The Ductile Iron Society held its first ever Heavy Section DI Conference on October 27-29, 2010 in Cleveland, Ohio. There were 160 attendees over the two and half days and 25 quality presentations. If you pour heavy section ductile iron and you missed this conference, it was a good one. Some of you may ask, “What is a heavy section”? We concluded that anything over 2 inches in thickness was considered heavy section. For the non-heavy section casting producers, there were some general topics covered along with some general interest presentations. There was a mixture of foundries, windmill OEM’s, mining OEM’s and suppliers to round out the program.

Even as the ductile iron production has been improving for the past 50 years, there are still some struggling factors to understand the finer points in the metallurgical process. Also some foundries, due to cost pressures, are not using optimal materials. Some foundries costs are too high due to some old methods in gating, risering and sand controls. Not many are attempting to make riser less castings, which requires strict metallurgical controls and the understanding of mold filling and feeding of castings. There are foundries that are getting the most out of the process controls and others who are lacking in these controls. It seems that European heavy section ductile iron producers are producing large castings, which meet the low temperature impact standards. Some reasons are; MgFeSi alloys with small amounts of rare earths (La?) and also use nickel magnesium when tapping several ladles to pour one casting. Silicons are usually kept below 2.2% and enough Mg to produce nodular graphite. They utilize the ATAS cooling curves to control the metallurgy, and would like the iron to solidify as eutectic. Most of them use chills to equalize variations in section thickness. Use of mold washes are encouraged and remember to make sure it is dry before pouring.

These are some of the problems exhibited in heavy sections concluded from the conference; chunky graphite, graphite floatation, low nodule count, nodule alignment, carbides, flake graphite at the surface, difficulties meeting low temperature impact properties, shrinkage, porosity, and dross defects.

What we learned was the possibility to make riser less castings, pour cold and still get dross free castings if the gating system is designed right and the gating system is kept full throughout the pour, when using chemically bonded sand molds they should be poured in less than 2 minutes, it is possible to treat large quantities of iron with magnesium
ferrosilicon and nickel magnesium alloys, and many have problems with chunky graphite when producing heavy sections castings, and can Antimony help eliminate chunky graphite in Ferritic Ductile Iron? Sb and Ce balance is essential to avoid chunky graphite. A Ce/Sb ratio around 1 seems to work well. Instead of Ce could La be used too and what will be the La/Sb ratio? Heat treatment of heavy section castings has its own problems due to heating and cooling rates which are different from the surface to the center of the castings.

Quality requirements of castings are as critical for large castings as for smaller castings when planning on Austempering. Heating and quenching rates will need to be carefully matched with chemistry; due to the center of the casting will be cooling slower than the surface. This will result in pearlite in the center of the casting.

**Watch for Rare Earth prices to increase due to Chinese export controls. Contact your supplier and make sure you are covered.**

The registrants at the conference were given a DVD compilation of 23 of the 25 presentations. As promised we have included the missing presentations in this edition of Ductile Iron News. Also we have included some written reports for those who didn’t attend. If you are interested in receiving a copy of the whole program (Power Point Format), they are available for $100 each plus shipping & handling. You can email Jim Wood (DIS Executive Director) at jwood@ductile.org for a copy.

We also had four university students from three different universities attend the meeting as guests of the DIS. The DIS, College & University Committee attempts to invite students who are in their senior year to attend both annual meetings and cover their travel expenses. For this meeting we had Megan Haycock from Michigan Technological University in Houghton, MI; Chris Cowhick from Kent State University in Kent, OH, and Alexander Hoimes and Nicholas Shovelin from Penn State University in University Park, PA. All the students made a presentation during our lunch breaks. Their resumes are also available on the links on the left side of this page.

At the banquet on Thursday evening, our President Scott Gledhill presided over the program.

Scott thanked our many guests who attended the conference. He also introduced our new
members since the last meeting in Vancouver, Canada. They are Ferrosource, Div. of Stemcor U.S.A., Fundicion Aguilas S.A. de C.V. and Primetrade, Inc. Thanks to all three companies for joining the DIS.

Next Scott asked all five Technical Chair Persons to come to the front and present a small token of appreciation to each speaker. He also presented a gift to each Technical Chair as thanks for their contribution to the organizing of this conference.
Thanks goes out to Buck Company, especially Dick McMinn, Mike Galvin and Matt Sullivan for donating the gifts. Also thanks to Alex Hoimes from Penn State for his Windmill design. He was employed as a past summer intern at Buck Company.

Scott then introduced our evening guest speaker who is Dale Reckman of Great Lakes Wind Network here in Cleveland, Ohio.
Dale Reckman of Great Lakes Wind Network

Dale brings to Great Lakes Wind Network over 25 years in operations, engineering and product development, estimating, sales and project management, procurement, and supply chain management. Prior to joining Great Lakes Wind Network, Dale was the VP of the Commercial Products Group for Magma Machine Company, a supplier to major wind power OEM’s and an owner of AR Industries, a large fabricating firm that was sold to ALSTROM Power in 2000.

Today Dale is the director of field services for Great Lakes Wind Network, a Cleveland based, non-profit supply chain organization whose mission is to increase the domestic content in North America’s wind turbines. Great Lakes Wind Network has an expanding network of more than 1400 manufacturing companies located throughout North America, and it connects wind turbine OEM’s manufacturers, and regional economic development organizations in ways that accelerate investment and new manufacturing jobs.

Dale and his family live in the Cincinnati area. Dale spoke to the group on the topic of “Winds of Opportunity”.

This ended the banquet festivities.

Mark your calendar early as our next DIS meeting will be our Annual Spring meeting on June 1-3, 2011 at the Marriott Dallas/Fort Worth Airport South with a tour of Oil City Iron Works in Corsicana, Texas.

Also watch the DIS website for an announcement on the next DIS Production Seminar sometime early in 2011. Plans are on the way and it is a bargain to attend.

**FEF COLLEGE INDUSTRY CONFERENCE**

On November 19, 2010, the DIS presented four students with scholarships at the FEF College Industry Conference at the Westin Hotel in downtown Chicago. These scholarships are made possible by the DIS Keith Millis Scholarship Fund. I want to acknowledge John (Chip) Keough of Applied Process, a lifetime patron and former FEF student, for selecting the students this year. 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 was a past Executive Director for the DIS. He also served as the FEF Board
President in 1967. Those four students along with their key professors were; Rhiannon Bragg of the University of Alabama-Birmingham (no photo available) and key professor Alan Druschitz, Alexander Hoimes of Penn State University and key professor Bob Voigt, Kris Boss of the University of Northern Iowa and key professor Scott Giese, and Brett Currier of Pittsburg State University and key professor Russ Rosmait. Congratulations to all four recipients.

Alexander Hoimes w/Jim Wood
Kris Boss w/Jim Wood
Brett Currier w/Jim Wood

James Wood
Executive/Technical Director
Ductile Iron Society
Contributions also by Al Alagarsamy-Consultant and DIS Alumni Member
Heavy Section Ductile Iron Conference Speaker Bios
Wednesday, October 27 Morning Session

KEVIN TILL

KEVIN TILL ATTENDED BOTH THE UNIVERSITY OF ARIZONA IN TUCSON AND THE UNIVERSITY OF NORTH DAKOTA IN GRAND FORKS DURING HIS UNDERGRADUATE CAREER. HE OBTAINED HIS BSc IN MECHANICAL ENGINEERING WITH A MINOR IN MATHEMATICS FROM THE UNIVERSITY OF NORTH DAKOTA IN 2005. DURING HIS UNDERGRADUATE STUDIES KEVIN WORKED ON THE HYDROGEN FUEL CELL CAR PROJECT AT THE UNIVERSITY OF NORTH DAKOTA AND THE HYDROGEN FUEL CELLS AT THE UNIVERSITY OF MICHIGAN-DEARBORN FOR A SUMMER INTERNSHIP. IN 2006, HE BEGAN WORKING FULL TIME AS A MECHANICAL DESIGN ENG AT ROSEMOUNT IN MINNEAPOLIS WHICH IS A COMPANY WITHIN EMERSON ELECTRIC. IN 2008 KEVIN WAS PROMOTED TO A MECHANICAL PROJECT ENGINEER AT ROSEMOUNT WHERE HE WAS INVOLVED WITH STAINLESS STEEL, ALUMINUM DIE CASTING DESIGN, AND MORE EXOTIC MATERIALS SUCH AS CAST HASTELLOY AND MONEL AS WELL AS WELDING PROCESSES. LATER IN 2008, KEVIN TOOK A NEW JOB AT CLIPPER WINDPOWER IN CALIFORNIA AS A MECHANICAL DESIGN ENG. IN THIS ROLE, KEVIN PARTICIPATED HEAVILY IN CONTINUATION AND REDESIGN MECHANICAL ENG EFFORTS ON LARGE DUCTILE IRON CASTINGS AND STEEL WELDMENTS. IN 2010, HE WAS PROMOTED TO A POSITION OF TECHNICAL LEAD FOR THE MECHANICAL ENG ANALYSIS GROUP AT CLIPPER. TODAY KEVIN RESIDES IN CARPINTERIA, CALIFORNIA.

THE DIS WELCOMES KEVIN WHO IS HERE TO TALK ABOUT “DESIGN OVERVIEW OF LARGE DUCTILE IRON CASTING WIND TURBINE GENERATOR COMPONENTS”

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DR. SVEN UEBRICK

DR. SVEN UEBRICK RECEIVED HIS PhD IN METALLURGY FROM FREIBERG MINING ACADEMY, UNIVERSITY OF TECHNOLOGY, WHICH IS THE OLDEST UNIVERSITY OF MINING AND METALLURGY IN THE WORLD. THIS UNIVERSITY WAS ESTABLISHED IN 1765. DR. UEBRICK
BEGUN HIS FOUNDRY CAREER AT DOERING GMBH AS QUALITY MANAGER. DOERING PRODUCED CASTINGS SUCH AS AUTOMOTIVE DIES, AND CASTINGS FOR MACHINERY AND PROCESSING INDUSTRIES. HE LEFT DOERING AS PLANT MANAGER TO JOIN HERGER GUSS GMBH, ENKENBACH-ALSENBOURN GERMANY, AS PLANT MANAGER. HERGER GUSS PRODUCED CASTINGS 15,000 LBS TO 45,000 LBS. PRIOR TO JOINING SKW, HE WAS THE MANAGING DIRECTOR OF HASENCLEVER & SOHN GMBH IN BATTENBURG, GERMANY. HASENCLEVER PRODUCES EXHAUST AND TURBO CHARGERS FOR THE AUTOMOTIVE INDUSTRY. DR. UEBRICK IS CURRENTLY THE MANAGING DIRECTOR OF SKW GIESSEREI GMBH, A MEMBER OF THE ASK CHEMICALS GROUP. SKW IS LOCATED IN BAVARIA AND PRODUCES MASTER ALLOYS, INOCULANTS, CORED WIRE, SPECIALTY PIG IRONS AND METAL REFINING ALLOYS.

THE DIS WELCOMES DR. UEBRICK WHO IS HERE TO TALK ABOUT “WIND ENERGY CASTINGS – METALLURGICAL CHALLENGE”

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CESAR BRAGA

CESAR BRAGA GRADUATED WITH HIS METALLURGICAL ENG DEGREE IN 1981 FROM THE FEDERAL UNIVERSITY OF MINAS GERAIS, MINAS GERAIS, BRAZIL. HE HAS 11 YEARS OF EXPERIENCE IN THE RESEARCH AND DEVELOPMENT OF SPECIALTY STEELS, NI-CU ALLOYS, FORGING, HOT ROLLING AND COLD DRAWING PROCESSES AT ELETROMETAL, BRAZIL. HE THEN SPENT 3 YEARS AS QUALITY MANAGER AT NORDBERG MINING EQUIPMENT COMPANY AND 3 YEARS AT TEKDID ALUMINUM FOUNDRY.

CESAR IS CURRENTLY THE TECHNICAL DIRECTOR & QUALITY ASSURANCE MANAGER AT AARROWCAST. HE HAS BEEN AT AARROWCAST IN SHAWANO, WISC FOR 12 YEARS.

THE DIS WELCOMES CESAR WHO IS HERE TO TALK ABOUT “EXPERIMENT TO PROVE THAT ANTIMONY HELPS ELIMINATE CHUNKY GRAPHITE IN THICK WALL FERRITIC DUCTILE IRON”
VYTAS SVALBONAS

VYTAS SVALBONAS GRADUATED FROM COOPER UNION AND NEW YORK UNIVERSITY, BOTH IN NEW YORK CITY WITH HIS BACHELOR OF SCIENCE AND MASTERS IN STRUCTURAL MECHANICS. HE THEN WENT ON TO BROOKLYN POLYTECHNICAL TO RECEIVE HIS PHD. HE STARTED HIS WORKING CAREER WITH GRUMMAN AEROSPACE IN ANALYTICAL METHODS DEVELOPMENT FOR AEROSPACE STRUCTURES. HE HAD CONSULTING CONTRACTS WITH NASA ON THE LUNAR LANDING AND SATURN ROCKET APPLICATIONS. HE THEN MOVED ON TO FRANKLIN INSTITUTE RESEARCH LABS IN PHILADELPHIA IN VARIOUS FIELDS, INCLUDING FAILURE ANALYSIS OF MINING STRUCTURES. VYTAS IS CURRENTLY THE DIRECTOR OF ENG TECHNOLOGIES, IN COMMUNICATION DIVISION WORLDWIDE FOR KOPPERS-SVEDALA-METSO IN YORK, PA.

THE DIS WELCOMES VYTAS WHO IS HERE TO TALK ABOUT "EVALUATION METHODS FOR FLAWS IN HEAVY DUCTILE IRON SECTIONS, IN MINING"

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HENRIK BARTH

HENRIK BARTH GRADUATED FROM THE UNIVERSITY OF JONKOPING IN SWEDEN IN FOUNDRY ENGINEERING. HE THEN STARTED HIS CAREER AT VOLVO ENGINEERING AS AN APPRENTICE. HE THEN MOVED ON TO ARVIKA AS A FOUNDRY ENGINEER AND PRODUCTION MANAGER. AFTER ARVIKA HE WENT TO FOSECO AS A PRODUCT MANAGER. THEN HENRIK MOVED OVER TO NOVACAST FOUNDRY SOLUTIONS AS AN EXPORT MANAGER. HE THEN CHANGED POSITIONS TO MANAGING DIRECTOR, LEAN PRODUCTION ENGINEER AND SINCE 2008 HE IS THE PRESIDENT OF NOVASCAST USA.

ALONG WITH HENRIK IS ERIK PERSSON WHO GRADUATED WITH HIS
Masters in Metallurgy from the University Royal Technology of Stockholm. He also went to work for Volvo in the department for cast materials and foundry technology. He then moved on to the Swedish Foundry Association as a development engineer in the process simulation and properties in gray and ductile iron. Erik then went to Daros Piston Rings as the foundry manager and then changed jobs and went to Novacast Foundry Solutions as the senior metallurgist and product manager of thermal analysis.

The DIS welcomes Henrik & Erik who are here to talk about “Tight Process Control Essential for Tough Requirements”

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Wednesday, October 27 Afternoon Session

Thorsten Reuther

Thorsten Reuther started his working career in the steel plant of Buderus in Wetzlar in 1986. After his studies he went to work for the Fritz Winter foundry where he did his thesis under the direction of Dr. Milan Lampic. He became the leader in Plant 2 where he was responsible for the hot blast cupola. In 2001, Thorsten started at Hofmann Ceramics as the technical leader and technical support for their main customers. His main activities are in the fields of risering and gating of iron castings. He is also responsible for developing new ideas and resources for the foundries to solve their filtering problems, especially heavy section castings.

