

Digital Innovative Design

for Reliable Casting Performance



Diana David

Steel Founders' Society of America (SFSA)

ddavid@sfsa.org

Frank Peters

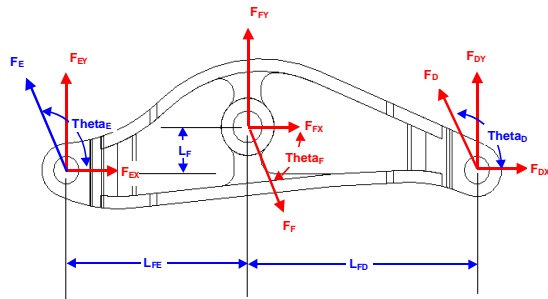
Iowa State University (ISU)

fpeters@iastate.edu

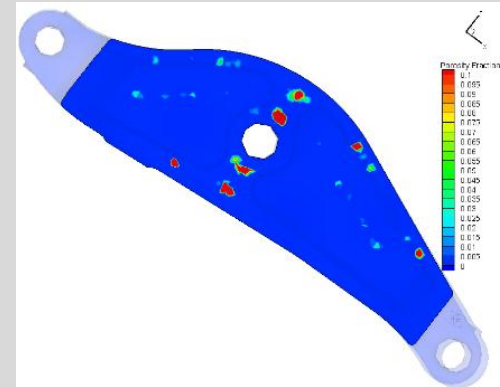
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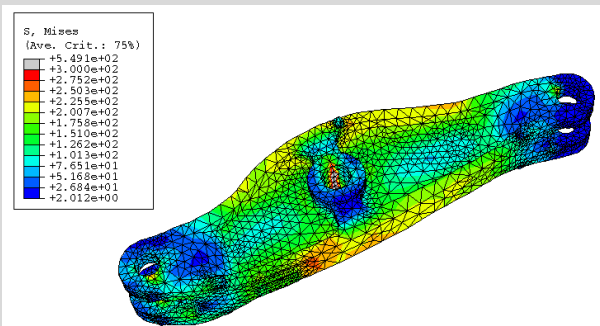
Simulation with local properties and NDT



