Carbon, and 8-12 lbs of Cover steel.

**Standard Inoculation Practice**
600 lb pouring ladle
Post: 5 lbs of standard Calcium-bearing 75% FeSi
In-Mold: 17 gram Germalloy insert per mold
## Alloy Specifications

### Magnesium Ferrosilicon : Globe Metallurgical R6-8

<table>
<thead>
<tr>
<th>% Si</th>
<th>% Mg</th>
<th>Total % RE</th>
<th>% Ca</th>
<th>% Al</th>
<th>Sizing</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 - 49</td>
<td>6 - 6.7</td>
<td>0.60 – 0.70</td>
<td>0.8 – 1.3</td>
<td>1% Max</td>
<td>1 in. x 1.25 in.</td>
</tr>
</tbody>
</table>

**Post Inoculant:** CCMA Calsifer 75

<table>
<thead>
<tr>
<th>% Si</th>
<th>% Al</th>
<th>% Ca</th>
<th>Size Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>74 - 79</td>
<td>0.75 – 1.5</td>
<td>1.0 – 1.5</td>
<td>3/8 in. x 12 Mesh</td>
</tr>
</tbody>
</table>

**In-Mold Inoculant:** ASK Chemicals Germalloy K15 (Solid Cast Insert)

<table>
<thead>
<tr>
<th>%Si</th>
<th>%Al</th>
<th>%Ca</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>70-78</td>
<td>3.2 – 4.5</td>
<td>0.3 – 1.5</td>
<td>15g</td>
</tr>
</tbody>
</table>
Pouring Ladle Weight Reduction

Light sectioned jobs have smaller mold weights and take longer to pour per ladle than normal work.

The treatment size was reduced to 1000 lb.
  Increased the average pouring temperature.
  Reduced the cold pouring defects.
  Reduced the potential for carbide formation.
### Standard: Magnesium Treatment Ladle Additions:

<table>
<thead>
<tr>
<th>Addition</th>
<th>Standard</th>
<th>% Addition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Metal</td>
<td>1200 lb</td>
<td></td>
</tr>
<tr>
<td>MgFeSi</td>
<td>21 lb</td>
<td>1.75</td>
</tr>
<tr>
<td>Cover Steel</td>
<td>8 lb</td>
<td>.7</td>
</tr>
<tr>
<td>Graphite (10x100M)</td>
<td>1 lb</td>
<td>.08</td>
</tr>
</tbody>
</table>

### Improved: Magnesium Treatment Ladle Additions

<table>
<thead>
<tr>
<th>Addition</th>
<th>Reduced</th>
<th>% Addition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Metal</td>
<td>1000 lb</td>
<td></td>
</tr>
<tr>
<td>MgFeSi</td>
<td>17.5 lb</td>
<td>1.75</td>
</tr>
<tr>
<td>Cover Steel</td>
<td>7 lb</td>
<td>.7</td>
</tr>
<tr>
<td>Graphite (10x100M)</td>
<td>1 lb</td>
<td>.1</td>
</tr>
</tbody>
</table>
Ductile Iron Inoculation: Standard

The treated ductile base iron is split in half from the treatment vessel and poured into two teapot pouring ladles. Post inoculant is added during the transfer.

Standard Inoculation Practice

<table>
<thead>
<tr>
<th>Additions</th>
<th>lb</th>
<th>% Addition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg Treated Ductile Iron</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>FeSi 75 – Calcium</td>
<td>4.5</td>
<td>.75</td>
</tr>
</tbody>
</table>

Specification: CCMA Calsifer 75

<table>
<thead>
<tr>
<th>% Si</th>
<th>% Al</th>
<th>% Ca</th>
<th>Size Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>74 - 79</td>
<td>0.75 – 1.5</td>
<td>1.0 – 1.5</td>
<td>3/8 in. x 12 Mesh</td>
</tr>
</tbody>
</table>

The standard inoculation practice was found to be ineffective to prevent chill formation in some thin sectioned parts.
Iron Inoculation: Improved

Inoculation Improvement

Increasing the amount of post inoculation using a blend of calcium FeSi 75, aluminum/calcium FeSi75 and oxysulfide inoculant combined with in-mold inoculation eliminates carbide formation in all thin sectioned ductile iron castings that have been tested.