The DIS welcomes Thorsten who is here to talk about “How to Filter a Heavy Section Casting – The Do’s and Don’ts”

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TORBJORN SKALAND

TORBJORN SKALAND GRADUATED FROM THE NORWEGIAN INSTITUTE OF TECHNOLOGY IN TRONDHEIM, NORWAY WITH HIS MASTERS IN 1988 AND HIS PHD IN 1992 IN METALLURGY. HE THEN WENT TO WORK FOR THE FOUNDATION OF SCIENTIFIC AND INDUSTRIAL RESEARCH (SINTEF) IN TRONDHEIM, NORWAY AS A SCIENTIFIC RESEARCHER AND PHD STUDENT. HE THEN MOVED ON TO ELKEM METALS, FOUNDRY PRODUCT DIVISION MANAGER OF R&D, CORPORATE SPECIALIST RESPONSIBLE FOR FOUNDRY-FERROALLOY DEVELOPMENTS. IN 2005 TORBJORN WENT TO WORK FOR VESTAS WIND SYSTEMS, FOUNDRY TECHNOLOGY DEPARTMENT IN KRISTIANSAND, NORWAY WHERE TODAY HE IS THE VP OF TECHNOLOGY AND RESPONSIBLE FOR WIND TURBINE CASTINGS AND DUCTILE IRON FOUNDRY PROCESS DEVELOPMENTS. HE HEADS THE TECHNOLOGY DEPARTMENT OF 20 FOUNDRY ENGINEERS. HE IS ALSO A MEMBER OF THE AMERICAN FOUNDRY SOCIETY AND THE DUCTILE IRON SOCIETY.

THE DIS WELCOMES TORBJORN WHO IS HERE TO TALK ABOUT “HEAVY SECTION DUCTILE IRON CASTINGS FOR WIND TURBINES”

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BILL LA FRAMBOISE

BILL LA FRAMBOISE STARTED HIS CAREER WITH GENERAL MOTORS IN 1971, WHERE HE WENT FROM A LAB TECHNICIAN TO A LAB SUPERVISOR. IN 1987 HE TOOK A SPECIAL EARLY RETIREMENT AND OPENED AUBURN ANALYTICAL LABS, WHICH HE IS TO THIS DAY THE CEO. IN 2000 HE STARTED B&K CONSULTANTS. THIS IS WHERE HE ACTUALLY STARTED ADVISING FOUNDRIES ON WHAT THE SLAG ANALYSIS. BILL HAS BEEN IN 300 PLUS FOUNDRIES AND HAS A LOY OF HANDS ON EXPERIENCE. BILL IS A CO-AUTHOR OF THE SiC TEST PROCEDURE WHICH IS CURRENTLY BEING USED THROUGHOUT THE WORLD. AUBURN ANALYTICAL IS A FOUNDRY SERVICE LABORATORY WITH IT’S MAIN FOCUS BEING ON SLAGS AND ALLOYS AND OTHER FOUNDRY ADDITIVES. BILL IS NOW SERVING HIS 3RD TIME AS THE
CHAIRMAN OF THE AFS CUPOLA COMMITTEE AND IS ALSO GOING THROUGH THE AFS DIVISION 8 OFFICERS FOR THE 3RD TIME.

THE DIS WELCOMES BILL WHO IS HERE TO TALK ABOUT “THE BENEFITS OF SLAG ANALYSIS FOR ALL MELTING OPERATIONS”  

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RALPH SHOWMAN

RALPH SHOWMAN GRADUATED FROM THE OHIO STATE UNIVERSITY IN 1972 WITH HIS BATCHELOR OF SCIENCE IN METALLURGICAL ENGINEERING. RALPH IS CURRENTLY THE SENIOR STAFF METALLURGIST, GLOBAL TECHNOLOGIES, FOR ASHLAND CASTING SOLUTIONS IN COLUMBUS, OHIO. HE STARTED HIS CAREER AT FRANK FOUNDRY CORP AS THE MELTING & POURING SUPERVISOR. HE WAS ALSO AN INSTRUCTOR IN CAST METALS TECHNOLOGY AT MUSKEGON COMMUNITY COLLEGE. HE THEN MOVED ON TO NIBCO INC. WHERE HE WAS THE CORPORATE METALLURGIST. THEY MANUFACTURED COPPER FITTINGS, BRASS, IRON AND STEEL VALVES. HE THEN WAS PROMOTED TO THE DIRECTOR OF CORPORATE ENGINEERING WITH NIBCO INC.

RALPH HAS HAD MANY OTHER POSITIONS WITH ASHLAND INCLUDING LAB MANAGER, PRODUCT DEVELOPMENT, TRAINING MANAGER, & PRODUCT MANAGER OF FILTERS. RALPH HAS AUTHORED NUMEROUS AFS PAPERS.

THE DIS WELCOMES RALPH WHO IS HERE TO TALK ABOUT “THE EFFECTS OF MOLD & CORE CONSUMABLES ON SURFACE DEFECTS – KNOW YOUR ROLE”  

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Kathy Hayrynen presenting speaker gift to Greg Selip

GREGORY SELIP

GREG SELIP GRADUATED FROM CASE WESTERN RESERVE UNIVERSITY HERE IN CLEVELAND WITH A BACHELOR OF SCIENCE IN

THE DIS WELCOMES GREG WHO IS HERE TO TALK ABOUT “ENERGY CONSERVATION PROJECTS”
Heavy Section Ductile Iron Conference Speaker Bios
Thursday, October 28 Morning Session

ANTHONY GIAMMARISE
ANTHONY GIAMMARISE GRADUATED FROM THE UNIVERSITY OF WISCONSIN IN METALLURGICAL ENGINEERING. HE ALSO HOLDS A DEGREE IN HISTORY FROM THE UNIVERSITY OF BUFFALO. ANTHONY IS A CONSULTING METALLURGICAL ENGINEER WITH GE TRANSPORTATION IN ERIE, PA. HE HAS HELD VARIOUS POSITIONS OVER A 28 YEAR SPAN ALL INVOLVING MATERIAL SELECTION, MATERIALS PROCESSING, AND FAILURE ANALYSIS, IN SUPPORT OF THE DESIGN, MANUFACTURE AND PRODUCT SERVICE FOR LOCOMOTIVES AND OFF HIGHWAY PROPULSION SYSTEMS. HE IS CURRENTLY FOCUSED ON SUPPORTING THE DRIVE TRAIN TECHNOLOGIES GROUP AT ERIE AND THEIR WORK IN DESIGNING, DEVELOPING AND BUILDING GEARBOXES FOR WIND TURBINES.

THE DIS WELCOMES ANTHONY WHO IS HERE TO TALK ABOUT “CHALLENGES IN HEAVY SECTION POWER GENERATION IRON CASTINGS”

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JIM GARRETT
JIM GARRETT GRADUATED WITH HIS BACHELOR OF SCIENCE DEGREE FROM THE UNIVERSITY OF TOLEDO IN INDUSTRIAL ENGINEERING. HE THEN CAME ON TO BOWLING GREEN STATE UNIVERSITY TO OBTAIN HIS MASTER OF BUSINESS ADMINISTRATION DEGREE. JIM IS CURRENTLY A DIRECTOR AND ACTIVE IN DEVELOPING NEW BUSINESS FOR FOUNDRY SOLUTIONS AND DESIGN. HE HAS OVER 30 YEARS OF FOUNDRY EXPERIENCE. HE HAS RECENTLY PROVIDED EXPERTISE ON FOUNDRY SOLUTIONS & DESIGN PROJECTS AT GENERAL MOTORS, MAHLE ENGINE COMPONENTS, NORTHROP GRUMMAN AND BREMBO. PREVIOUSLY JIM WAS THE VP OF FOUNDRY SYSTEMS FOR CONSOLIDATED ENGINEERING COMPANY (CEC) WHERE HE DIRECTED SALES FOR THE FIRM'S PROPRIETARY CASTING AND HEAT TREATMENT EQUIPMENT SYSTEMS. MAJOR EQUIPMENT PROJECTS WERE COMPLETED FOR DAIMLER BENZ- STUTTGART, NEMAK-MONTERREY, FORD CLEVELAND ALUMINUM CASTING PLANT, FORD WINDSOR, NEMAK WINDSOR, TEKSID AND CIFUNSA. PRIOR TO JOINING CEC HE WAS THE PROJECT MANAGER WITH THE MOUAT COMPANY. EARLIER, JIM SERVED AS A
MANUFACTURING MANAGER FOR OUTBOARD MARINE CORPORATION AND MANAGER OF PLANT ENGINEERING AT DOEHLER JARVIS CASTINGS.

HE IS A MEMBER OF THE AMERICAN FOUNDRY SOCIETY. HE HAS BEEN A SPEAKER AT NUMEROUS TECHNICAL SOCIETY FUNCTIONS, AND HAS PUBLISHED SEVERAL TECHNICAL ARTICLES FOR INDUSTRY PUBLICATIONS AND HOLDS PATENTS FOR METAL CASTING TECHNOLOGIES.

THE DIS WELCOMES JIM WHO IS HERE TO TALK ABOUT “HEAVY CASTING AUTOMATED CLEANING AND FINISHING”

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Michael Koch receiving speaker award from Greg Selip

MICHAEL KOCH

MICHAEL KOCH GRADUATED WITH HIS DEGREE IN FOUNDRY ENGINEERING AND METALLURGY FROM THE UNIVERSITY OF GIESSEN-FRIEDBERG IN GERMANY. MICHAEL IS CURRENTLY WITH FERROPEM AND RESPONSIBLE FOR CENTRAL EUROPE AND STRATEGIC DEVELOPMENT OF SOUTH EAST ASIA INCLUDING CHINA, AS WELL AS TECHNICAL SUPPORT FOR OUR FERROATLANTICA USA/SILICON SOURCES DIVISIONS. BEFORE JOINING FERROPEM IN 2000, MICHAEL WAS THE PROCESS ENGINEER AT INTERNET COLUMBUS FOUNDRY NEUNKIRCHEN FROM 1995-1996. THEN IN 1996 HE MOVED TO SAINT-GOBAIN FOUNDRY AS THE PROCESS DEVELOPMENT MANAGER AT THE NEWLY CONSTRUCTED CUPOLA MELTING SHOP. IN 1997 TO 2000 HE WAS THE MANAGER OF S-G FOUNDRY WHICH MANUFACTURED 120,000 TONS PER YEAR OF DUCTILE IRON PIPE.

THE DIS WELCOMES MICHAEL WHO IS HERE TO TALK ABOUT “INOCULATION OF BIG SECTION CASTINGS – THE PAST & THE FUTURE”

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Ian Lee receiving speaker award from Greg Selip
IAN LEE


THE DIS WELCOMES IAN WHO IS HERE TO TALK ABOUT “HEAT TREATMENT OF HEAVY SECTION DUCTILE IRON CASTINGS”

CHANTAL LABRECQUE

CHANTAL LABRECQUE GRADUATED WITH HER BACHELOR OF SCIENCE IN 1991 IN PHYSICS ENGINEERING FROM THE UNIVERSITY LAVAL IN QUEBEC CITY QUEBEC, CANADA. SHE THEN WENT ON TO RECEIVE HER MASTERS IN METALLURGICAL ENGINEERING AT LAVAL UNIVERSITY. CHANTAL STARTED HER WORKING CAREER IN 1994 AS A RESEARCH ENGINEER WITH QUEBEC HYDRO RESEARCH INSTITUTE IN VARENNES, QUEBEC. IN 1997 SHE MOVED TO BECOME THE RESEARCH ENGINEER WITH RIO TINTO IRON & TITANIUM IN SOREL-TRACY, QUEBEC. SHE WAS RESPONSIBLE FOR SORELMETAL LABORATORY CUSTOMER SERVICES AND RESEARCH PROJECTS RELATED TO DUCTILE IRON. SHE HAS AUTHORED & CO-AUTHORED SCIENTIFIC PAPERS INCLUDING 2 BEST PAPERS AWARDS. SHE HAS ALSO MADE NUMEROUS PRESENTATIONS, INCLUDING THE DIS AND PRODUCED MORE THAN 200 REPORTS INCLUDING RESEARCH, FAILURE ANALYSIS AND CUSTOMER TECHNICAL SERVICES. IN 2010 SHE BECAME THE FERROUS PRODUCTS RESEARCH DIRECTOR FOR RIO TINTO. SHE IS THE MANAGER OF THE FERROUS PRODUCTS R&D TEAM AND THE METALLURGICAL LABORATORY. CHANTAL IS A MEMBER OF THE AMERICAN FOUNDRY SOCIETY AND CURRENT IS A MEMBER OF THE DIS RESEARCH COMMITTEE.

THE DIS WELCOMES CHANTAL WHO IS HERE TO TALK ABOUT “NODULE COUNT
AND IMPACT STRENGTH IN HEAVY SECTION DUCTILE IRON CASTINGS

Thursday, October 28 Afternoon Session

STEFAN METTLER

STEFAN METTLER GRADUATED WITH HIS MASTERS IN SCIENCE FOUNDRY ENGINEERING IN 1989. HE THEN BEGAN HIS WORKING CAREER IN 1989 AT POLYTECHNIKUM MECHANIC SWISS IN BANDUNG, INDONESIA AS THE HEAD OF THEORY AND LABORATORIES FOUNDRY DIVISION. IN 1993 HE MOVED TO SIEMPELKAMP FOUNDRY IN KREFELD, GERMANY AS THE SALES MANAGER. THEN IN 1999 HE WENT TO WORK FOR BRECHMANN GUSS IN SCHLOSS HOLSTE-STUKENBROCK, GERMANY AS THE SALES DIRECTOR. IN 2004 STEFAN RETURNED TO SIEMPELKAMP FOUNDRY AS THE MANAGING DIRECTOR WHERE HE CURRENTLY HOLDS THIS POSITION.

THE DIS WELCOMES STEFAN WHO IS HERE TO TALK ABOUT “VERY HEAVY DUCTILE IRON CAST COMPONENTS AND THEIR SPECIFIC CHARACTERISTICS”

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PETER GRAHAM

PETER GRAHAM IS THE MANAGING DIRECTOR, FOR HIS FAMILY OWNED COMPANY, GRAHAM CAMPBELL FERRUM LOCATED IN WEST FOOTSCRAY, AUSTRALIA.

PETER HAS BEEN IN THE FOUNDRY INDUSTRY FOR 36 YEARS, AND HAS EXTENSIVE KNOWLEDGE IN FOUNDRY PROCESSES AS WELL AS METALLURGY.

GRAHAM CAMPBELL FERRUM PRODUCES SMALL AND LARGE FERROUS CASTINGS WHICH ARE PREDOMINANTLY MADE IN DUCTILE IRON. THESE CASTINGS ARE TYPICALLY SUPPLIED AS FULLY MACHINED AND INSPECTED CASTINGS WHICH ARE SHIPPED AND INSTALLED ALL OVER THE WORLD PREDOMINANTLY FOR THE MINING AND CEMENT INDUSTRIES.

THE LARGE CASTINGS ARE CONSIDERED AS HEAVY SECTION, AND WITHIN THIS AREA GRAHAM CAMPBELL FERRUM IS ALWAYS PUSHING THE BOUNDARIES TO FIND NEW MARKETS TO REPLACE STEEL CASTINGS AND FORGINGS WITH DUCTILE IRON.