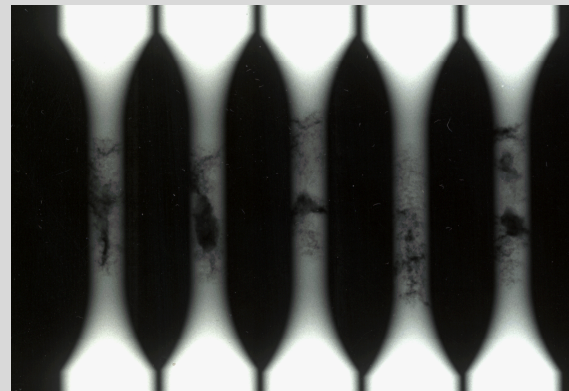
Load case



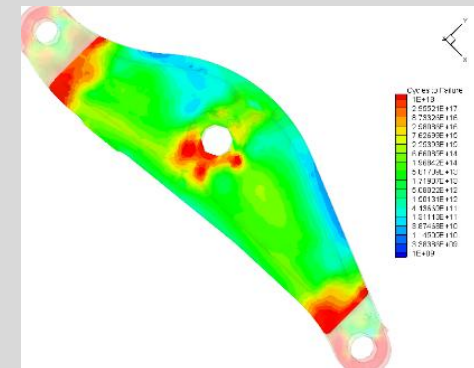
Solidification analysis



Structural analysis

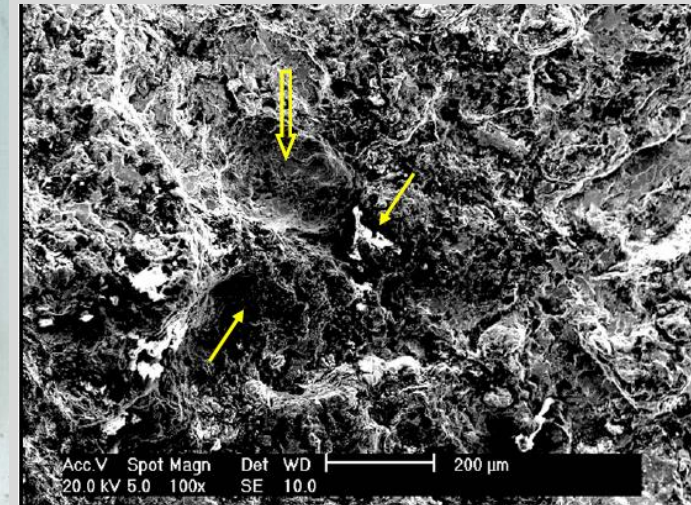
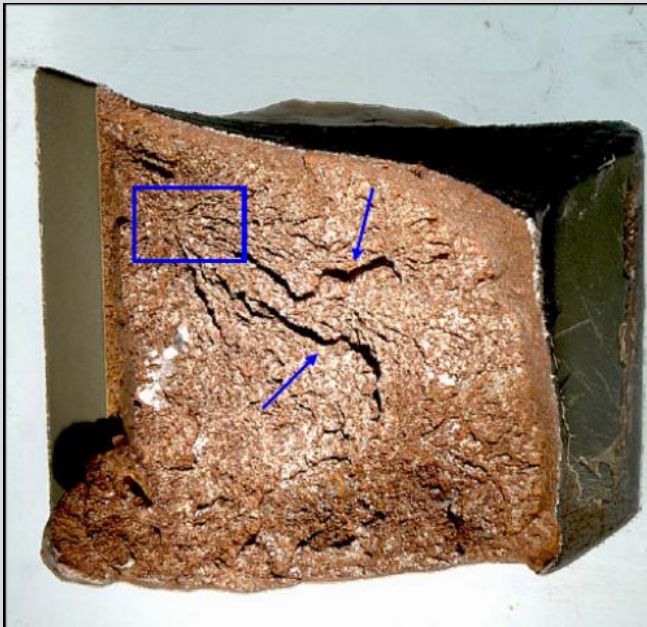
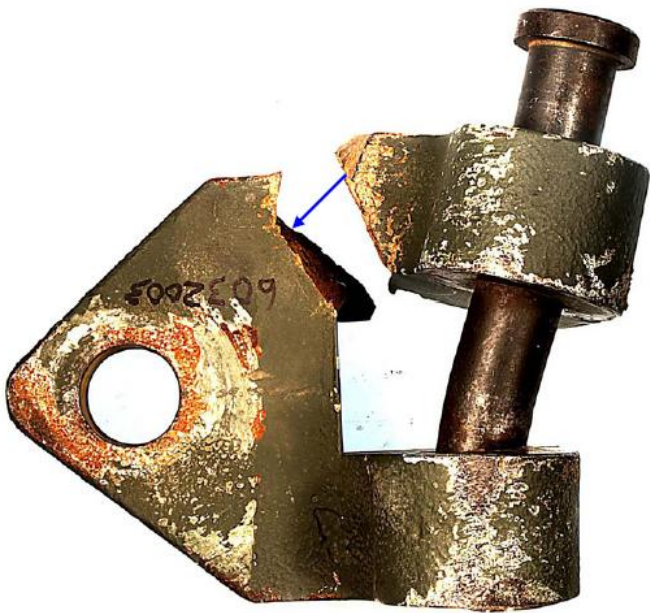