Ladle Inoculation (500 lb pouring ladle of Mg-treated ductile base iron):

<table>
<thead>
<tr>
<th>Additions</th>
<th>lb</th>
<th>% Addition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg Treated Ductile Iron</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>FeSi75 - Calcium</td>
<td>3</td>
<td>.6</td>
</tr>
<tr>
<td>FeSi – Calcium/Aluminum</td>
<td>3.5</td>
<td>.7</td>
</tr>
<tr>
<td>Oxysulfide</td>
<td>.6</td>
<td>.12</td>
</tr>
</tbody>
</table>
Specifications for Inoculants Used

Ladle Inoculant (Aluminum/Calcium Containing): ASK Chemicals VP216

<table>
<thead>
<tr>
<th>% Si</th>
<th>% Al</th>
<th>% Ca</th>
<th>Size Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>66-73</td>
<td>3.2 - 4.5</td>
<td>0.3 - 1.5</td>
<td>¼ in x 28 Mesh</td>
</tr>
</tbody>
</table>

Ladle Inoculant (Oxysulfide): ASI Sphere-o-doxx G (US Patent: 6,293,988 B1)

<table>
<thead>
<tr>
<th>% Si</th>
<th>% Oxy sulfides (Ca + Al + S + O₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>36 – 37</td>
<td>32 - 35</td>
</tr>
</tbody>
</table>

In-Mold Inoculant: ASK Chemicals Germalloy K15 (Solid Cast Insert)

<table>
<thead>
<tr>
<th>%Si</th>
<th>%Al</th>
<th>%Ca</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>70-78</td>
<td>3.2 – 4.5</td>
<td>0.3 – 1.5</td>
<td>15g</td>
</tr>
</tbody>
</table>

In-Mold Inoculation:
15g Germalloy cast insert placed in each mold sprue on top of the filter.
Changes in Iron Chemistry

Changes were made to the iron chemistry to improve graphite nucleation and reduce the potential for carbide formation.

• Carbon Equivalent was increased by raising both carbon and silicon to improve graphite nucleation and eliminate carbide formation.
• % Sulfur was increased due to the addition of oxysulfide inoculant.
• % Manganese was lowered to decrease the potential for carbide formation.
• % Aluminum was increased by the addition of calcium/aluminum 75%FeSi inoculant.
## Changes in Iron Chemistry - Chemical Analysis Specifications

<table>
<thead>
<tr>
<th></th>
<th>Original</th>
<th></th>
<th>Improved</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>Min</td>
<td>Max</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>CE*</td>
<td>4.40</td>
<td>4.53</td>
<td>4.63</td>
<td>4.76</td>
</tr>
<tr>
<td>C</td>
<td>3.55</td>
<td>3.65</td>
<td>3.65</td>
<td>3.75</td>
</tr>
<tr>
<td>Si</td>
<td>2.55</td>
<td>2.65</td>
<td>2.95</td>
<td>3.05</td>
</tr>
<tr>
<td>S</td>
<td>.008</td>
<td>.012</td>
<td>.010</td>
<td>.014</td>
</tr>
<tr>
<td>Mg</td>
<td>.030</td>
<td>.040</td>
<td>.030</td>
<td>.040</td>
</tr>
<tr>
<td>Mn</td>
<td>.20</td>
<td>.30</td>
<td>.10</td>
<td>.20</td>
</tr>
<tr>
<td>P</td>
<td>-</td>
<td>.025</td>
<td>-</td>
<td>.025</td>
</tr>
<tr>
<td>Cu</td>
<td>-</td>
<td>.20</td>
<td>-</td>
<td>.1</td>
</tr>
<tr>
<td>Cr</td>
<td>-</td>
<td>.08</td>
<td>-</td>
<td>.05</td>
</tr>
<tr>
<td>Mo</td>
<td>-</td>
<td>.05</td>
<td>-</td>
<td>.05</td>
</tr>
<tr>
<td>Ni</td>
<td>-</td>
<td>.1</td>
<td>-</td>
<td>.1</td>
</tr>
<tr>
<td>Al</td>
<td>-</td>
<td>.015</td>
<td>.015</td>
<td>.025</td>
</tr>
</tbody>
</table>

*CE Formula:
CE = %C + %Si/3
Chill Wedge Comparison: Standard vs. Improved Method

Chill Wedges are used to determine the effectiveness of foundry metallurgical practice.