THE DIS WELCOMES PETER WHO IS HERE TO TALK ABOUT “SOLUTION STRENGTHENED FERRITIC DUCTILE IRON IN HEAVY SECTIONS”

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BILL DeWOOD

BILL DeWOOD GRADUATED FROM BOWLING GREEN STATE UNIVERSITY IN 1976 WITH HIS BACHELOR OF SCIENCE DEGREE IN CHEMISTRY. HE BEGAN HIS FOUNDRY CAREER IN C.E. CAST QUALITY AND PRODUCT DEVELOPMENT LABORATORY AT THEIR FOUNDRY COATINGS PLANT IN TOLEDO, OHIO. BILL WORKED AS A PRODUCT DEVELOPMENT CHEMIST, PRODUCT MANAGER AND VICE-PRESIDENT OF MANUFACTURING FOR IFS INDUSTRIES, BEFORE FOUNDING REFCOTEC IN 1989. REFCOTEC PRODUCES FOUNDRY COATINGS AND RELATED PRODUCTS IN ORVILLE, OHIO AND DALLAS, TEXAS. BILL PROVIDES TECHNICAL AND SALES SUPPORT TO THEIR CUSTOMERS AND DISTRIBUTORS ACROSS NORTH AMERICA.

THE DIS WELCOMES BILL WHO IS HERE TO TALK ABOUT “FOUNDRY COATINGS IN THE 21ST CENTURY”

STEPHEN MILLER & RICHARD EDMONDS


AND CO-PRESENTER, RICHARD EDMONDS IS THE VP OF STEMCOR USA AND HAS BEEN WITH STEMCOR FOR 17 YEARS. DURING HIS VARIED CAREER, RICHARD HAS LOOKED AFTER STEMCOR’S INTEREST IN SOUTH AMERICA, SPEARHEADED STEMCOR’S E-COMMERCE AND INTERNET ACTIVITIES AND BUILT UP AND RUNS A SUCCESSFUL COATED PRODUCTS IMPORT BUSINESS INTO THE UNITED STATES. MORE RECENTLY RICHARD IS INTO TRADING RAW MATERIALS AND NOW HAS CORPORATE RESPONSIBILITY FOR STEMCOR’S FERROSOURCE DIVISION AS WELL AS OVERALL RESPONSIBILITY FOR STEMCOR USA’S RAW MATERIALS TRADING ACTIVITIES IN NORTH AMERICA.
THE DIS WELCOMES STEPHEN & RICHARD WHO ARE HERE TO TALK ABOUT “SOURCING OPTIONS FOR DUCTILE IRON IN HEAVY SECTIONS”

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John Keough receiving speaker award from John McGoldrick

JOHN (CHIP) KEOUGH


THE DIS WELCOMES JOHN WHO IS HERE TO TALK ABOUT “HEAVY SECTION AUSTEMPER DUCTILE IRON”
Heavy Section Ductile Iron Conference Speaker Bios
Friday, October 29 Morning Session

Rick Gundlach receiving speaker award from Prem Mohla

RICK GUN DLACH


THE DIS WELCOMES RICK WHO IS HERE TO TALK ABOUT “DIS PROJECT #44 – EFFECT OF SURFACE DEFECTS ON FATIGUE PROPERTIES OF FERRITIC DUCTILE IRON”

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GREG BOUSE

GREG BOUSE GRADUATED FROM MICHIGAN TECHNOLOGICAL UNIVERSITY IN 1974 WITH A BS IN METALLURGICAL ENGINEERING. HE ALSO GRADUATED FROM THE PROCESSING RESEARCH INSTITUTE AT CARNEGIE-MELLON UNIVERSITY IN PITTSBURGH, PA, RECEIVING HIS MASTERS OF ENGINEERING DEGREE IN 1976.

GREG HAS WORKED 34 YEARS IN THE POWER GENERATION INDUSTRY. 16 OF THOSE YEARS HAVE BEEN WITH INVESTMENT CASTING, WHERE HE WAS STAFF ENGINEER AT HOWMET CORP., WHITEHALL, MI. IN 1999, GREG WAS A CO-INVENTOR FOR GE ENERGYS’ NEW “WORKHORSE” SUPERALLOY, USED FOR LATTER-STAGE BUCKETS IN ADVANCED POWER GENERATION MACHINES.

THE OTHER 18 YEARS HAVE BEEN WITH GENERAL ELECTRIC CO. IN SCHENECTADY, NY AND GREENVILLE, SC. THE LAST 9 YEARS HAVE BEEN AS SR. ENGINEER FOR THE PRODUCTION AND QUALIFICATION OF HEAVY SECTION STEEL AND IRON COMPONENTS, UP TO 12 METRIC TONS, INCLUDING INLETS, COMPRESSOR CASES, COMPRESSOR DISCHARGE CASES, TURBINE SHELLS, BEARING HOUSINGS, INNER BARRELS, DIFFUSERS, AND WIND HUBS AND BEDPLATES.

THE DIS WELCOMES GREG WHO IS HERE TO TALK ABOUT “GENERAL ELECTRIC QUALITY REQUIREMENTS FOR DUCTILE IRON CASTINGS EXCEEDING 10 TONS USED FOR WIND & GAS TURBINE COMPONENTS – REVISITED”

****

CHRISTOF HEISSER

CHRISTOF RECEIVED HIS EQUIVALENT OF A MASTERS DEGREE IN FOUNDRY TECHNOLOGY AT THE TECHNICAL UNIVERSITY OF CLAUSTHAL IN
CLAUSTHAL/GERMANY. AFTER HIS FIRST EMPLOYMENT AS LEADER OF RESEARCH & DEVELOPMENT AT THYSSEN FEINGUSS, AN ALUMINUM INVESTMENT CASTING FOUNDRY IN SOEST/GERMANY, HE JOINED MAGMA GMBH IN AACHEN/GERMANY IN A MARKETING & SUPPORT POSITION. CHRISTOF MOVED TO MAGMA FOUNDRY TECHNOLOGIES, INC.’S CHICAGO OFFICE IN 1995 AS THE FOUNDRY APPLICATION ENGINEER. HE NOW IS THE PRESIDENT OF MAGMA FOUNDRY TECHNOLOGIES, INC. CHRISTOF IS A MEMBER OF AFS, WHERE HE PARTICIPATES IN SEVERAL AFS COMMITTEES. HE ALSO IS A MEMBER OF DIS AND SAE AND IS KNOWN AS THE AUTHOR OF SEVERAL TECHNICAL PAPERS.

THE DIS WELCOMES CHRISTOF WHO IS HERE TO TALK ABOUT “SIMULATION OF HEAVY SECTION IRON CASTINGS”

******

ELI DAVID

ELI DAVID IS CURRENTLY, AND FOR THE LAST 7 YEARS, HAS BEEN EMPLOYED BY GLOBE METALLURGICAL INC AS GENERAL MANAGER FOR FOUNDRY PRODUCTS. PRIOR TO THIS POSITION ELI WAS TECHNICAL MANAGER FOR GLOBE BETWEEN 1989 AND 2003.

ELI STARTED HIS FOUNDRY CAREER AT QUALITY CASTINGS COMPANY IN ORRVILLE, OHIO AS CHIEF METALLURGIST AND TECHNICAL DIRECTOR, WHERE HE WAS EMPLOYED FOR SLIGHTLY OVER 10 YEARS BETWEEN 1979 AND 1989.

ELI HAS A BACHELOR’S DEGREE IN MATERIALS ENGINEERING FROM THE ISRAEL INSTITUTE OF TECHNOLOGY – HAIFA ISRAEL AND AN MBA IN FINANCE FROM THE KENT STATE UNIVERSITY – KENT, OHIO.

HE HAS MADE NUMEROUS PRESENTATIONS AT AFS AND DIS MEETINGS ON VARIOUS METALLURGICAL AND OTHER CAST IRON FOUNDRY RELATED TOPICS. ELI IS ALSO A VERY ACTIVE MEMBER OF THE DIS RESEARCH COMMITTEE.

THE DIS WELCOMES ELI WHO IS HERE TO TALK ABOUT “SHRINKAGE IN CAST IRON – A COMPREHENSIVE REVIEW”

******

Eli David receiving his speaker award from Prem Mohla
JOHN McGOLDRICK

JOHN McGOLDRICK GRADUATED FROM THE OHIO STATE UNIVERSITY.

JOHN THEN STARTED HIS CAREER IN THE USS PIPE MILL IN LORAIN, OHIO. HE THEN ENTERED THE FOUNDRY INDUSTRY IN THE LAB AT STERLING FOUNDRY IN WELLINGTON, OHIO IN 1984. THERE, HE SERVED AS LAB TECHNICIAN, SUPERVISOR IN THE MOLDING AND MELTING DEPARTMENTS, AND AS QUALITY CONTROL MANAGER MAKING IRON CASTINGS TO 30,000 POUNDS. JOHN MOVED TO HODGE FOUNDRY IN 1991 AS PROCESS CONTROL MANAGER, THEN ENTERED INTO THE QUALITY ASSURANCE MANAGER POSITION, LATER ADDING THE TECHNICAL DIRECTOR RESPONSIBILITIES. JOHN HAS BEEN INVOLVED WITH ULTRASONIC TESTING OF DUCTILE IRON FOR ALL OF HIS TENURE AT HODGE FOUNDRY. JOHN IS ACTIVE IN THE NORTH WEST PENNSYLVANIA CHAPTER OF THE AFS AND ICRI. JOHN IS CURRENTLY THE CHAIRMAN OF THE DIS RESEARCH COMMITTEE.

THE DIS WELCOMES JOHN WHO IS HERE TO TALK ABOUT “UNDERSTANDING ULTRASONIC REQUIREMENTS”
Quality Requirements for General Electric Ductile Iron Castings Exceeding 10Tons Used for Wind and Gas Turbine Components - Revisited

by G. K. Bouse and J. Parolini¹, N.Rojek², and C.Zhou³

(General Electric ENERGY, Materials & Processes Engineering, ¹Greenville, SC, USA; ²Warsaw, Poland, and ³Shanghai, China.)

Abstract: Nodular Ductile Iron (NDI) components >10Tons for gas or wind turbines frequently utilizes either ASTM A395 or EN1563 (EN-GJS-400-18U-LT) material. This paper reviews the actual cast components beyond external damage and microshrinkage, and focuses on darkened metal (chunky graphite) exposed by rough or finish machining (where the machined plane has intersected a solidification hot spot). Within the hot spot it will be shown that a chunky graphite morphological change has occurred. This will cause reductions in tensile and fatigue properties. Steps for identifying, investigating, and eliminating such indications are also discussed.

Key words: nodular ductile iron, chunky graphite, dark spots, wind turbines, gas turbines, low cycle fatigue, UTS, YS, % EL, nodularity.

Introduction. The use of ASTM A395 and EN1563 (EN-GJS-400-18U-LT, JS1049) are common for the casting of gas and wind turbine parts, respectively. The ASTM specification is common for gas turbine inlets and compressor cases, and the EN spec is well known for wind components such as hubs and bedplates [1], as shown in Figure 1. The use of these materials for modern components routinely exceeds 10 metric tons (T), and 200 mm in wall thickness. These materials continue to work well for turbines as megawatts increase, but require continued monitoring as parts size increases or as new suppliers are added [2]. Additionally, it is important to insist on good quality now to provide for the ever-increasing parts of the future. As such, foundries are being challenged to reduce variability, which will reduce the chances that a component could be scrapped at machining or at the point of assembly.

GE takes a very active role in the production of these components, focusing on risk reduction techniques. These techniques use tools from the Six Sigma® toolkit, and focus on FMEA or failure mode and effects analysis, RCA or root cause analysis, and CA or corrective action. The focus is very intense during production of the first few components. By deciding what steps of the manufacturing processes are likely to fail, FMEA’s are conducted both within GE, and the supply chain to reduce production risks. It is the goal of the supply chain to identify deficiencies early, determine their cause, and then fix the cause/control so it doesn’t happen again. This will provide components at the point of assembly which meet all required properties, preventing the
Figure 1. Cutaways of the GE 1.5MW wind turbine (left) and gas turbine (right) showing the locations of the bedplate and hub, inlet and compressor case, which are made of nodular ductile iron.

Figure 2. Typical “Rule of 10’s” for GE costs when a supplier’s component has a deficiency.

escalation of remediation costs, which typically grow by factors of 10 from manufacture, point of assembly, to customer site, as shown in Figure 2. Participation in this process has the added beneficial effect to make suppliers World Class.

Besides a trepan specimen through the component, a cast-on or attached test coupon is the next best way to gauge the capability of the casting. The reader must be clear to understand the minimum UTS, %EL, etc for the ASTM and EN specifications are for the test coupons, usually not the casting itself. The coupon is cooled on 5 sides, and very seldom has one been deficient. Therefore, with the appearance of chunky graphite, the Materials Engineer may be required to define additional quality considerations to include tests from within the casting, conveniently removed by a trepan drill in the location of a planned hole. However, language within specifications may use “circular” reasoning to accept the component (and avoid corrective action), unless of course additional agreements are made. The arguments go something like this:

- The component shall not contain an abnormal form of graphite, and
- Use of metallography is permitted to determine the graphite form.
- Abnormal becomes normal over time, so metallography is avoided.

But machine shops, where the chunky graphite is most noticeable, seldom have the tools to examine the microstructure. Even if metallography is used, moving the microscope objective as little as 1 mm can present an entirely new view or form of graphite - from being primarily nodular to being primarily chunky. Even a specification that utilizes darkening as criteria is subjective unless visual standards are created. It is the
authors opinion the criteria to eliminate the darkening is much easier to define, than criteria involving normality and metallography.

Designers expect uniform properties everywhere within the casting, and so the supply chain must work to remove these dark spots, as there are numerous papers in the literature that associates dark spots or degeneration to some property deficiency. For GE, this realization came in the early 1980’s [3], which draws on a reserve of publications as far back as 1967, so the problem has been around a long time. Then, two articles by Gagne and Argo in 1986 [4] characterized the chunky graphite form and properties. However, at that time, modeling of the mechanical stress state was in an early stage and designers didn’t know what to do with the information, unless there was some service related issue. As modeling tools have improved, the ability to analyze a small volume of the darkened metal (based upon a change in microstructure) for full life have become available, and may allow the use of a casting that contains some darkening, depending upon its location. Thus, the casting might be used instead of being rejected, which helps improve casting yield. Eventually though, it would be desired to eliminate the darkening through continuous improvement.

Quality Considerations. An “abnormal” region on a machined ductile iron casting is shown in Figure 3. An extreme abnormal structure is shown in Figure 4. Truly, these are both features that do not require much training to identify.

It may be intuitive that graphite degeneration and large castings just go together. Indeed, when GE and the foundry supplier sit down to discuss acceptance or rejection criteria for a large casting that might contain a dark spot, that is the first argument advanced. Our GE counterparts who must assemble these components concentrate first on fit (dimensions) and so may not notice the dark spots, and are surprised when someone from Materials Engineering points out they are not like all the others before them. Wind parts have only a small window for review, as they are usually coated for corrosion protection soon after machining, and therefore the dark spots cannot be reviewed at the point of assembly. When a component with discoloration is found, the foundry is requested to review their records, but in many cases, a specific difference in the process for that one casting is not
Figure 5. A cause-and-effect or “fish bone” diagram commonly used to identify processes with an influence on the formation of chunky graphite.

found. It is important to GE to determine the cause of the problem, and usually requires the supplier to perform an RCA. The RCA might involve the creation of a cause-and-effect or “fishbone” diagram, Figure 5, so as to narrow the study for the root cause. Then experiments might be performed using a simplified shape to recreate the hot spot containing the chemistry and cooling rates of interest. This has been done with success at some of GE’s foundry suppliers, as long as the experimental shape is at least ~100 x 150 mm in cross-section and solidifies in a manner similar to the actual component. Nowadays, most risk can be removed from an experiment of this type using solidification software, which is common throughout the sand casting industry.

Once a root cause of the degeneration is narrowed, a CA is put into place, to reduce the risk for a reoccurrence. As a result, the foundries will usually track/control additional characteristics of their process, in an attempt to reduce total variability.