X-ray inspection



Fatigue life analysis

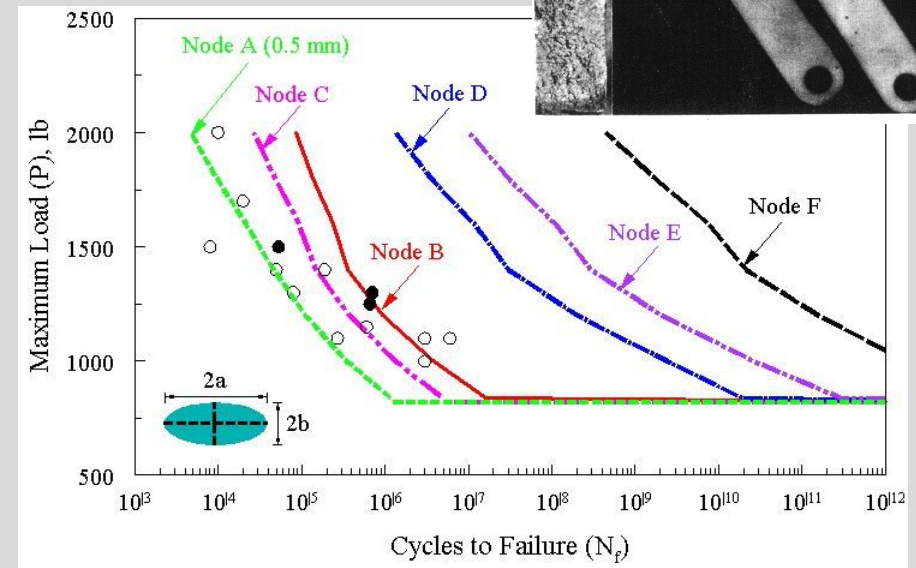
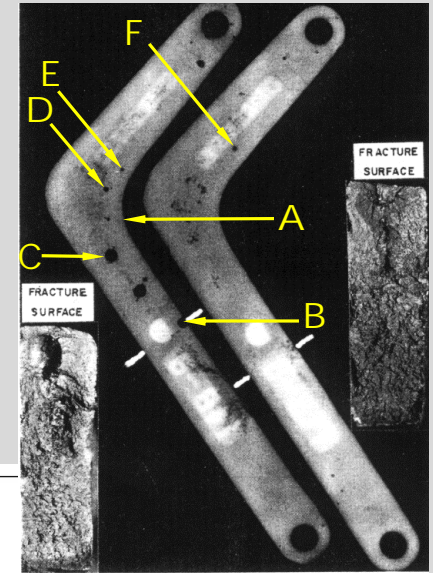






Suitability for Service

- Local quality will not limit service if
 - less than a critical size
 - in certain orientation
 - less than critical stress level
- DID Strategic Goal: Provide our current and potential customers with the tools and information needed to utilize the value of steel castings.





150 Extra Engineers

An IBM Electronic Calculator speeds through thousands of intricate computations so quickly that on many complex problems it's just like having 150 EXTRA Engineers.

No longer must valuable engineering personnel . . . now in critical shortage . . . spend priceless creative time at routine repetitive figuring.

Thousands of IBM Electronic Business Machines . . . vital to our nation's defense . . . are at work for science, industry, and the armed forces, in laboratories, factories, and offices, helping to meet urgent demands for greater production.

IBM
INTERNATIONAL BUSINESS MACHINES
1952

- Our current castings are:
 - The grandchildren of traditional castings that are well designed by experience
 - Are evolutionary modifications of old designs
 - Are based on successful historical performance



- Our current castings are:
 - Large complex shapes that cannot be made with other processes



- Our current castings are:
 - Are failed steel component designs that are re-designed as castings to solve a problem



Change the way we think!