Sample Specimens taken at the end of the pour.

W3 Wedge: ¾” wide at top, 1½” taper height, 3” Long w/ 1” riser.
Chill Wedge Comparison: Standard vs. Improved Method

Chemical Analysis:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>Si</th>
<th>S</th>
<th>Mg</th>
<th>Mn</th>
<th>P</th>
<th>Cu</th>
<th>Cr</th>
<th>Ni</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>3.60</td>
<td>2.61</td>
<td>0.07</td>
<td>0.46</td>
<td>0.27</td>
<td>0.17</td>
<td>0.091</td>
<td>0.040</td>
<td>0.023</td>
<td>0.011</td>
</tr>
<tr>
<td>I</td>
<td>3.66</td>
<td>2.98</td>
<td>0.010</td>
<td>0.042</td>
<td>0.20</td>
<td>0.015</td>
<td>0.071</td>
<td>0.040</td>
<td>0.029</td>
<td>0.022</td>
</tr>
</tbody>
</table>

Standard Inoculation vs. Improved Method

- **Middle: Standard-Unetched, 100X**
  - Graphite: 93% Nodularity, 150 Nod/mm²

- **Middle: Improved- Unetched, 100X**
  - Graphite: 95% Nodularity, 225 Nod/mm²
Chill Wedge Comparison: Standard vs. Improved Method

Tip: Standard - Unetched, 100X Mag
Graphite: 95% Nodularity, 150 Nod/mm²
Matrix: 90%

Tip: Improved - Unetched, 100X Mag
Graphite: 95% Nodularity, 300 Nodules/mm²
Matrix: 5% Carbides, 85%

Tip: Standard - Etched, 200X Mag

Tip: Improved - Etched, 200X Mag

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Chill Wedge Comparison: Standard vs. Improved Method

Summary:
Chill wedge testing displayed the ability of the improved method to increase graphite nucleation and reduce carbide formation to a minimal amount in the tip of the chill wedge.

![Chill Wedge Comparison Image]
Case Study 1: 65-45-12 Ductile Iron part

The specification for the part is 65-45-12 ductile iron. The customer required the part below to be 100% carbide free in the yoke section.

The standard inoculation method was not sufficient to prevent carbide formation. The excessive primary carbide formation yielded poor machining properties.
Case Study 1: 65-45-12 Ductile Iron part

Standard Inoculation Method:
Ladle Inoculation: 4.5 lb Ca-bearing FeSi 75 per 600 lb Treated Base Iron
In-Mold Inoculation: Germaalloy - 15 g

<table>
<thead>
<tr>
<th>C</th>
<th>Si</th>
<th>S</th>
<th>Mg</th>
<th>Mn</th>
<th>P</th>
<th>Cu</th>
<th>Cr</th>
<th>Ni</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.60</td>
<td>2.61</td>
<td>.007</td>
<td>.046</td>
<td>.27</td>
<td>.017</td>
<td>.091</td>
<td>.040</td>
<td>.023</td>
<td>.011</td>
</tr>
</tbody>
</table>

Graphite: 95% Nodularity, 250 Nod/mm²
Matrix: 20% Carbide, 20% Ferrite, 60% Pearlite

The previous producer 100% carbide removal annealed the part, but the end user wanted to produce the casting as-cast and avoid heat treatment.
Case Study 1: 65-45-12 Ductile Iron part

Improved Inoculation Method:
Ladle Inoculation: 3 lb Ca - FeSi75, 3.5 lb Al/Ca-FeSi75, and .6 lb Oxysulfide Inoculants per 500 lb Mg Treated Base Iron
In-Mold Inoculation: Germalloy – 15gms