The foundry may track more variables, but often lack of data or the statistical savvy or manpower to identify trends. It’s a fact that raw materials, foundry returns (recycle), sand, and chills change with time, accompanied by personnel changes that put variation into the manufacture of the mold, molten metal, or casting. With smaller components, maybe only 12 elements measured for heat chemistries were adequate for good control. But now, as component size has increased (and hot spots become more troublesome), and price pressure forces the use of less pig iron and more returns, the foundry may have to measure more than 12 elements. Rare Earth (RE) elements such as Cerium (Ce), in low concentrations, are not easy to measure, and their effect on the microstructure is definitely interrelated with the metal purity, time, and temperature during the iron-making process.

Any discoloration found during machining needs to be fed back quickly to the foundry, so adjustments in the casting process can be made. This is possible if the foundry is in charge of machining – they know where the hot spots are likely to occur, and will watch for them as an internal control. But casting and machining may be contracted separately, even in different
countries. The end result is once the casting leaves the foundry, the chance of recording this deficiency decreases considerably. It then takes a larger effort by the OEM Quality Engineers to fix a foundry problem, especially if the foundry no longer has access to the casting.

To combat any lingering quality issues, additional requirements are placed upon drawings or purchase orders by GE, for each supplier to document any graphite degeneration, including size and locations. This will eventually help the foundry move the risers to less critical areas (usually off the joining flanges), so that if the graphite degeneration does occur, it is in less critical areas, and therefore the component has a greater probability of reaching full life.

**Microstructural Characterizations of Discolored Machined Surfaces.** A good ductile iron microstructure in a heavy section is shown in Figure 6, having >90% nodularity and a nodule density of ~50/mm². By contrast, a microstructure not meeting these criteria is shown in Figure 7.

The microstructure in Figure 7 is exactly the type of structure that causes darkening on the machined surface of a ductile iron casting. The darkening is similar to the traditional grey surfaces associated with a flake graphite casting. Note in this case, the weak material was within threads of a bolt that stripped it from a large casting during assembly. Consider this reason #1 to avoid graphite degeneration around a threaded hole.

**Degradation of Mechanical Properties.** There are numerous examples in the literature where the mechanical properties of the dark spots are measured vs good material. Figure 8 is a typical plot for real nodular ductile iron castings. This data came from a series of parts and several suppliers,

Figure 7. Example of a microstructure where there is a high percentage of chunky graphite amongst & between the nodules. This material was stripped from a heavy casting during a bolt tightening operation.

Figure 8. A plot representing UTS and YS, showing a drop in the property as the nodularity is reduced.
where trepan specimens were extracted from a finish machined flange 100-200 mm thick. The two main components of the microstructure were nodular and chunky graphite. After testing, each test bar was mounted and the nodularity was measured using ASTM A247 criteria. UTS and 0.2% YS are shown, but notice the UTS degrades with lower nodularity, whereas the 0.2% YS remains constant. Percent elongation has behavior similar to UTS. Design engineers will have to accommodate this behavior for real components, especially at connection flanges.

Fatigue behavior is also affected by chunky graphite. The illustration in Figure 9 shows that final life for test bars taken from an area with chunky graphite has a lower fatigue life. With this type of data, designers are able to model volumes of material with a known stress state, to predict if the substandard material could reach full life.

**Elimination of Chunky Graphite in a Nodular Ductile Iron Casting.** This subject has been extensively studied, recently by several teams from Sweden [5, 6]. Some important observations made by them includes:

1. UTS and %EL are lowered, while YS and hardness remain unaffected within a region of chunky graphite.
2. Chunky graphite forms early during eutectic solidification, and “is a branched and interconnected network within eutectic cells.”
3. Low carbon equivalent (CE), chills, “non-excessive amount of rare earth (RE) elements”, and low supercooling can help eliminate chunky graphite.
4. “High purity charges in combination with excessive amount of RE elements will promote chunky graphite formation.”
5. In the presence of excessive Cerium, Antimony (Sb) is the most suitable element to add to prevent chunky graphite formation.
6. “Chunky graphite occurs after nodular graphite when RE’s are added, but before nodular graphite in any other case [7].”
7. “High nodule counts reduces the probability that other types of graphite will form [8],” and
8. There is no single factor promoting chunky graphite, but several factors act together.

Several of these observations bear additional comments, which would apply to a heavy-section ductile iron casting, where chemistry would be the controlling factor for the formation of chunky graphite. This applies to the thermal-center of the section, outside the reach of external chills.

The first is the use of too much pig iron. While a certain percentage of pig iron is usually necessary to “normalize” heats, too much of it presents a base alloy denuded of nucleation sites for the primary graphite nodule that is the first to precipitate from the melt. This can produce a heat lacking in a good nodule count. The same could be said of a heat taken too high in temperature. As a starting point, the authors suggest 1/3 pig, 1/3 scrap steel, and 1/3 recycled metal when formulating heats. Acceptable heavy-section ductile iron castings can be
made with a nodule count as low as 50/mm², but the preferred nodule density would probably be within the range of 100-150/mm².

The second comment has to do with "non-excessive amounts of rare earth elements". For a foundry in China, which has abundant supplies of rare-earth elements like Ce in the inoculant, the definition of "non-excessive" will differ from foundries in countries, which may not have rare-earth elements in their inoculation materials. Worse yet, most foundries do not even report individual values of Ce.

The third comment has to do with the subject of inoculating with materials containing Ce and Sb. Larranaga [9] and Tsumura [10] have produced a simple diagram that shows how chunky graphite can be eliminated if the final Sb/Ce ratio is >1.5. Figure 10 shows this relationship between the amount of chunky graphite and the Sb/Ce ratio, and is mentioned because of limited success in using it in at least one foundry making heavy section ductile iron castings.

A fourth comment has to do with low superheat. Although reducing superheat increases the chance that dross can become entrapped within the casting, doing so will reduce the supercooling and this is also characteristic of a casting free of chunky graphite, as described by Larranaga [9].

**Chemical/Process Drift.** Another point to consider is when a CTQ like a dark spot "comes-and-goes" without a controlling reason. If one had a grading scale for dark spots and plotted this variable as a function of time as in Figure 11, one might see a cyclic variation repeating itself every year or ½ year.

This long-range order might then suggest another variable to track, potentially yielding another cause for chunky graphite. That variable might be how the Sb and Ce contents of the recycle material have changed over time. The inoculation material must then be adjusted to maintain the desired final ratio of Sb/Ce.

![Figure 11](image1.png)

Figure 11. The variable causing chunky graphite may also be related to long-range order, especially when the effect "comes-and-goes" for no apparent reason.
Final Comments. The subject of dark spots and chunky graphite was discussed. This type of graphite within a nodular ductile iron casting occurs infrequently due to several factors including chemistry, inoculation practice, pour temperature (superheat), and solidification time. The area of the casting that retains heat, i.e. a “hot spot” - a function of part geometry, is a significant factor.

Dark spots are easily recognized on saw-cut or finish-machined surfaces, and the microstructure within a dark spot was shown. The dark spots have a microstructure that don’t meet the intent of ASTM A395 or EN1563 and must be dealt with separately if it is of concern to the OEM. Within the dark spots, the microstructure contains chunky graphite, a type of graphite degeneration. A degradation of tensile UTS, %EL, and LCF were shown to exist within the volume of affected metal (the thermal center of the casting section). The supply chain must understand that stress and temperatures continue to increase in advanced turbine applications. The quality of thick-section iron needs to improve in order for it to be a viable candidate for future applications.

Finally, key references were cited, which the authors believe, have narrowed the causes of chunky graphite and removed some of the conflicting evidence in the literature. But then, as now, the challenge remains to find a way to measure solidification rates, temperatures, and chemistries within the areas that present the greatest risk to the casting, and then be able to take actions within the steel-making, molding, or casting processes that would influence the outcome of the final component. Foundry personnel are especially encouraged to read those articles and to incorporate more complex solidification models within their process, in order to produce a more uniform nodular ductile iron casting.

Acknowledgments. The authors would like to acknowledge N.Jasinski, G. Klack, O. Lopez, and C. Liu for helping to collect much information that was helpful during the preparation of this paper.

Abbreviations:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<tbody>
<tr>
<td>&gt;</td>
<td>greater than</td>
</tr>
<tr>
<td>%EL</td>
<td>percent elongation</td>
</tr>
<tr>
<td>CA</td>
<td>corrective action</td>
</tr>
<tr>
<td>CTQ</td>
<td>critical to quality</td>
</tr>
<tr>
<td>FMEA</td>
<td>failure mode and effects analysis</td>
</tr>
<tr>
<td>LCF</td>
<td>low cycle fatigue</td>
</tr>
<tr>
<td>NDI</td>
<td>nodular ductile iron</td>
</tr>
<tr>
<td>OEM</td>
<td>original equipment manufacturer</td>
</tr>
<tr>
<td>RCA</td>
<td>root cause analysis</td>
</tr>
<tr>
<td>RE</td>
<td>rare earth</td>
</tr>
<tr>
<td>T</td>
<td>ton</td>
</tr>
<tr>
<td>UTS</td>
<td>ultimate tensile strength</td>
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</tbody>
</table>

References


10. O. Tsumura, et. al., Effects of rare earth elements and Antimony on Morphology of spheroidal graphite in heavy-walled ductile cast iron”, Japan Castings, 67, no. 8, 1995, p540-545
Heavy Casting Automated Cleaning and Finishing

Jim Garrett
Foundry Solutions and Design, LLC
The fight for Survival

Neenah Enterprises Files for Bankruptcy Reorganization

Municipal castings giant Neenah Enterprises Inc., Neenah, Wis., announced it has filed voluntary petitions for reorganization under Chapter 11 of the U.S. Bankruptcy Code in order to restructure its balance sheet.

According to a press release issued by the company, Neenah will continue to do business as usual throughout the restructuring process.

“We’ve been going through efforts to streamline operations and reduce expenses over the last few years, with the intent of keeping sufficient liquidity to move operations forward,” said Robert Ostendorf Jr., the company’s president and chief executive. “We will emerge from this stronger and more financially sound than ever. There is a bright future ahead.”

Mueller to Close North Birmingham Ductile Pipe Plant

U.S. Pipe and Foundry Co. LLC, Birmingham, Ala., will close its ductile iron pipe casting plant in North Birmingham, Ala., by March 31, according to an announcement by parent company Mueller Water Products Inc., Atlanta.

The plant closure is expected to eliminate approximately 260 positions. The company said production from the North Birmingham plant will be moved to U.S. Pipe’s Bessemer, Ala., and Union City, Calif., facilities.
Low Labor Cost Countries...

... are not always the competition.

George Fischer Automotive Secures $60 Million Order from Visteon

George Fischer Automotive Products, Inc., Northville, Michigan, has signed a letter of intent with Visteon Corp., Dearborn, Michigan, to develop and manufacture a light truck component over a period of at least five years. The total amount of the order volume may reach $60 million.

George Fischer Automotive Products is part of the Automotive Products Group of Georg Fischer AG, Schaffhausen, Switzerland. According to the Swiss firm, Visteon’s declaration of intent will provide the company’s North American business additional progress.

“This is an important milestone for Automotive Products in our efforts to expand our customer base in the world’s single largest car and truck market,” said Ferdinand Stutz, head of the Automotive Products Group. “The automotive industry is increasingly looking to suppliers that operate worldwide.”

Last year the group generated 960 million Euros in sales with iron castings accounting for 65% and light alloy castings 45%.

MC
The Competition…

Whether in China, Korea or Europe, progressive foundries are investing in modernizing their finishing departments.

Daewoo Motors – Korea and China
“Cost reduction”....

Is globally recognized as the way to stay in business

Of the costs that are within the control of the foundry... labor costs are the most significant, and the highest portion of labor is in the finishing department.
“Cost reduction”….

Additional benefits are obtained by:

- Reducing workmen compensation costs
- Improving repeatability, hence quality
- Improving ergonomics & safety
- Upgraded work environment
“Boxes, Pallets, and Fork Trucks everywhere...

Most foundries tend to handle casting many times. Working to and from boxes & pallets. Moving Boxes and pallets with Fork Trucks Back and Forth.
Or....No Casting Handling at all
Most common excuses for not developing good handling and finishing systems:

“ We make too many different castings….
We are a jobbing shop….we have to make large and small castings….
Our volumes are too low…..
Pareto’s Law

20 percent of the patterns make up
80 percent of the volume!
Yet we handle the entire product line the same.

Suggestion:
Segregate the higher running jobs
and focus the investment on
how to handle and finish them more efficiently.
Robotic Casting Handling
Cluster / Large Casting Extraction

Automated Large Casting Extraction of Horizontal Molds
Automated casting Handling

- Localized handling to avoid crane and forklift handling
- Manipulator shown with gripper plus impactor for riser and runner removal
- Avoids man-handling heavy castings
Robotic Casting Shot Blasting
Robotic Casting Blasting
Advanced Surface Technology
Robotic Blast Cleaning
Robotic Casting Blasting
Advanced Surface Technology

- High efficiency
- Low labor costs
- Low operating costs (energy savings)
- Low maintenance costs
Robotic Blast Cleaning
Robotic Casting Blasting
Advanced Surface Technology

EQUIPMENT FOR MOVING AND TURNING WORK PIECES

- All equipment for moving and turning work pieces is designed according to customers’ needs by creating solutions ideal for the harsh conditions of a blast room

- Moving and turning can be a part of the robot’s control system, also in automatic use
Robotic Casting Blasting
Robotic Casting Blasting Advanced Surface Technology
Robotic Casting Blasting
Advanced Surface Technology

SAFETY

Manual abrasive blasting is hard, unhealthy, and dangerous:
- The operator is exposed to noise, dust, and physical strain, which also weakens work motivation
- Heavy and restrictive protective clothing is required
- Ladders are often needed and the risk of injury is high
- Accidents and work-related injuries are common
- Delays in production can often result
- Personnel costs can be high

- Robotic blasting solves all these problems
Robotic Casting Blasting
Advanced Surface Technology

ROBOT PROGRAMMING

Online programming:
- “Teach-in” from control cabin
- “Point-to-Point” with teach pendant

Offline programming
- Workstation with 3D-programming software
Robotic Blast Cleaning
Casting Cut-Off
Automated Finishing

- Manipulator abrasive wheel
Automated Finishing

- Manipulator Riser Cut-Off
Casting Cut-Off

NC Controlled Automatic Cut-Off Machine
Hole Opening
Robotic Casting Finishing

Automatic Hole Opening Station
Robotic Casting Finishing

Casting inside Hole Opening Cell
Robotic Casting Finishing

Small Castings in Hole Opening Cell fixture
Robotic Casting Finishing

Castings in Hole Opening Cell
Casting Grinding
Casting Grinding

Automated Cylinder Block Grinding
Robotic Casting Finishing

System for Handling & Finishing
Large Truck/Off-road Castings
Casting Grinding

Manipulator Casting Grinding
Automated Finishing

- Manipulator Grinding
Automated Finishing

- Work table with tilting and clamping capability
Casting Grinding

Automated Casting Grinding
Casting Final Finishing
Automated Finishing
Automated Finishing
Robotic Casting Final Finishing

Final Finishing Cell
Robotic Casting Final Finishing

Final Finishing Cell
Robotic Casting Final Finishing

Final Finishing System for Cylinder Heads
Robotic Casting Final Finishing

Final Finishing System for Axle Housing
Automated Trim Press Operation
Core & Casting
Inspection
Shadow Modulation
Shadow Modulation
Core-Vision® Typical Defects

- Cracks
- Misalignment
- Breakouts
Mold/Core Inspection for Horizontal Molding Machines

Cell Layout

Vision Cameras

Core Inspection

Mold Inspection
Vision Inspection of Engine Blocks

Tolerance scheme for water jacket inspection
3-D FlexInspector
3-D FlexInspector
3-D FlexInspector
In order to compete in a global market place, labor content (and cost) must be minimized, finishing work must be consistent and repeatable to assure quality.
For additional information, please contact:

- Jim Garrett
- Foundry Solutions and Design, LLC
- 316 Maxwell Rd. Suite 500
- Alpharetta, GA
- Phone: 770/667-4545
- Fax: 770/667-4544
- Email: jgarrrett@foundrysd.com
- Web Site Address: foundrysd.com
How to filter a heavy section casting – The do’s and don’ts

Thorsten Reuther
hofmann CERAMIC GMBH, Mühlweg 14, 35767 Breitscheid-Erdbach - Germany

ABSTRACT

Today the requirements for the quality of heavy section castings are increasing very fast. Because of that foundries had started to use ceramic filters for heavy section castings around 10 years ago. This paper gives a short overview about some critical mistakes which can occur when foundries use ceramic filters for filtering such heavy castings.