Designers



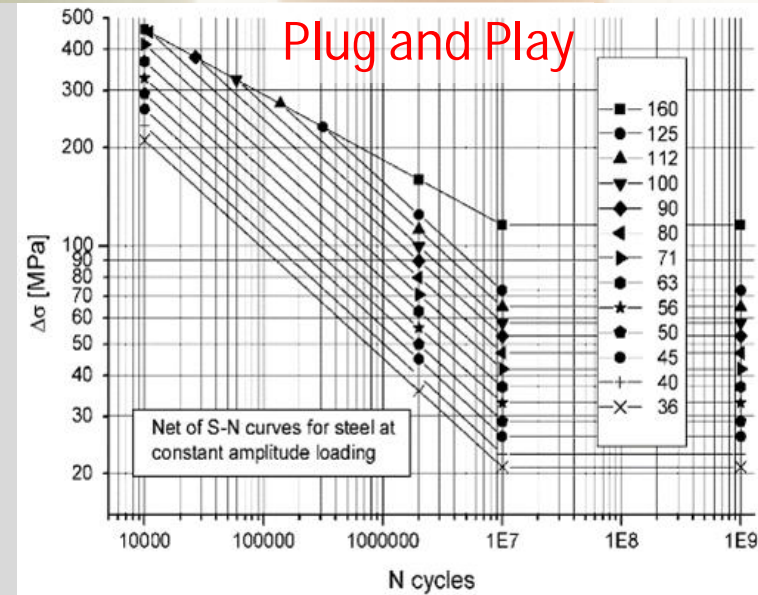
17-4PH



CB7Cu-1



No NDT callout required





Design, Manufacturability & Reliability

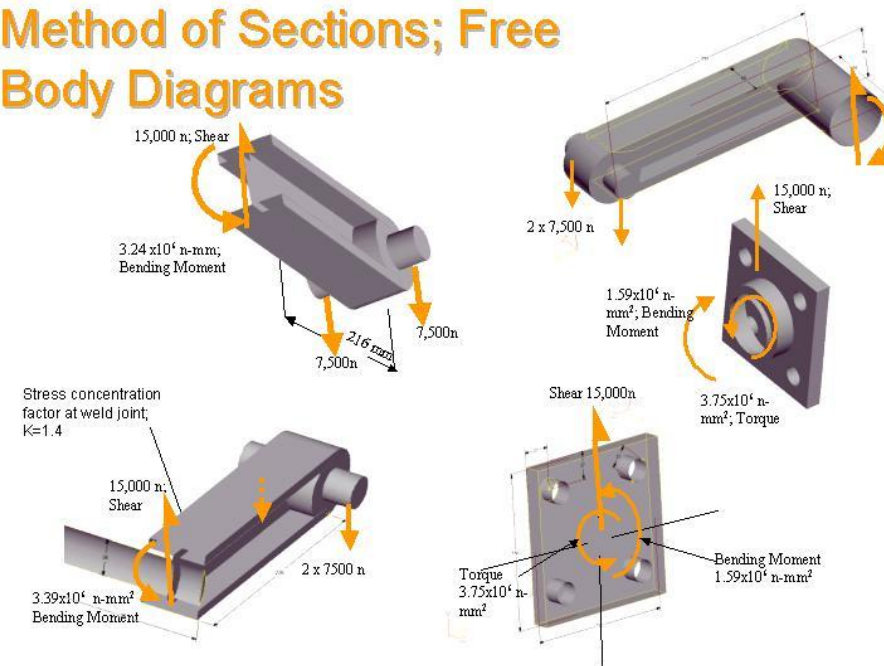
- What is DID?



**Digital
Innovative
Design**

for Reliable Casting Performance

Method of Sections; Free Body Diagrams





Team

Academia

- Iowa State University – Variability/Reliability, NDT development
- University of Iowa – Solidification and performance modeling
- University of Alabama at Birmingham – Material characterization and NDE development
- Lehigh University – Welding processes and parameters, microstructural modeling
- University of Arizona – Building construction component design and testing
- Penn State University – Building construction alloy
- Missouri University S&T – FeMnAl alloy