<table>
<thead>
<tr>
<th>C</th>
<th>Si</th>
<th>S</th>
<th>Mg</th>
<th>Mn</th>
<th>P</th>
<th>Cu</th>
<th>Cr</th>
<th>Ni</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.66</td>
<td>2.98</td>
<td>.010</td>
<td>.042</td>
<td>.20</td>
<td>.015</td>
<td>.071</td>
<td>.040</td>
<td>.029</td>
<td>.022</td>
</tr>
</tbody>
</table>

Unetched, 100X Magnification

Graphite: 97% Nodularity, 300Nod/mm²

Nital Etched, 200X Magnification

Matrix: 32% Pearlite, 58% Ferrite
Case Study 1

Summary for Case Study 1:

The improved method has:

• Eliminated carbide formation
• Increased nodule count
• Increased the % of ferrite in the matrix
• Improved the machining properties
Case Study 2: 65-45-12 Ductile Iron part

Using the improved inoculation method, elimination of carbide formation and increased the ratio of ferrite to pearlite.

Standard Inoculation: Chill in Ring Section

Improved Inoculation: Chill Eliminated

Heavy Carbide formation in ring section.
Case Study 2: 65-45-12 Ductile Iron part

Photomicrographs were taken from the ring section

Standard: Unetched, 100X Mag
Graphite: 95% Nod, 150 Nod/mm²

Improved: Unetched, 100X Mag
Graphite: 95% Nod, 300 Nod/mm²

Standard: Etched, 200X Mag
Matrix: 30% Carbide, 55% P, 5% F

Improved: Etched, 200X Mag
Matrix: 5% Pearlite, 81% Ferrite
Case Study 2: 65-45-12 Ductile Iron part

Summary:

The improved method has:

• Eliminated carbide formation
• Increased nodule count
• Increased the % of ferrite in the matrix
Case Study 3: 65-45-12 Ductile Iron part

When the standard inoculation was used, there was significant carbide formation in the knife edge. Using the improved methods eliminated the carbide formation completely at the tip of the knife and increased the ratio of ferrite to pearlite.
**Case Study 3:**

**Photomicrographs from the Tip:**

- **Standard: Unetched, 100X Mag**
  - 100% carbide at the tip.

- **Improved: Unetched, 100X Mag**
  - Graphite: 93% Nodularity, 300 Nod/mm²

- **Standard: Etched, 100X Mag**
  - 100% carbide at the tip.

- **Improved: Etched, 100X Mag**
Case Study 3:

Photomicrographs from the Tip:

- Standard: Etched, 200X Mag
  - Matrix: The casting is almost solid carbide.

- Improved: Etched, 200X Mag
  - Matrix: 2% Pearlite, 88% Ferrite.
Case Study 3:
Photomicrographs from the Middle Section

**Standard: Unetched, 100X Mag**
Graphite: 95% Nodularity, 175 Nod/mm²

**Improved: Unetched, 100X Mag**
Graphite: 95% Nodularity, 250 Nod/mm²

**Standard: Etched, 100X Mag**
Matrix: 40% Pearlite, 60% Ferrite.

**Improved: Etched, 100X Mag**
Matrix: 7% Pearlite, 83% Ferrite.

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Case Study 3:

Summary:

The improved method has:
• Eliminated carbide formation at the knife tip.
• Increased nodule count.
• Increased the % of ferrite in the matrix.
Mechanical Properties: Improved Method

Average Mechanical Properties of 10 ASTM A536 test bars poured with the improved inoculation method:

<table>
<thead>
<tr>
<th></th>
<th>UTS (PSI)</th>
<th>YS (PSI)</th>
<th>% El</th>
<th>BHN*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spec</td>
<td>65,000</td>
<td>45,000</td>
<td>12%</td>
<td>156-217</td>
</tr>
<tr>
<td>Min.</td>
<td></td>
<td>Min.</td>
<td></td>
<td>Min.</td>
</tr>
<tr>
<td>Avg.</td>
<td>68,600</td>
<td>48,000</td>
<td>19.9</td>
<td>162</td>
</tr>
</tbody>
</table>

* Brinell Hardness Test: 3000 kg, 10 mm Ball

The improved inoculation method did not affect tensile strength and significantly improved % Elongation to consistently above 18%.
Photomicrographs: Test Bar Breaking Gage (1 inch Y Block)