Due to the heavy weight and the high amount of handcraft, the costs for internal rejection are very high, if a casting fails because of defects like dross or sand inclusions. Also due to the high transport costs of such heavy parts external rejection has to be avoided too. This paper can not explain every detail but it gives a guideline for the design of filtration systems for heavy section castings. This paper shows the dangers which appear when foundries transfer the general recommendations of filtering castings to heavy section castings and shows how they can be avoided. It shows also that the new knowledge of the mechanisms of filtering can be used to get high quality castings without defects.

INTRODUCTION

The following lecture contains a simple summary of a few important problems which are often sources of errors in foundries. The intention is to present the most important special features of this topic to the reader in a simple and comprehensive manner.

In the past we transferred the old recommendations of the literatures on how to use ceramic filters for castings one by one to the heavy section casting manufacturing. In “smaller” castings up to around 5 or 6 tons it worked more or less well but when the foundries went to bigger pouring weights it often failed and resulted in rejected castings because of filter breakages and/or surface defects like dross or sand inclusions.

Because of the new knowledge on how filters are working it is possible to create some general rules to avoid such problems.

BACKGROUND

Today we are forced to manufacture our heavy section castings economically and with a very high standard of quality. Apart from that, specifically in the fast growing wind energy industry, the designer demand of weight reduction is to be met by reducing the wall thickness of the castings. Especially the increasing power of the wind turbines also requires increasingly higher casting quality.

This means that customer requirements, especially those directed at casting suppliers, with respect to surface quality and the absence of non-metallic inclusions in the casting, have increased greatly and become much more demanding. These casting defects are those which can occur due to an unsuitable gating system and wrong application of ceramic filters, which can lead to dangerous weak spots in highly stressed components.

BASICS OF FILTERING OF LIQUID METAL

As we know today the mechanism of filtration is based of the influence of the filter to the metal stream and on hydro mechanic effects. Because of this we can divide the areas around the filters in to four zones.

Figure 1 : Flow in front and after a filter.

Zone (1) is an area of turbulent flow. When the melt is reaching the filter there is a tailback (zone 2) and the flow velocity is slowed down so that the inclusions can be separated (zone 3). After the filter we find an area of laminar flow (zone 4) which helps to avoid the oxidation of the metal.

To get these effects some important parameters of the filters and of the design of the ingate system have to be seriously considered.

All our practical experiences show how the filter geometry is connected to the filtration effect. The filter geometry should be designed to avoid blocked filters.
because of solidified metal but should not have too less a resistance to the flow, that it will not support a tailback and a slowed down flow velocity. Sometimes the limits of the filter geometry which gives the best effect could be very tight. This is the reason why we have to use filters with a very small tolerance of dimensions and more importantly with a very small tolerance of “porosity” respective to the resistance to the flow.

Figure 2: Ratio of cross sections of “conventional” ingate systems.

A bigger cross section after the filter supports a laminar flow and also reduces the turbulences because of a lower flow velocity (Reynolds!). This system gives very good results in green sand moulding lines where most part of the ingate system is in a horizontal level.

When the runner is placed in the drag box and the ingates are in the cope box, the ingate system can be kept completely filled due to the positioning of the ingates and the runner (the ingates are above the runner and the filter can work).

And exactly this is one of the most important conditions which become understandable with a view on figure 1. The filter can only fulfil its work if the filter chamber and the runner are completely filled. Only then inclusions could be separated in front of the filter and it also eliminates the danger of slag or dross created due to the trapped air oxygen. Another danger is that splashing metal can also block the front side of the ceramic filters and the open area could be extremely reduced.

TRANSMISSION TO HEAVY SECTION CASTINGS

At the early stage of filtering heavy section castings, foundrymen transferred this general recommendation of a pressure less ingate system from the greensand moulding lines to their bigger castings (with the pouring weights of around 5 or 6 tons) and faced serious troubles with nonferrous inclusions and filter breakages. Unfortunately it was not easy to find the reason for these problems at the beginning.

But with a view on the hydraulic parameters it became more and more clear what happened.
The bottle neck of the ingate systems was placed in front of the filters and after the filters the cross section were increased as it is recommended in the general guidelines (figure 2). In hand (chemically bonded) moulds ceramic tubes are used to build the ingate system and so smaller tube diameters were used in front of the filters as a down sprue and bigger diameters were used after the filters to get bigger cross sections to reduce the flow velocity. But the result is that, during the pouring process the filter chamber can not be kept filled until the counter-pressure is high enough to get the complete ingate system filled. This leads to, the trapped air oxygen in the filter chamber aiding the re-oxidation of the liquid iron for a longer period of the pouring process (figure 4). And also in the tubes after the filters, air can be trapped and the metal flow is disturbed.

Another point is that the filter area is much bigger than the cross section of the bottle neck and so most of the molten iron runs over the first filters. Due to this, these filters are overloaded and can break because of the uneven heat allocation and hot spots, even though the right numbers of filters were used. The overloaded filters become weak and after a while they break. We have also to realize that the metal flow at this position is not calm and splashing iron will block the surface of the other filters. If filters are blocked by solidified metal they will not open again when the filter chamber is filled when the iron level within the mould cavity comes over the level of the filters. If the casting is not very big, then this system can bring more or less good castings but it never can bring the most possible benefit.

Often it is difficult to detect problems like these, after the pouring process because the solidified ingate system gives nearly no indications for the critical situation during the pouring process. If the filters have to be used in the parting line between cope and drag box, there is only one chance to avoid this phenomenon:

The bottle neck of the ingate system has to be placed after the filters how as shown in figure 5.

That means that the cross sections of the tube diameters behind the filters have to be smaller as the cross sections of the down sprue tubes. These so called pressure systems were already used in the past when foundrymen had no ceramic filters. It allows the ingate system to fill quickly at the beginning of the pouring process. The disadvantage is that the high flow velocity at the ingates leads a turbulent mould filling.

**MOVE OF FILTERS OUT OF THE PARTING LINE**

The filters were placed down at the ingates to prevent the above explained problems:

1. The unfilled filter chambers in pressure less systems and
2. The high flow velocity at the ingates in pressure systems.
Placing the filters down at the ingates also help a better effect of filtration. But this method also hides some critical details which have to be observed to avoid problems with broken filters, especially when the system is designed as it is shown in figure 6.

Figure 6: Filter at the ingates of a wind turbine hub

Of course two conditions are fulfilled:
1. Filling the filter chamber before the iron flows into the mould cavity and
2. The right numbers of filter were used.

Another advantage is that only one filter chamber is used. But the biggest disadvantage is that the amount of liquid metal not evenly distributed to each filter.

The following practical example shows this system in a wind turbine hub with pouring weights of around 9 and 12 tons.

Figure 7: Filter chamber in 9t wind turbine hub

For 9t pouring weight, 10 pressed filters with a dimension of 150x150x24mm were used and it worked. But when the pouring weight was increased to 12 tons the system failed.

Figure 8: Filter chamber of a 12t wind turbine hub

Because of less space underneath the wind hub and the higher number of filters, the design of the filter chamber had to be changed. After some good results it happened that during the machining process, broken filter pieces were found and the castings were rejected. With the fact that enough filters were used the real reason for the problems was obscure.

Figure 9: Main flow rate in filter chamber of a 12t wind turbine hub

In this example large quantity of the metal flow was only through some filters and due to these hot spots, the filters became week and broke.
This is a very dangerous situation and often a reason for serious issue of broken filters. And so it is not only important to use the right number of filters, but also a correctly designed ingate system to ensure that the liquid iron is uniformly distributed to all filters.

The next evolution in heavy section casting filtration was, placing the filters at the ingates in big filter chambers. Filter chambers were designed to accommodate a battery of filters. The following example shows a design for an ingate system for a 30t ductile iron casting. In Figure 10 an ingate system is exhibited where in 12 filter chambers with 6 filters in each chamber. All in all 72 filters were used for this casting.

![Figure 10: Ingate system for 30t casting](image)

The filter chambers could be built with coated cores, which can easily be connected with the ceramic tubes of the ingate system. The advantage of this system is that the filter chambers get filled quickly and also that the filter are placed as close as possible to the ingates, which bring the best benefit. With such systems, pouring weights up till over 100 tons are suitable today.

It’s not only important to monitor the filters for overloading, but also for every filter chambers to have uniform loading. Therefore it is very important to design an ingate system as much symmetric as possible so that also all the filter chambers will get the same amount of liquid metal. In simple term, the distance travelled by the liquid iron through each ingate has to be the same. Otherwise, it can lead to any single filter chamber getting overloaded because of the different liquid friction (resistance to the flow).

While designing such a system, it is advisable to limit the number of filters up to 4 to 6 in a row. Higher number of filters in a row will increase the risk of over loading on any single filter (figure 11). Getting a most balanced flow through all the filters is not (realistic) easy to achieve even if it is limited to a battery of 4 to 6 no. of filters. The risk of unbalanced metal flow can be minimised with less number of filters in a row or smaller battery of filters.

![Figure 11: Risk of overloaded Filters in a Filter Battery](image)

The risk of over loading or an unbalanced metal flow can be easily understood; when we compare the open areas of the various components of the ingate system. For example, if an ingate tube of 8cm diameter (with its open area of around 50cm²) is used along with a battery of 133x133mm filters (the open area of 133x133mm filter is around 100cm²), a typical filter for heavy section castings, we can realise that the entire amount of liquid metal can flow through the first filter itself.

The worst case scenario can be the application of filters in a non symmetric ingate system along with a badly designed battery of filters. The risk of overloading a single filter will be increasing many folds in such a situation. Overloading and or an unbalanced metal flow are often the main reason for serious troubles with broken filters.

![Figure 12: Generator carrier (80t ductile iron)](image)
MOVE OF FILTERS BACK TO THE PARTING LINE IN FLAT CASTINGS

Ceramic tubes are often used in heavy section castings but sometimes it could also be advantageous to avoid the use of the tubes – especially for flat castings. One example for this is could be a casting of planet carrier with a casting weight of around 2,5t of ductile iron. Before the ingate system was optimized; the foundry used ceramic tubes and a pressure-less gating system, which means that the open area of the tube after the parting line and after the filter chamber was bigger than the down sprue tube (Figure 13).

The foundry faced some serious trouble with dross defects at the surfaces, even though they used the right number of filters. This dross was obviously created by turbulences and trapped air in the ingate system while the system was not filled during the pouring process.

Because of the small depth of the casting in the drag box, the ingate system could be changed completely. All the filters were placed in a vertical position with the filter prints designed at the parting line in the drag box. The ingates were placed in the cope box, to ensure that the ingate system will be filled first and will stay filled during the pouring process as shown in figure 2. This system works usually until the depths of mould cavities in the drag box is around 30° or less. If the depth is greater, then it should be more advantageous to use a system with ceramic tubes to get a mould filling from the bottom of the mould cavity.

For the pouring weight of around 2,5t ductile iron, 6 pressed ceramic filters with a dimension of 133x133x22mm and a hole diameter of 3,8mm were used. The filters were placed between the runner and the casting, as close as possible at the ingates. The ratio of the cross sections between sprue, runner and ingates is around 1 : 2 : 4. This ratio was chosen to get a very slow flow rate at the ingates so that a smooth filling of the mould cavity could be achieved.

This system works without any problem and with the following advantages:
➢ Ingate system completely on pattern
➢ Less work.
➢ Less costs
➢ No Dross

Figure 15: 2.5t planet carrier

Another advantage is that the filters get a little time for temperature equalization and the impact energy is reduced. This helps the ceramic filters to resist the hard pouring conditions of the heavy section castings.

In the figures 16, 17 and 18 two examples of such successful systems are shown.

Figure 16: Mould of a tool table for a die casting machine (7.5t ductile iron)

We can notice that the complete volume of the casting is in the drag box and the depth of the mould cavity is around 25°.

Figure 17: Casting of a tool table for a die casting machine (7.5t ductile iron)

Figure 18: Boot for a mould die for a deep drawing machine (2.6t gray iron)

But two other important conditions should also be considered, when such systems are used. The mould has to stay exactly straight and horizontal. In case of an inclined standing mould, the liquid metal could be guided more to one side of the ingate system and could overload those filters.

To get a most balanced flow rate, each of the filters should have the same flow resistance. This condition is sometimes not satisfied when foam ceramic filters are used, because of the bigger tolerance of the porosity of these filters.

Some times the bigger tolerance was the reason for serious problems of

1. Unstable pouring times, which could result into cold runs.
2. Uneven load on filters with some frozen & some over loaded.
3. Highly over loaded filters leading to broken filter pieces in the casting.

SUMMARY OF CONDITIONS FOR GOOD RESULTS

To get the best possible effect and benefit of filtering of heavy section castings the following basic but very important conditions have to be respected.

- Symmetric ingate system design.
- Reduced kinetic energy of metal stream.
- The Filter Chamber has to be filled as fast as possible.
- The Ingate system has to be filled before mould cavity.
- Turbulence free mould filling.
- Balanced flow rates to each filter chamber respectively to each filter.
- No direct casting on the filters
- Mould has to stay exactly horizontal
- Filters have to have the same resistance to the flow (tight tolerances of porosity)
- Filters have to have a high thermal shock and mechanical resistance

REFERENCES

Design Overview of Large Ductile Iron Casting
Wind Turbine Generator Components
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Prepared by:

Kevin R. Till
Clipper Windpower
6305 Carpinteria Ave Suite 300
Carpinteria, CA 93013 U.S.A
Email: ktill@clipperwind.com

Abstract

This short paper will give a brief overview of wind turbine generators and more specifically of large ductile iron casting usage in specific wind turbine generator components. This paper was prepared to accompany and supplement the presentation on the same subject that will be given at the Ductile Iron Society's Fall 2010 Conference in Cleveland, Ohio.

Wind Turbine Generator 101

Wind turbines are, in simplest terms, like other power 'generators' better described as devices that accomplish energy conversion. That is to say that one form of energy is being converted by the wind turbine generator to another form. The initial form of energy being utilized, in this case, is kinetic energy of a fluid flow - and that fluid is Earth's atmospheric blend of gaseous elements called air. This is most commonly referred to as wind. The form of energy that the wind turbine generator produces via its conversion process is, just like all other major forms of generation, electrical energy.