- Standard: Unetched, 100X Mag
  - Graphite: 93% Nodularity, 100 Nod/mm²
  - Matrix: 10% Pearlite, 80% Ferrite

- Improved: Unetched, 100X Mag
  - Graphite: 95% Nodularity, 150 Nod/mm²
  - Matrix: 8% Pearlite, 82% Ferrite

- Standard: Etched, 100X Mag

- Improved: Etched, 100X Mag

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Mechanical Properties: Improved Method

Summary:

The improved method has:
- Displayed exceptional tensile and yield properties.
- Increased nodule count.
- Not affected Ferrite Formation as much in the Y Block as it did in the thinner castings (probably due to faster breakdown of the shell sand mold from the greater metal mass of the Y Block).
Process Changes:

- The amount of treated ductile base iron was reduced from 1200 lb. to 1000 lb. to reduce the ladle pouring time in light sectioned jobs.
- The % Carbon was raised to enhance graphite nucleation and reduce carbide formation.
- The % Manganese was lowered, by increasing pig iron additions, to increase the percentage of ferrite in the matrix, and reduce the carbide formation potential.
- A combination of Calcium, Calcium/Aluminum and Oxysulfide post-inoculants, combined with Calcium/Aluminum In-Mold Inoculant are used to eliminate carbide formation in thin sectioned ductile iron castings. This practice raised the % Silicon in the final chemistry significantly.
Conclusions:
The improved method utilized increased ferrosilicon and oxysulfide inoculant additions to eliminate iron carbide formation and increase nodule count in the critical section.

- Formation of pro and post eutectic nodules increased.
- Nodule formation is more homogeneous.
- Carbide formation has been eliminated in several castings.
- Machining properties have been dramatically improved.
- Improved inoculation method has not affected tensile properties, and has significantly improved % Elongation.
For additional information please contact:

Mr. Marc King  
Metallurgist  
Hiler Industries  
LaPorte, IN  
mking @hilerindustries.com
FEF CONFERENCE

The 2011 FEF College Industry Conference was held at the Westin Hotel in downtown Chicago from November 17 & 18, 2011. Again the DIS participated in the Career Information Session on Thursday November 17th. Thanks go out to John Keough of Applied Process for transporting and arranging to have the shirts produced, and Kathy Hayrynen of Applied Process along with Eric Meyers of Oil City Iron Works for helping out at the DIS table top. Thanks also go out to the following companies who donated funds to cover the cost of producing the shirts:

Roberts Sinto Corp.
Elyria/Hodge Foundries
Foseco
Fundicion Aguilas
Hitachi Metals Automotive Corp.
Hickman Williams & Company
Pure Power Technologies
ASK Chemicals
Primetrade, Inc.
Farrar Corp.
ThyssenKrupp Waupaca
Elkem
Buck Company
Grede Holdings LLC
FerroPem Group
Blackhawk de Mexico
Applied Process
Benton Foundry
Blue Water Thermal Solutions

This year's slogan for the front of the shirts was "Stretch the Possibilities"
During the Friday luncheon, once again the DIS through the FEF Keith Millis National Scholarship, presented four scholarships to deserving recipients.

We want to acknowledge the persons who selected the students this year, Lifetime Patrons and former FEF students, John Keough CEO for Applied Process and Gary Gigante, CEO of ThyssenKrupp Waupaca.

This endowment was established with a variety of companies as well as the Ductile Iron Society to honor the life work of Keith Millis. Keith is the inventor of Ductile Iron and past Executive Director for DIS. He also served as FEF Board President in 1967.

Four scholarships at $2,000 each were awarded this year and the students along with key professors were;

Key Professor is: Scott Giese
The student is: Erica Hill
School: Northern Iowa

Key Professor: Sam Ramrattan
The student is: Joseph Gray
School: Western Michigan

Key Professor is: Scott Giese
The student is: Ryan Brattrud
School: Northern Iowa
Key Professor is: Russ Rosmait          School: Pittsburg State
The student is: **Kane Rohrig**

We would also like to thank Bill Sorenson and Pam Lechner of the FEF for inviting the DIS to participate in the Career Session.

Jim Wood
DIS Executive Director
Joseph Hsieh  
(215) 833-4559  
Joseph.c.Hsieh@drexel.edu  
132 Brandamore Rd., Honey Brook, PA 19344

Education
Drexel University          Philadelphia, PA
Bachelor’s Degree of Science in Materials Engineering  
Anticipated Graduation - June 2012
Minor in Nuclear Engineering
Cumulative GPA: 3.24

Honors
AJ Drexel Academic Scholarship
Drexel University Pennoni Honors College
James W. Lindemer Endowed Memorial Scholarship: in recognition of academic merit (Feb 17 2010)

Relevant Coursework
Ceramics Processing          Thermodynamics of Materials
Processing of Metallic Metals Comp Lab and Numerical Methods
Mechanical Behavior of Solids Special Topic: Electronic & Photonic Properties

Experience
Research: Dynamic Characterization Group, PI: Dr. Mitra Taheri, MSE  
January 2009 - Current
Current Project: Grain boundary engineering on stainless steel
Goal: Develop thermal mechanical processing to generate coincident site lattice (CSL) boundaries and analyze material behavior response (e.g. corrosion, stress corrosion cracking).
   Key requirements: - the use of electron backscatter diffraction (EBSD) in a SEM for grain boundary analysis
   - very detailed sample machining, organized thermal mechanical processing and EBSD-level polishing
Previous Projects: Diffusion of Intermetallics into Iron Particles
Goal: Characterize diffusion behavior of coated powder into Fe, for soft magnet application.
   Key requirements: - the use of scanning electron microscopy work to characterize particles in Fe matrix via energy-dispersive X-ray spectroscopy (EDS)

Employment
Drexel University          Philadelphia, PA
Undergraduate researcher (co-op), Dynamic Characterization Group  
March 2011-current
- worked closely alongside a PhD student on the project Grain boundary engineering on stainless steel to develop the project into publishable information
- organized and processed samples for a three variable matrix, requiring very methodical sample preparation and identification
- was trained on a scanning electron microscope (SEM), and ran over 100 hours of EBSD.

Carpenter Technology          Reading, PA
Technical Services, Forge Bar and Billet Co-op  
March 2010 - September 2010
- collected extensive qualification data for existing grades for new customers, compiling the data and information into a presentation
- maintained long term data collection projects with the goal of increasing lean manufacturing through trend analysis; data included furnace performance, ultrasonic inspection, and other root causes
- performed sample preparation, etching, optical analysis with optical microscope, and image analysis with Clemex
- accumulated fiscal year data for various reporting projects using Data Warehouse

Technical Services, Coil Finishing Co-op  
March 2009 - September 2009
- provided lab support and data collection for the Coil Finishing Group
- performed extensive work with sample preparation, etching, and image analysis with stereoscopes and optical microscopes
- compiled and arranged data for multiple root cause analysis projects
- actively worked with manufacturing to develop cold roll inventory system

Skills, MATLAB, Maple, AutoCAD, Pro Engineer, Microsoft Excel, Word, PowerPoint
Objective:
• Further my Knowledge of multiple aspects of the Technology Industry and gain experience through hands on experience.

Education:
• Kent State University – 2007-2012; Bachelors of Science in Technology; Casting/Manufacturing concentration. Anticipated graduation May 2012
• Relevant course work in AutoCAD, Solid Edge, and Microsoft office, Cast Metals, Metallurgy and Materials Science.
• Business course work in accounting, statistics, law, and management.
• Archbishop Hoban High School – graduated with Honors May 2007

Work Experience:
• O’Reilly Auto Parts Parts Specialist January 2011 - present
  Parks Department; assist in new construction projects and park maintenance
• Rockne’s Sep 2007 – May 2008
  Kitchen assistant
• Comunale Automatic Sprinkler Summers of 2006 and 2007
  Assemble sprinkler components; deliver material to job-sites in Ohio, West Virginia and Pennsylvania; assist in hanging systems at job-sites
• Boston Mill/Brandywine Ski Resort Winter of 2005 and 2006
  Snowboard instructor
• RadTech Summer 2005
  Sort graphite material and general facility clean-up

Accomplishments:
• Foundry Education Foundation Scholarship - FEF
• President of Kent State AFS student chapter
• Access Scholarship – Kent State University

References:
• Available on request
FOR IMMEDIATE RELEASE NOVEMBER, 2011

FEF COLLEGE INDUSTRY CONFERENCE

The FEF College Industry Conference was recently held at the Westin Michigan Avenue in Chicago. Over 275 industry executives, student delegates, key professors and university administrators were in attendance this year.