For starters, why is there wind in the first place? This can be answered in two words: the Sun. The Earth's Sun radiates energy to Earth. Everyone who has been outdoors on a sunny day knows personally how intense the Sun's radiation of energy can be. However, it's also intuitive to us that in the winter we receive a little bit less radiant energy than in the summer, that it's cooler in the shade than in direct sunlight, and that darker objects absorb more radiant energy from sunlight than lighter objects do. For these reasons amongst others, the amount of received and absorbed radiant energy found at the surface and throughout the atmosphere of Earth are subject to variability from location to location. This amount of received and absorbed radiant energy is directly related to the local temperature as temperature is in essence a measure of internal kinetic energy of, in this case, a gas' molecules. These resulting temperature distributions give rise to pressure gradients as the pressure of a certain volume of gas is related to the temperature of said volume of gas. And so long as volumes of gas have pressure gradients, the laws of nature assure us that there will be associated fluid (gaseous) flow per the perpetual strive for equilibrium. Fluid flows from high to low pressure and is affected along the way by macro and micro climatic effects as well as physical entities such as the terrain. The flow of fluid - of air - which we refer to as wind is mass in motion (i.e. kinetic energy) and is available to be
harnessed. Furthermore, so long as the Sun continues to radiate and the Earth and its atmosphere continues to be irregular (don't worry - it always will be!) then there will always be energy in the wind available for utilization. Oh, and my recollection is that last I heard the Sun has something like 4 billion years before it might 'burn out' - so we've got some time left.

Ok great, there's wind...but what, exactly, is the energy conversion process that a wind turbine employs? Glad you asked. Enter the wind turbine generator - the energy conversion process all starts with converting the kinetic energy from one volume of mass in one state to another volume of mass in another state. The kinetic energy of the wind is first converted into kinetic energy of the 'rotor'. The rotor of a wind turbine is commonly defined as the blades plus the central hub of the blades. This first kinetic energy conversion is most commonly accomplished by means of aerodynamic lift via the blades. The shapes of the blades are such that as the wind passes over them, non-equal pressure gradients are created on the two sides of the blade (Bernoulli's principle) which causes a net force to act on the blade - that net force is called lift. And in the case of our wind turbine, that lift causes the rotor to rotate. The rotating mass of the rotor now carries kinetic energy associated with it. Basic wind turbine aerodynamic theory puts a limit on the maximum amount of energy that the rotor can harness from the energy in the inflow at a shade under 60% (Betz limit).

The wind turbine rotor is typically rigidly affixed to a main shaft. These components typically rotate at a relatively low rotational speed even at full power. Most frequently, there is a desire to step-up the rotational speed from the rotor and main shaft rotational speed to something much larger to allow for more efficient energy conversion downstream. Enter the wind turbine gear box. The gear box's primary function is to increase the rotational speed of the rotor and main shaft to a higher speed better suited for the electrical generators which will complete the energy conversion from kinetic to electrical. The gear box commonly will use gearing on shafts and bearings to mechanically increase the rotational speed. There is typically some loss in kinetic energy across the gear box due to friction, etc.

The output of the gear box is typically one or more high speed shafts. These high speed shafts directly engage what are referred to as generators. The primary function of the generators is to convert the high rotational speed kinetic energy of the high speed shafts into electrical energy. This process exploits the principles of electromagnetic induction whereby either permanent or electro magnets interact with conductors and drive the flow of electrons thereby creating electrical energy. The output electrical energy from the generators is typically conditioned to be made suitable for the local electrical grid or potentially even stored temporarily (battery and/or capacitor banks or otherwise) for non-immediate usage.

**Wind Turbine Generator Sizes**

Wind turbines come in a wide range of sizes and power outputs. For the purposes of this paper however, only utility scale wind turbines will be discussed. 1MW rated power and greater is usually considered utility scale. Wind turbines in this category are, in physical terms, big. Land based wind turbines range from 1 to 3+ MW in rated power and the height of the tower (from ground to the center of rotor rotation) is commonly 50 to 100 m. The diameter of rotors for land based turbines ranges from 60 to 120 m.
The Clipper Liberty 2.5 MW land based wind turbine has a 80 m hub height and has rotor diameters ranging from 89 to 99 m with rotor sizes as large as 104 m in the works. Figures 1 through 3 below give a sense of the scale of this wind turbine. Figure X shows an individual practicing for a self-rescue operation from the top of the turbine. Figure X shows my steel-toed boot compared to the studs which secure the bottom of the tower to the foundation. And Figure X shows a full view of 3 operating turbines - the little dark speck next to the base of the closest turbine's tower is a person.
Offshore wind turbines are even larger than land based wind turbines. There are exiting designs in the 5+ MW range and designs in development that are in the 10+ MW range. As big as the land based wind turbines are, the offshore wind turbines are even bigger. Figure 4 below shows visually a comparison between the Clipper Liberty 2.5 MW wind turbine and other preceding turbine designs as well as the Statue of Liberty, the Seattle Space Needle, and the Clipper Britannia 10 MW wind turbine which is in development.
Wind Turbine Components Typically Made of Large Ductile Iron Castings

Wind turbine generators typically employ ductile iron castings for a number of components. These components include hubs, main shaft bearing housings, gear box housings and support bases. The reasons that the designs of wind turbine generators have arrived at the cast ductile iron material and process for common usage for these components are numerous but in the end it all boils down to ductile iron castings being the lowest total cost material / manufacturing method. As will be discussed further hereafter, the complex geometric requirements of typical wind turbine components made from ductile cast iron as well as the corresponding structural demands (in large part fatigue durability) are such that cast steel or steel weldment alternatives typically come in at a higher total cost than cast ductile iron.

Hubs Made of Large Ductile Iron Castings

As mentioned previously, the blades of the rotor of the wind turbine are usually connected to a central hub. This hub is effectively the interface between the blades and the main shaft. The hub includes features for the blade pitching system (bearings, drives, electronics / power supplies cabinets, etc.). The hub also will usually contain considerations for self enclosure (protection from the elements, etc.) mounting - sometimes referred to as the spinner. The hub location in relation to the rest of the uptower wind turbine for the Clipper Liberty wind turbine can be seen in the figure below.
Hubs are usually one of the largest and most massive wind turbine components made from ductile cast iron. A rough estimation for the mass of a hub for a given wind turbine is as such:

\[
\text{Mass estimate} = 0.95 \times \text{Single Blade Mass} + 5680 \text{ kg}, \text{ where Single Blade Mass} = 0.145 \times \text{Rotor Radius}^2.92 [1].
\]

For example, the mass of a 2.5 MW wind turbine generator's hub is \(~16,000\) kg. On a cost (\$USD) basis, typically the cast and fully machined hub comes in at somewhere around 4.3x the mass of the cast hub [1].

The physical shapes of hubs for wind turbines usually include a spherical shell with appreciable thickness, two or three flat circular blade / pitch system mounting faces (some hub designs employ ‘coning’ whereby the angle of the blade faces relative to the axis of the main shaft are rotated into the wind), openings in blade faces for blade and assembly access circular mounting face for engaging main shaft, features for hub and assembly access. Additionally, some hub designs use ‘hub arms’ where the blade faces are significantly raised off the spherical shell surface of the main volume of the hub via cylindrical protrusions. The physical size of hubs varies as a function of turbine size / rated power output, but for reference a 2.5 MW wind turbine might have a hub that is 3.3 m long with 2.5 m blade root diameter. The shape and the size of the Clipper Liberty wind turbine hub can be seen in the figure below.
The functional requirements of a wind turbine hub are numerous. Some of the more critical demands include providing adequate support / stiffness for the blade pitch bearings as the bearing load distribution is heavily reliant upon the hub stiffness to limit out-of-round and out-of-flat deflections under various loading conditions to ensure adequate pitch bearing life. In addition to the pitch bearing mounting face stiffness considerations, other hub assembly components and systems may also be sensitive to other hub stiffnesses. This might include the pitch drive mounting for gear mesh alignment and/or electronics / power supplies cabinets, etc. mounting and other mounted components.

Furthermore, the hub geometry itself, in the overall structural system from blade root to main shaft, must be capable of reacting all dynamic loads from the blades, self loading, and any other external and internal forces for 20 or more years of design life. These forces typically are dominated by the aerodynamic and gravitational forces acting on the rotor as well as entire turbine system dynamic loads (system and/or component natural frequency excitation). There are commonly at least 500 unique extreme / survivability loading events that are calculated (and validated) and analytically imposed on the hub to ensure material yielding is avoided. For reference, an extreme single blade root moment might be as large as 8000 kN-m for a 2.5 MW wind turbine. These extreme events are worst case scenarios that statistically are expected to happen once in a lifetime or less for given population of wind turbine configuration. These events are not considered for fatigue life, but the hub must be assured to be able to survive and operate without issue thereafter should such an extreme event actually occur. Fatigue loading events, on the other hand, are any and all events considered to have a probability of greater than once in a lifetime for given population of wind turbine configuration. Loading magnitudes are smaller than the extreme events' but the number of estimated repetitions is substantially greater. There are commonly at least 100 unique fatigue loading events that are calculated (and validated) and analytically imposed on the hub to ensure fatigue crack initiation within the design lifetime.
is avoided. For reference, an single blade root fatigue damage equivalent moment might be as large as 3000 kN-m with $1 \times 10^9$ occurrences for a 2.5 MW wind turbine.

**Main Shaft Bearing Housings Made of Large Ductile Iron Castings**

As mentioned previously, the hub's downstream end is typically connected to a main shaft. Commonly this main shaft is supported on bearings which are contained within a housing or housings. These main shaft bearing housings are the interface between the main shaft and the gear box and support structure. The main shaft bearing housing location in relation to the rest of the uptower wind turbine for the Clipper Liberty wind turbine can be seen in the figure below.

![Figure 7](image)

Main shaft bearing housings are usually one of the smaller and least massive primary load path, structural wind turbine components made from ductile cast iron. Both mass and cost estimate generalizations are difficult to make for main shaft bearing housings due to the wide variety of drive train designs across various wind turbine generators. But, for example the mass of a 2.5 MW wind turbine generator's main shaft bearings housing is ~7,000 kg.

The physical shapes of main shaft bearing housings for wind turbines usually include a circular / tubular main structure to house one or more bearings, additional features that resemble feet to engage the support structure, and additional stiffening features. The physical size of main shaft bearing housings varies as a function of turbine size / rated power output, but for reference a 2.5 MW wind turbine might have a main shaft bearings housing that is approximately 1 m long with 1 m diameter bearing bores. The shape and the size of the Clipper Liberty wind turbine main shaft bearing housing can be seen to the right in the figure below.
The functional requirements of a wind turbine main shaft bearing housing are numerous. Some of the more critical demands include providing adequate support / stiffness for the main shaft bearings as the bearing load distribution is heavily reliant upon the housing stiffness. Housing stiffness may be critical for sustaining adequate main shaft bearing preload in some applications as well. Additionally, the main shaft bearing/s housing may also play a significant role in overall drive train stiffness which for some applications may be very important for drive train gear mesh alignment.

Furthermore, the main shaft bearing/s housing geometry itself, in the overall structural system from the main shaft to the gear box housings and support structure, must be capable of reacting all dynamic loads from the rotor and any other external and internal forces for 20 or more years of design life. These forces typically are dominated by the aerodynamic and gravitational forces acting on the rotor as well as entire turbine system dynamic loads (system and/or component natural frequency excitation). There are commonly at least 500 unique extreme / survivability loading events that are calculated (and validated) and analytically imposed on the main shaft bearing/s housing to ensure material yielding is avoided. For reference, an extreme over turning moment at the hub center might be as large as 7500 kN-m for a 2.5 MW wind turbine. These
extreme events are worst case scenarios that statistically are expected to happen once in a lifetime or less for given population of wind turbine configuration. These events are not considered for fatigue life, but the main shaft bearing/s housing must be assured to be able to survive and operate without issue thereafter should such an extreme event actually occur. Fatigue loading events, on the other hand, are any and all events considered to have a probability of greater than once in a lifetime for given population of wind turbine configuration. Loading magnitudes are smaller than the extreme events' but the number of estimated repetitions is substantially greater. There are commonly at least 100 unique fatigue loading events that are calculated (and validated) and analytically imposed on the main shaft bearing/s housing to ensure fatigue crack initiation within the design lifetime is avoided. For reference, an over turning moment at the hub center fatigue damage equivalent moment might be as large as 3500 kN-m with 1E9 occurrences for a 2.5 MW wind turbine.

**Gear Box Housings Made of Large Ductile Iron Castings**

As mentioned previously, the main bearing/s housing's downstream end typically interfaces with the gear box housings in some manner. The gear box housings are the interface between the main bearing/s housing, the generators and the support structure. The gear box housings houses gears, shafts, bearings, lubrication systems, etc. The gear box housings location in relation to the rest of the uptower wind turbine for the Clipper Liberty wind turbine can be seen in the figure below.

![Figure 9](image)

Gear box housings are also usually one of the smaller and least massive primary load path, structural wind turbine components made from ductile cast iron. Again, both mass and cost...
estimate generalizations are difficult to make for gear box housings due to the wide variety of drive train designs across various wind turbine generators. But, for example the mass of the 2.5 MW wind turbine generator's gear box housings is ~12,000 kg. The physical shapes of gear box housings for wind turbines usually include a rectangular prismatic and hollow primary shape with bores for bearings, additional features that resemble feet to engage the support structure, and additional stiffening features. The physical size of gear box housings varies as a function of turbine size / rated power output, but for reference a 2.5 MW wind turbine might have a main shaft bearings housing that is approximately 2.5 m tall, 4 m wide and 1 m deep. The shape and the size of part of the Clipper Liberty wind turbine gear box housing can be seen in the figure below.

![Figure 10](image.png)

The functional requirements of a wind turbine gear box housing are numerous. Some of the more critical demands include providing adequate support / stiffness for the gears and bearings of the drive train as the gear mesh and bearing load distribution is heavily reliant upon the housing stiffness under operational loads.

Furthermore, the gear box housings geometry itself, in the overall structural system from the main bearing/s housing to the support structure, must be capable of reacting all dynamic loads
from the rotor, the torque transfer resultant forces from the drive train and any other external and internal forces for 20 or more years of design life. These forces typically are dominated by the aerodynamic and gravitational forces acting on the rotor as well as entire turbine system dynamic loads (system and/or component natural frequency excitation). There are commonly at least 500 unique extreme / survivability loading events that are calculated (and validated) and analytically imposed on the gear box housings to ensure material yielding is avoided. For reference, an extreme over turning moment at the hub center might be as large as 7500 kN-m for a 2.5 MW wind turbine. These extreme events are worst case scenarios that statistically are expected to happen once in a lifetime or less for given population of wind turbine configuration. These events are not considered for fatigue life, but the gear box housings must be assured to be able to survive and operate without issue thereafter should such an extreme event actually occur. Fatigue loading events, on the other hand, are any and all events considered to have a probability of greater than once in a lifetime for given population of wind turbine configuration. Loading magnitudes are smaller than the extreme events' but the number of estimated repetitions is substantially greater. There are commonly at least 100 unique fatigue loading events that are calculated (and validated) and analytically imposed on the gear box housings to ensure fatigue crack initiation within the design lifetime is avoided. For reference, an over turning moment at the hub center fatigue damage equivalent moment might be as large as 3500 kN-m with 1E9 occurrences for a 2.5 MW wind turbine.

Support Bases Made of Large Ductile Iron Castings

As mentioned previously, the main bearing/s housing's and gear box housing's downstream ends typically interface with support structure. The support base is this support structure. It is the interface between the drive train (which includes the gear box housings and the main bearing/s housing) and the tower top. The support base includes features for nacelle access, the yaw system, work platforms, walkways, cranes, and so on. The support base in relation to the rest of the uptower wind turbine for the Clipper Liberty wind turbine can be seen in the figure below.
Support bases are also usually one of the larger and more massive primary load path, structural wind turbine components made from ductile cast iron. A rough estimation for the mass of a support base for a given wind turbine is as such: Mass estimate = 1.72*Rotor_Diameter^1.95 kg [1]. For example, the mass of a 2.5 MW wind turbine generator's support base is ~16,000 kg. On a cost ($USD) basis, typically the cast and fully machined support base is as such: 17.92*Rotor_Diameter^1.67 [1].

The physical shapes of support bases for wind turbines usually include a long and tub-like primary structural shape with large ribs / stiffeners, a circular opening at the bottom / tower connection region for nacelle access and yaw system configuration and mounting pads / feet atop for drive train interfacing and work platforms, walkways, cranes, nacelle support columns, etc. The physical size of support bases varies as a function of turbine size / rated power output, but for reference a 2.5 MW wind turbine might have a main shaft bearings housing that is approximately 4 m long, 3 m diameter yaw bearing. The shape and the size of part of the Clipper Liberty wind turbine support base with some of the walkways and platforms assembled can be seen in the figure below.
The functional requirements of a wind turbine support base are numerous. Some of the more critical demands include providing adequate support / stiffness for the gears and bearings of the drive train for the same reasons as mentioned previously. Also, the support base must provide adequate support / stiffness for the yaw bearing as load distribution, again here, is reliant upon the support base stiffness under operational loading to ensure adequate bearing longevity over the design life. The same goes for the yaw drive mounting regions for yaw gear mesh alignment considerations as well as for work platforms, walkways, etc.

Furthermore, the support base geometry itself, in the overall structural system from the main bearing/s housing to the support structure, must be capable of reacting all dynamic loads from the rotor, the torque transfer resultant forces from the drive train and any other external and internal forces for 20 or more years of design life. These forces typically are dominated by the aerodynamic and gravitational forces acting on the rotor as well as entire turbine system dynamic loads (system and/or component natural frequency excitation). There are commonly at least 500 unique extreme / survivability loading events that are calculated (and validated) and analytically imposed on the support base to ensure material yielding is avoided. For reference, an extreme over turning moment at the hub center might be as large as 7500 kN-m for a 2.5 MW wind turbine. These extreme events are worst case scenarios that statistically are expected to happen once in a lifetime or less for given population of wind turbine configuration. These events are
not considered for fatigue life, but the support base must be assured to be able to survive and operate without issue thereafter should such an extreme event actually occur. Fatigue loading events, on the other hand, are any and all events considered to have a probability of greater than once in a lifetime for given population of wind turbine configuration. Loading magnitudes are smaller than the extreme events' but the number of estimated repetitions is substantially greater. There are commonly at least 100 unique fatigue loading events that are calculated (and validated) and analytically imposed on the support base to ensure fatigue crack initiation within the design lifetime is avoided. For reference, an overturning moment at the hub center fatigue damage equivalent moment might be as large as 3500 kN-m with 1E9 occurrences for a 2.5 MW wind turbine.

Grades of Large Ductile Iron Castings Typically Used in Wind Turbine Components

In addition to the aforementioned component specific requirements, all wind turbine components must be able to operate reliable across a range of operational and survivability temperatures. Typically, the high end of the temperature range is of no consequence for the large ductile iron castings used for many of the wind turbine components. However, the low end of the temperature range does have an impact on the grades of ductile iron that may be used for casting these wind turbine components. Standard weather wind turbine application is usually defined as operation down to -10 C with survivability down to -20 C. Cold weather applications, which are necessary in many mid-west United States locations, are defined as operation down to -30 C and survivability down to -40 C. As such, CW applications sometimes further narrow the number of possible grades of ductile iron that may be used for casting these wind turbine components.

Probably the most commonly utilized grade of cast ductile iron for wind turbine components is ferritic spheroidal graphite cast iron - 'EN-GJS' series of grades per EN1563. The subset of this series of grades which is appropriate for usage in wind turbine components can have minimum tensile strengths between 320 and 400 MPa and minimum proof strengths between 200 and 240 MPa with fracture elongations between 12 and 22%. Usually, Charpy impact requirements must be met at -20 C for standard weather applications and at -40 C for cold weather applications. Commonly the microstructure must be at least 90% form V and VI and the size between 3 and 7 - pearlite must be kept below 10% of the matrix. All this said, the most common family of grades within this subset of the EN1563 ductile irons is the lower strength requirement, low temperature toughness requirement ferritic spheroidal graphite cast iron. For instance, a common specific grade would be EN1563's EN-GJS-400-18U-LT (EN-JS1049). This grade has the following minimum requirements per EN1563 [2]:

- Minimum tensile strength = 370 MPa
- Minimum 0.2% Proof stress = 220 MPa
- Minimum elongation = 12%
- Minimum mean value of 3 Charpy impact tests at -20 C = 10 J
- Minimum individual value from 3 Charpy impact tests at -20 C = 7 J

The microstructure of such a grade might look something like what is shown in the figure below.
Additional Requirements of Large Ductile Iron Castings Typically Used in Wind Turbine Components

On top of the requirements of EN1563 or otherwise, it is commonplace for wind turbine components to have a number of additional requirements that suppliers must meet to ensure the design intent is met. These additional requirements include visual inspections, dimensional inspections, surface Brinell hardness inspections, volumetric non-destructive testing inspections (ultrasonic and/or radiographic) and surface non-destructive testing inspections (magnetic particle and/or liquid penetrant). Also, dross type defects are usually fundamentally inadmissible due to their detrimental effect on properties tightly correlated to fatigue life. The mechanical properties obtained from cast-on test coupons must be assured to be representative of the component as a whole. Weld repairing of any casting defects is not impossible, but typically requires an extensive qualification and approval process. And residual stresses which negatively impact machining or design life (fatigue life, especially) may be required to be reduced or eliminated by process controls (ensured adequate in mold stress relief, post shake-out thermal or vibratory/mechanical stress relief, etc.) and/or empirical validation of residual stresses through non-destructive testing.

Summary of Large Ductile Iron Casting Wind Turbine Generator Components

To summarize this document, suffice it to say that wind turbine components typically made of ductile iron castings are numerous. Some are quite large and all are fairly complicated in geometry. All are multi-purpose with strength and stiffness critical attributes and numerous, complicated and demanding loadings. The appropriate casting materials for these components are lower strength, higher ductility / toughness grades (i.e. ferritic). These components have
additional requirements above and beyond the basic material specifications to ensure adequate quality and that the design intent is met - these requirements may be more stringent and challenging than components for other industries but cast ductile iron wind turbine component manufacture is only growing in the future and therefore casting vendors with experience and good track record on quality will likely find rewards to be had with doing business in this industry.

- KRT

References


Wind Energy Castings – Metallurgical Challenge

Dr. Sven Uebrick
SKW Giesserei GmbH/Germany

Tecpro Corporation
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2. Wind Energy – Developments
4. Wind Energy Production - The Process
5. Conclusion
## SKW Giesserei GmbH/Germany

### Company index:

<table>
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<td>166</td>
<td>73 Mio. €</td>
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<tr>
<td>2011</td>
<td>166 (185)</td>
<td>77 Mio. €</td>
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SKW Gusserei GmbH/ Germany

Ferrosilicon production

Fig.: Three phase submerged arc furnace
SKW Giesserei GmbH/Germany

• Ferrosilicon is produced in three phase submerged arc furnaces

• SKW has two furnaces with an electric power consumption of 11 MW (= approx. 15,000 ton) each

• Raw Material: pure quartz with SiO₂ content > 98 %, iron scrap chips, flaming coal with a low ash content, petroleum coke, Söderberg paste

• Reactions in the furnace occur according to the simplified schema:

  \[
  \text{SiO}_2 + 2 \text{C} + \text{E-Power} \rightarrow \text{Si} + 2 \text{CO} \\
  \text{Fe} + \text{Si} \rightarrow \text{FeSi (basic product)}
  \]

• Electro-thermical reduction of quartz

  FeSi 75  8,0 MW / ton
SKW Giesserei GmbH/Germany

Inoculation material for ladle and in-stream application in different grain sizes, grey and ductile cast iron

Master alloys for the Mg-treatment process in different grain sizes and chemical compositions, with or without Cerium

Inoculation material for in-mould and heavy section application in different sizes, Optigran for grey iron and Germalloy for ductile iron

Cored wire for the Mg-treatment and inoculation process in different chemical compositions depending on customer specifications
Wind Energy – Developments

Fig.: Installed wind energy capacity in Germany

**Bild 5: Installierte Windenergieleistung in Deutschland**

Quelle: dena
Wind Energy – Development

Energy: Electric power, water power, wind power, methane power plants (agriculture), solar power:

2005: 5,8 %
2010: ~15,0 %
2020: ~20,0 %
2030: ~48,0 %

Wind energy: Europe: 280.000 MW installed electrical capacity
(170.000 MW On-shore, 110.000 MW Off-shore)

Wind energy: Germany: 22.250 MW (2007) → ~ 50.000 MW On-shore

Wind energy: China: 2009 – 37,5 GW, new installed 2010 13 GW,
Europa – 10 GW, USA – 9,9 GW

Development of world population: 6,9 Mrd. people → 8,0 Mrd. (2030)
→ 16 % more demand of energy
### Basic Standard – DIN EN 1563:1997

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<tr>
<th>Material</th>
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<th>Yield strength N/mm²</th>
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<td>210</td>
<td>18</td>
<td>12 (-40°C)</td>
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<tr>
<td></td>
<td>60&lt;t&lt;200</td>
<td>320</td>
<td>200</td>
<td>15</td>
<td>10 (-40°C)</td>
</tr>
</tbody>
</table>

Fig.: Ferritic nodular cast iron according to the German standard: DIN EN 1563:1997
Modulus of elasticity: 169 GN/mm²
Basic Standard – DIN EN 1563:1997

• Measurement of the standard mechanical properties for ductile iron
• Influence of the mechanical properties depend on the wall thickness

Fig.: Charpy impact testing machine

Fig.: Charpy impact test bar

Fig.: Standard test bar, $R_m$, $R_p0.2$, $A_5$, HB
Wind Energy Production - The Process

Main components of the wind energy casting process

1. Rotor hub (800 kW – 7.500 kW (7,5 MW))
2. Axial pin
3. Plate adapter
4. Machine holder
Wind Energy Production - The Process

Fig.: Rotor hub, weight: 9210 kg

Fig.: Microstructure of GJS 400-18U LT
Wind Energy Production - The Process

Preparation of a 7.5 MW rotor hub for the pouring process with a gating system, 2 pouring ladles and riser system.

Fig.: Simulation of the mould filling process, solidification process, calculation of the filling time, casting weight, shrinkage tendency, feeding profil.

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October 27-29, 2010
Wind Energy Production - The Process

Fig.: Optimization process of the moulding boxes, Optimization of the sand to metal ratio

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Wind Energy Production - The Process

Coating and Moulding Material

- Application of special coatings, furan or phenolic resin binder and TSA catalyst for the moulding material with a low content of nitrogen, oxygen and sulfur

- Use the right content of furan or phenolic resin binder and TSA in the moulding material for the right strength; 0.8-1.1% furan resin, 0.3-0.5% TSA acid, basic moulding material: 50 GFN sand

→ Moulding material strength ~200-250 N/cm², no mould wall movement

→ Graphite expansion → influence of the shrinkage and micro-porosity in the microstructure

Target

- Reduction of the graphite degeneration and gas issues in the casting surface, reduce the stress concentration on the casting surfaces
Wind Energy Production - The Process

Fig.: Microstructure without a coating, influence of the moulding material on graphite degeneration

Fig.: Microstructure with an ordinary coating material, Reduction of the zone of degeneration of graphite

Fig.: Microstructure with a special coating, additional material Calcium Carbonate, further reduction of the zone of graphite degeneration
Wind Energy Production - The Process

• Application of electric melting furnace

• Melting process with pure steel scrap, foundry returns, pig iron without a large content of interfering elements

• Charge for GJS 400-18 LT: ~30 - 60 % pig iron special quality with low sulfur and manganese content

• C: 3,4 – 3,5 %; Si: 1,7 – 2,0 %; Mn: 0,10 – 0,12 %; S: 0,004 – 0,006 %; Mg: 0,04 – 0,05 %; P < 0,03 %, (Ni: 0,3-0,5 %, impact value problems)

Fig.: Scrap and pig iron for ductile iron applications

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• Calculation of the K-Factors

  \[ K_1 = 4.4\text{Ti} + 2.0\text{As} + 2.3\text{Sn} + 5.0\text{Sb} + 290\text{Pb} + 370\text{Bi} + 1.6\text{Al} \]

  • \( K_1 \leq 1.0 \); (ladle treatment with master alloys without rare earth)
  • \( K_1 \leq 2.0 \); (ladle treatment with master alloys with rare earth)

  \[ K_2 = K_1 / \text{Mg}_{\text{residual}} \]

  • \( K_2 = (1.6\text{Al} + 4.4\text{Ti})/\text{Mg} \)
  • \( K_2 \leq 12 \); (ladle treatment with master alloys and without rare earth)
  • \( K_2 \leq 15 \); (ladle treatment with master alloys and with rare earth)
Wind Energy Production - The Process

Mg-treatment process

1. Cored wire
   alloy or mixed cored wire

2. Master alloy
   with 0,7 % Ce, 5,5-6,3 % Mg
Wind Energy Production - The Process

Fig.: Relationship between Mg content and shrinkage tendency

Remark: An elevation of the Mg-content from 0.04 % to 0.05% means the shrinkage tendency will increase about 100 %
Wind Energy Production - The Process

Inoculation process

Fig.: Application of Germalloy inserts in the moulding basin, ~0.15-0.2 % of the pouring weight
Wind Energy Production - The Process

Fig.: Application of different types of Germalloy inserts in the pouring basin
Wind Energy Production - The Process

The use of the inserts takes place according to this chart. One has to know the amount of inoculation, pouring time, pouring temperature, dissolving time of inserts as well as selection and arrangement of inserts in the pouring basin.

Fig.: Calculation sheet for the mould inoculation process from 300 kg up to >100 t liquid iron

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Wind Energy Production - The Process

Chunky - Graphite

<table>
<thead>
<tr>
<th>Elogation, %</th>
<th>Tensile strength, MPa</th>
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<tr>
<td>without Chunky graphite</td>
<td>with Chunky graphite</td>
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<tr>
<td>25</td>
<td>5</td>
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<tr>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>22</td>
<td>4,5</td>
</tr>
</tbody>
</table>

Fig.: Relationship between mechanical properties and chunky graphite in the microstructure

---

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Wind Energy Production - The Process

How we can achieve a sound casting without chunky graphite or Dross?

1. Application of preconditioning agents, f.e. appr. 0,1 % VL (Ce) 2 or Tecprosid B to reduce the oxygen and sulfur content in the liquid iron:

Ce + O → CeO and Ce + S → CeS, Ce content should be < 0,004 % in the iron

2. Application of melt-cleaning agents, f.e. appr. 0,1 % Dispersit, Mg and RE (rare earth) based material to clean the liquide iron

3. Chemical Composition: carbon equivalent 4,1-4,2 and degree of saturation 0,96-0,99 depending on the wall thickness, for heavy section application

4. Mg-Treatment with cored wire or master alloys, Mg content 0,04-0,05 % depend on the wall thickness and the foundry transport process (holding time), Mg-treatment temperature: 1450 – 1480 °C
Wind Energy Production - The Process

6. Inoculation process with 0,10-0,12 % mould Germaalloy inserts in combination with a special Bi/Ce-based inoculant material (Bi content: 0,8-1,2 %, RE content: 0,8-1,2), additional rate 0,05-0,15 % for the stream metal process,

Target: Bismuth, in combination with Cerium dramatically increases the number of nodules. To be effective against the degeneration of graphite, Rare Earth elements must be present in appropriate concentrations. Amount of ferrite in the casting are increased through the increase in the number of nodules and the shorter diffusion paths ferrite as cast can be achieved. Increasing of the numbers of spherolite, f.e. ~300-450/mm², Bi content in the iron: 0,004-0,0015 %, Patent: DE 38 07 455 C2, 07.11.1996

![Normal Inoculant, Nodularity Rating: 91 %, Nodule Count: 245/mm²](image1)

![SMW 605 Inoculant, Nodularity Rating: 92%; Nodule Count: 424/mm²](image2)

7. Pouring temperature: 1330 – 1360 °C depending of the wall thickness
Wind Energy Production - The Process

Fig.: Dross inclusions
MgO, MgS, MgAl slag products
SiO$_2$, CaO, Al$_2$O$_3$, FeO, MnO

Mg reaction products, ladle management, pure charge compositions, treating conditions, temperature, turbulent flow

Fig.: Slag inclusions

Sand strength, addition rates of furan binder and catalyst coating, dimension of gating system, filling time, ladle management

DIS Heavy Section Ductile Iron Conference
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Conclusion
Conclusions

1. Preparation of the pouring process, simulation of all important elements

2. Optimization of all process materials: steel scrap, foundry returns, pig iron, moulding material and pouring boxes as well.