The conference began on Thursday, November 17, with the Career Information Session which gave 85 student delegates the opportunity to interact with representatives of 42 companies in the metal casting industry. The Information Session and social time before and after the event is structured to facilitate the sharing of job opportunities and to connect students to potential employers in the industry.

During the General Session on Friday, the following speakers addressed the top “Global Outlook for Metal Casting”: Lizeth Medina (Donsco Inc.), Glenn Byczynski (Nemak), and George Kokos (Caterpillar Inc.).

The FEF/AFS Distinguished Professor Award was given to FEF Key Professor, Kyle Metzloff, University of Wisconsin-Platteville, in recognition of his demonstrated personal interest in his students, as well as his knowledge of the industry. As part of the luncheon this year, the Student Delegate scholarships were presented (see next page for complete list) – 19 students were awarded a total of $40,500.00. Additionally, the Keith Millis and Ron Ruddle scholarship recipients were announced.

At the Annual Reception on the evening of November 18, FEF’s highest award, the E.J. Walsh Award, was presented to longtime FEF Board Member, Bob Mortenson. The evening concluded with the drawing of the winners of the 60%/40% raffle that was held to help defray the costs of travel and lodging for the students and professors who attended the CIC - 13 individuals received prizes between $100 and $500; 60% will go toward student/professor CIC travel. Thanks to all who bought and sold the raffle tickets!

Next year’s conference will be held on November 15 & 16 at the Westin Michigan Avenue in Chicago. Plan now to attend this exciting event.

CIC Student Delegate Scholarships - November 18, 2011

AFS-Saginaw Valley Scholarship - Cody Wolfe - Trine University
AFS Southwestern Ohio Scholarship - Jonathan Tinker - Ohio State University
Ron & Glenn Birtwistle Mem. Scholarship - Blake Whitley - University of Alabama
Ron & Glenn Birtwistle Mem. Scholarship - Graham Smith - Tennessee Tech
Donald Brunner Schol.-ThyssenKrupp Waupaca - David Impens - University of Windsor
Paul Carey Memorial Scholarship - Alexander Croll - Trine University
Clifford Chier-Badger Mining Corp. - Keith Ripplinger - Trine University
Wm. E. Conway Schol.-Fairmount Minerals
Tony & Elda Dorfmüller Scholarship
Burleigh Jacobs Scholarship-Grede Foundries
James P. & Katherine Keating Scholarship
Loper Award
Modern Casting Scholarship
Chester V. Nass Memorial Scholarship
Robert W. Reesman Mem. Scholarship
TMB Industries Scholarship
Gary Thoe Schol.-ThyssenKrupp Waupaca
Ray Witt Memorial Scholarship
Robert V. Wolf Mem. Scholarship

Morris Satin - Case Western Reserve Univ.
Richard Rusk - Mohawk College
Suzan Matti - University of Windsor
Maria Boyter - Cal Poly-Pomona Univ.
David Hengst - Missouri Univ. of Science & Tech.
Brandon Raineri - Penn State University
Mat Staudinger - Cal Poly-Pomona
Richard Brown - Pittsburg State University
Justin Tiffany - Mohawk College
Cameron Hoefing - Univ. of Northern Iowa
Mackenzie Meekhof - Western Michigan Univ.
Evan Kluesner - Missouri Univ. of Science & Tech

### Special Scholarships

<table>
<thead>
<tr>
<th>Scholarship</th>
<th>Recipient</th>
<th>University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keith D. Millis Scholarship</td>
<td>Ryan Brattrud</td>
<td>Univ. of Northern Iowa</td>
</tr>
<tr>
<td>Keith D. Millis Scholarship</td>
<td>Joseph Gray</td>
<td>Western Michigan</td>
</tr>
<tr>
<td>Keith D. Millis Scholarship</td>
<td>Erica Hill</td>
<td>Univ. of Northern Iowa</td>
</tr>
<tr>
<td>Keith D. Millis Scholarship</td>
<td>Kane Rohrig</td>
<td>Pittsburg State</td>
</tr>
<tr>
<td>Ron Ruddle Scholarship</td>
<td>Joseph Santa Maria</td>
<td>Univ. of Wisconsin-Milwaukee</td>
</tr>
</tbody>
</table>