3. Electric melting furnace, melting management, clean melting process

4. Calculation of final chemical composition, include the Si-content in the Mg-treatment material and the inoculation material, Si - appr. 1,7 – 2,0 %, embrittlement of the grain boundary, Ni – appr. 0,3 -0,5 % by problems with the impact value
Conclusions

5. Application of preconditioning agents based on Cerium, VL (Ce) 2, Tecprosid B

6. Mg-treatment process, Mg – content: 0,04 -0,05 %, shrinkage and porosity problems in the microstructure reduce the mechanical properties

7. Mould Inoculation process with appr. 0,1 % Germalloy inserts, additional rate is well adjusted to the size of the casting, no contact with the atmosphere during dissolvering, very effective also in combination with an inoculant based on Bi/Ce, SMW 605 (0,05-0,10 %)

8. Mould Inoculation process with appr. 0,15-0,2% Germalloy inserts for single application
Thank you for your attention

For additional information, please contact:

• Dr. Sven Uebrick
• SKW Giesserei GmbH, Unterneukirchen/Germany
• Phone: +49 (0) 86 34 61 7410
• Fax: +49 (0) 86 34 61 7420
• Email: sven.uebrick@skw.com
• Or contact Tecpro Corporation @ dsalak@tecprocorp.com
FOR IMMEDIATE RELEASE NOVEMBER, 2010

FEF COLLEGE INDUSTRY CONFERENCE

The FEF College Industry Conference was recently held at the Westin Michigan Avenue in Chicago. Nearly 250 industry executives, student delegates, key professors and university administrators were in attendance this year.

The conference began on Thursday, November 18, with the Industry Information Session which gave 90 student delegates the opportunity to interact with representatives of 36 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 “Reinventing Yourself for Sustainability in Metal Casting”: Corey Jarvis (Trumbull Metal Specialties), Kai Spande (General Motors), and Sid Tankersley (American Foam Cast).

The FEF/AFS Distinguished Professor Award was given to FEF Key Professor, Pradeep Rohatgi, University of Wisconsin-Milwaukee, 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) – 21 students were awarded a total of $39,500.00. Additionally, the Keith Millis and Ron Ruddle scholarship recipients were announced.

At the Annual Reception on the evening of November 19, FEF’s highest award, the E.J. Walsh Award, was presented to former FEF student and President Lifetime Patron, Richard Poirier. 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 & sold the raffle tickets!

Next year’s conference will be held on November 17 & 18 at the Westin Michigan Avenue in Chicago. Plan now to attend this exciting event.

CIC Student Delegate Scholarships - November 19, 2010

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<tr>
<th>Scholarship</th>
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<th>University</th>
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<td>AFS-Detroit Windsor-George Booth Schol.</td>
<td>Michelle Loomis</td>
<td>Michigan Tech</td>
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<td>AFS-Saginaw Valley Scholarship</td>
<td>Michael Kruse</td>
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<td>AFS Southwestern Ohio Scholarship</td>
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<td>Ron &amp; Glenn Birtwistle Mem. Scholarship</td>
<td>Paul Lynch</td>
<td>Penn State</td>
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<td>Pittsburg State</td>
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<td>Donald Brunner Schol.-ThyssenKrupp Waupaca</td>
<td>Christopher Armstrong</td>
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<td>Paul Carey Memorial Scholarship</td>
<td>Sean Derrick</td>
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<td>Clifford Cher-Badger Mining Corp.</td>
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<td>Wm. E. Conway Schol.-Fairmount Minerals</td>
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<td>Tony &amp; Elda Dorfmueller Scholarship</td>
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<td>Richard Frazier Scholarship</td>
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More information on this conference or any of the FEF activities can be obtained from the FEF office at 1695 N. Penny Ln., Schaumburg, IL 60173, Phone 847/490-9200, Fax 847/890-6270, email info@fefinc.org, web page: http://www.fefinc.org.
OBJECTIVE: To gain industrial knowledge that will aid in my educational experience leading to a career in the foundry industry.

EDUCATION: Kent State University August 2007 - Present
College of Technology BS General Technology – Expected graduation in May 2011
Relevant Coursework – Materials and Processes1&2, Cast Metals, Engineering Graphics, Survey of electricity, PLC’s
Medina County Career Center August 2004-May 2006
Certificate of completion of the Commercial Truck Program

Employment: Advanced Bronze Centrifugal Casting, Lodi, Ohio June 2010 –August 2010

Position: Floor worker/Melt deck
- Preparing dies
- Poring bronze into dies and pulling the casting out of the die
- Melting bronze and alloying

Soft-Lite Windows, Streetsboro, Ohio July 2009- August 2009

Position: Process engineer
- Updating processes
- Implemented 5s
- Improved efficiencies in the shipping department

Best Sand, Chardon Ohio June 2008- August 2008

Position: Maintenance
- Fixing conveyers – replacing lacings and rollers
- Cleaning- shoveling sand and washing sand out of buildings

PROFESSIONAL MEMBERSHIPS
American Foundry Society Student President 2007 - Present
SKILLS USA 2004 – 2006

SKILLS & ACTIVITIES
Commercial Truck Skills – Mechanic, welding, fabricating, CDL, Air Brakes
Computer Skills – Microsoft works, Auto-Cad, and Solid Edge
Activities – Hunting, fishing, Baseball, and Football

Volunteer
Black River Junior High Football Camp, Medina, Ohio
Coached young football players learn their techniques.
Meghan M. Haycock
Email: mmhaycoc@mtu.edu, Mobile: (810) 919-9511

Local Address
916 College Ave.
Houghton, MI 49931

Permanent Address
4305 Hastings Dr.
Grand Blanc, MI 48439

Objective:
To obtain a full time job employing my knowledge of metallurgy and materials science, along with the skills I have acquired, to solve real-world engineering problems.

Education:
Michigan Technological University (MTU) Houghton, MI
M.S. Materials Science and Engineering – GPA: 4.0 Exp. Graduation: May 2011
Research Topic: Mechanical and microstructural characterization of ductile cast iron at very low temperatures

Related Coursework: Scanning Electron Microscopy (SEM), Transmissions Electron Microscopy (TEM), Technical Communications

Work Experience:
Michigan Technological University Houghton, MI
Dept. of Materials Science and Engineering August 2009 - present
Graduate Research Assistant – Dr. Paul Sanders
• Conduct research on a variety of projects including:
  o Next-generation materials for lithium ion batteries
  o Characterization of a novel ductile cast iron
  o Alloy development and characterization of ductile iron for heavy section castings

Graduate Teaching Assistant
• Instruct lab sessions for the Scanning Electron Microscopy course
• Collaborate with course instructors on value of current labs
• Updated the lab work making it more relevant and applicable

ACMAL Staff Member
• Served as an user for electron microscopes (SEM, TEM, FESEM) for outside researchers
• Conducted training sessions on the Field Emission Scanning Electron Microscope (FESEM)
• Developed and improved online training modules for the TEM in a team setting

Dept. of Civil Engineering September 2006 – October 2006
Undergraduate Research Assistant – Dr. Larry Sutter
• Research focused on penetration of salt solutions in asphalt
• Responsible for image analysis and determining amount of area of cross-section that was penetrated

Katerina Aifantis – Recipient of European Research Council Starting Independent Research Grant Houghton, MI
Research Assistant February 2010 – July 2010
• Conducted research under Katerina’s guidance on lithium ion battery anode materials
• Conducted SEM and TEM imaging and analysis
- Performed XRD analysis
- Contributed significantly to technical paper

**Nucor Steel Arkansas**
**Cold Mill Metallurgical Intern**
Hickman, AR
Summer 2008
- Investigated, designed and carried out experiments (tensile testing, metallographic analysis) for a problematic steel grade
- Presented results to group of full-time employees
- Communicated with shift workers on a daily basis
- Conducted testing and analysis on quality claims in conjunction with full-time metallurgist

**Ford Motor Company**
**Laboratory Engineer Intern**
Dearborn, MI
Summer 2007
- Performed microstructural and metallurgical analysis and mechanical testing (tensile, hardness) on various automotive components
- Managed 11 jobs and co-managed on 2 others
- Presented all jobs to full-time engineers and scientists

**Computer Skills:**
Windows OS, AutoCAD, Auto Inventor Pro, Microsoft Office – including Excel, Unigraphics, MathCAD, Image J, Origin

**Technical Skills:**
Metallographic Analysis and Preparation for both optical and electron microscopes, Tensile Testing, Hardness Testing, SEM, TEM, FESEM, X-Ray Diffraction, Board Drafting, OSHA 30-Hour Safety Certified

**Characterization of High Strength Low Alloy Steel** – Senior Design Project
- Sponsored by Severstal in Dearborn, MI
- Cold rolled, annealed and tempered pieces of strip steel
- Characterized properties including tensile behavior, hardness and microstructure

**Leadership and Accomplishments:**
- **Alpha Sigma Tau National Sorority (ΑΣΤ):** Active Collegiate and Alumnae Member
  - Held numerous leadership positions as an undergraduate active member
  - As alumna, currently District Coordinator for all chapters in Michigan
- **Member of the Career Services Student Advisory Board**
  - Provide candid and honest feedback to Career Services employees
  - Present recommendations based on personal experience
  - Participate in Corporate Advisory Board meeting
- **Member of MTU’s Department of Engineering Research Scholars Program**
- **Initiated member of the Order of Omega, a leadership fraternity**
- **Developed and instituted the Executive Board for the MTU Honor’s Institute**
- **Awarded MTU Board of Control Scholarship based on academic performance**
- **Awarded multiple Materials Science and Engineering Departmental Scholarships**
- **Member of The Order of the Open Book** – an academic honor society within ΑΣΤ
OBJECTIVE: Gain a position where my knowledge of Industrial Engineering can be applied to develop and implement creative and economically prudent solutions that fulfill the mission of the company.

EDUCATION: The Pennsylvania State University
University Park, PA
Bachelor of Science in Industrial Engineering
Concentration: Manufacturing
Dec 2010 (exp)

EXPERIENCE: The Buck Company
Quarryville, PA
Manufacturing/Foundry Engineer Intern
Summer 2010
- Established and streamlined standard work for R&D tax credit software
- Developed and implemented fixtures for robotic grinding operations
- Facilitated lean manufacturing and continuous improvement projects
- Detailed plant equipment and utilities in AutoCAD
- Streamlined work order and preventative maintenance procedures
- Assisted sales and marketing departments with a website redesign
- Learned manufacturing processes through a rotation of work including molding, pouring, and finishing

The Pennsylvania State University
Research Intern
Fall 2009-Present
- Developed tempering curves to determine prototype steel properties
- Performed heat treatments of a stainless managing alloy to optimize performance/increase yield stress
- Involved in metallographic preparation and characterization of newly developed cast stainless steels

Brookhaven National Laboratory (BNL)
Upton, NY
Water Treatment Plant Intern:
Summer 2008
- Tested nitrogen, dissolved oxygen (DO), biochemical oxygen demand (BOD)
- Analyzed data and found structured correlations between temperature, DO, nitrate levels, and BOD
- Performed troubleshooting to determine cause for high nitrogen levels in effluent
- Provided an economically feasible solution and course of action to restore nitrogen levels within state and county regulations

AutoCAD Intern:
Summer 2007
- Detailed facility layout involving missing chemical storage vessels at the BNL site
- Assessed compliance of chemical storage with state and county codes
- Integrated new chemical storage data into master blue prints using AutoCAD

HONORS:
- American Foundry Society, Keystone Chapter, Herman Mandel Scholarship Fall 2010
- Foundry Educational Foundation scholarship Fall 2010
- Conestoga Foundry Association scholarship Spring 2009
- National Science Olympiad Medalist, University of Illinois at Urbana-Champaign Spring 2005

WORK: Penn State Fitness Center
State College, PA
- Assist in supervision of gym facility Spring 2006-Present
- Customize individual fitness programs for clients through the “Get Fit” program

Three Village Inn
Stony Brook, NY
- Responsible for managing and scheduling of restaurant employees Winter 2003-Present
- Coordinate and setup of large-scale special events of up to 500 persons

ACTIVITIES: American Foundry Society (Penn State Chapter)
State College, PA
- Vice President Fall 2009-Present
- Assist with community outreach program, involved in metal casting education during foundry nights

Society of Manufacturing Engineers (Penn State Chapter)
State College, PA
- Officer Fall 2009-Present
- Assist with implementation and production of manufacturing projects

Pan-Hellenic Penn State Dance Marathon (THON)
State College, PA
- Develop and manage ATLAS Thon T-shirt Fundraiser Fall 2007-Present
- Part of fundraising team which raised over $300,000 in donations

SKILLS: Proficient in:
- Engineering Software: AutoCAD, Solid Works, and Minitab
- Microsoft Office Suite: Access, Excel, PowerPoint, Visio and Word
- Material Processes: Welding, CNC Machining, Casting, and Rapid Prototyping
Objective:
Internship in Manufacturing Systems Engineering to learn about the role of engineers and how they work in teams to accomplish goals and objectives. Willing to learn about the various product lines and the niche processes used to maintain being a successful company in the global market.

Work Experience:
Tech Cast, LLC                         Myerstown, Pa                        May 2010-August 2010
Worked as an Industrial Engineering intern focusing on optimizing labor in the foundry. Monitored production efficiencies in various departments throughout the foundry. Designed grind fixtures for multiple parts to assist the ease of production in the finishing department. Developed standard operating procedures for multiple machines throughout the entire foundry.

Education:
The Pennsylvania State University
Industrial Engineering Major/Six Sigma Minor
Expected Graduation Date: December 2011
GPA: 2.52
Courses Taken:
Product Design                       Work Design                        Computer/Linear Programming
Probability/Statistics               Materials Science                   Strength of Materials
Engineering Economics                Process Engineering                 Manufacturing Engineering

Activities:
Berks Baja Team                       Vice President/Project Manager     August 2007-June 2009
Designed and built an off-road go-kart, from the ground up, for the SAE Baja Competition held in Montreal, Quebec for June 2008 and Milwaukee, WI for June 2009. This club helped build teamwork, networking, and project managing skills. It also assisted in the enhancement of Solid Works skills by designing all of the parts used on the car. The team also designed and mapped the test track for the car using GPS plotting on a plot of land donated by the Penn State Berks campus.

Boy Scouts of America                Eagle Scout                         1994-2007
The eagle project consisted of a winter clothing drive for homeless and children of less fortunate families. This experience was invaluable in helping build strong character and provided multiple life lessons.

Organizations:
IIE Student Member                   September 2009-Present
AFS Student Member and President     September 2009-Present
MEETINGS - BUSINESS - PEOPLE

MEETINGS

The Ductile Iron Society/Iron Casting Research Institute Annual Meeting will be held June 1-3, 2011 at the Marriott Dallas/Fort Worth Airport South Hotel. There will be a visit to Oil City Iron Works, Corsicana, Texas.

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BUSINESS

PEOPLE

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