More information on this conference or any of the FEF activities can be obtained from the FEF office at 1695 N. Penny Lane, Schaumburg, IL 60173, Phone 847/490-9200, Fax 847/890-6270, email info@fefinc.org, web page [http://www.fefinc.org](http://www.fefinc.org).

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Mr. Devanir Brichesi, President of ABIFA presenting the ABIFA Award to Mr. Renato Carvalho, Managing Director of ASK Chemicals do Brasil

**Press Release**

Technology, efficiently and effectively staged

ASK Chemicals takes a bow at FENAF 2011 in new guise as global player Campinas, Oct 17th, 2011 – At the 2011 FENAF industry trade fair held in Sao Paulo/Brazil from Oct. 4th – 7th 2011, ASK Chemicals GmbH presented itself for the first time in South America as a global complete supplier for the foundry industry. An array of exhibits at the company’s stand provided an insight into the extensive range of products and foundry-relevant services offered by the global player. A presentation by an ASK specialist as part of the CONAF Forum gave visitors to the fair some background knowledge about new coatings concepts as a comprehensive approach for defect and residue free castings. An award presented to ASK Chemicals by the president of the
Brazilian Foundry Association as a token of appreciation for its contribution to the progress in the foundry industry in Brazil. “We are looking forward to even more contributions from the now extended portfolio of foundry consumables that are offered by ASK Chemicals. Particular contributions are expected in the offering of products and solutions for more sustainable production in our industry, only with highly reliable suppliers the foundry business can grow,” said Mr. Devanir Brichesi, President of the National Foundry Association - ABIFA in Brazil.

The specialist for foundry chemicals kicked off its appearance on the South American markets at FENAF 2011 with the aim of helping both Brazilian and international professional visitors from other South American countries to understand the global product portfolio for foundry consumables and transfer of expertise offered by ASK Chemicals, particularly with regard to the pressing issues of environmental compatibility and resource conservation.

In addition to interesting presentations by ASK Chemicals specialists as part of the CONAF Technical Forum, which focused on “New coatings concepts as a comprehensive approach for defect and residue free castings” for highly demanding processes in automotive serial castings. At the stand visitors also had the opportunity to learn about the company’s latest product generations in metal filtration and products for emission reduced casting. The company illustrated its extensive portfolio through numerous exhibits detailing all foundry-relevant chemical aids such as binders, coatings, additives, feeders and filters, both organic and inorganic, as well as metallurgical products. Expert contacts from company locations in Brazil, Europe and Americas were on hand to answer the questions of the professional audience. This allowed the experts to address requests and requirements in person in more than 15 languages and discuss how individual customers could benefit from the latest technical solutions.

“In numerous discussions with customers and interested parties, our products, solutions and global full-service program have met with great interest, with issues such as production processes that save on resources and energy given particular emphasis”, states Renato Carvalho, Managing Director of the ASK Chemicals South American Operations. Customers were especially impressed by the one-stop shop with products ranging from the core shop (such as binders and sand additives) to the moulding line (such as filters, risers, refractory coatings) all the way to the core shop with its extensive range of inoculants and master alloys.

ASK Chemicals sees itself unequivocally as a technological leader in this regard. Proof of sustainable production procedures, energy and material efficiency and emission reduction is provided by the company’s product lines; process optimization is a daily business task. “The use of our products and procedures increases efficiency, enhances output and productivity while also reducing emissions and protecting resources,” comments Managing Director Renato Carvalho, referring to the company’s portfolio. In making this claim, the company lives up to its obligations to society as a whole. Further trade fair appearances planned are set to put these goals into action – with the company next participating in Metallurgica 2012 in Joinville/Brazil, and the World Foundry Congress in Monterrey Mexico.
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