IOWA STATE
UNIVERSITY

 THE UNIVERSITY
OF ARIZONA

S&T MISSOURI
University of
Science & Technology


THE UNIVERSITY
OF IOWA


THE UNIVERSITY OF
ALABAMA AT BIRMINGHAM

 LEHIGH
University

PENNSTATE



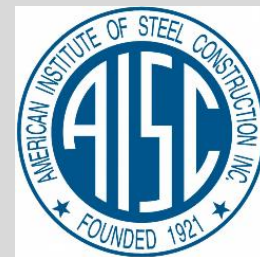

Team

Government

- Defense Logistics Agency (DLA)
- DOD

Industry/Consultants/Other Stakeholders

- SFSA Members
- Darrell Socie – BBM Plus
- OEM's/Partners – GD, Emerson, Magma, AISC, Deere and Cat





DID design: Tools need to be validated for the full range of design requirements

- DID recognizes 4 design needs
 - 4 Traditional (design using 50% of yield strength minimum across component)
 - 3 Handbook (design using guidelines which inform designer on appropriate alloy and NDT requirements)
 - 2 Engineered (design using localized properties predicted by process modeling and specify NDT correlated to material performance)
 - 1 Critical (provide designers a rich data set of material properties and quantitative NDT)
- These different design needs require different design tools and approaches



Baseline Material Property Data

- Collect material property data for common steel grades:

- Carbon steel
- SC86xx
- SC43xx
- CFxx
- AF9628

Collect heat data from member foundries
Ø Include different variations of each alloy grade (any carbon level)

Metallic Materials Property Development and Standardization (MMPDS)
MMPDS material testing requirements
Ø Test specific alloy chemistry



Proposed Grade	Alloy Description	Spec	Wrought Counterpart	Notes
WCB/LCB	Carbon steel	ASTM A216, A352 <i>*WCB also in MIL-S-24707-1 AMS 5334</i>	AISI 1020	AISI 1025 and AMS 5046E already in MMPDS-10
8625	Low alloy Ni-Cr-Mo	ASTM A915, A958 <i>*A487 Grade 4 (similar to 8625) is in MIL-S-24707-1</i>	AISI 8630	AISI 8630, AMS 6280M, and AMS 6281J already in MMPDS-10
CF8/CF3	Austenitic stainless steel	ASTM A351, A743, A744 <i>*CF8 also in MIL-S-24707-3 AMS 5370</i>	AISI 304	AMS 5910B, AMS 5911B, AMS 5912B, and AMS 5913B already in MMPDS-10
AF9628	High strength low alloy Ni-Cr-Mo	N/A	AF9628	-



Considerations

- Test material vs actual castings?
- Variables – section thickness? Heat treatment?
- Quality Factors
 - Porosity
 - Segregation
 - Welding
 - Inclusions
 - Cooling rate
 - Surface finish
 - Others
 - Grain size
 - Embrittlement

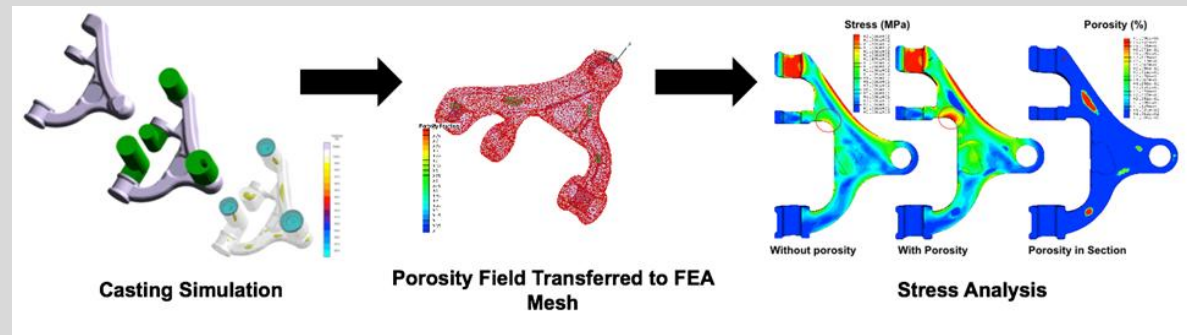




Modeling Tasks and Questions

- Tasks
 - Solidification Modeling for performance
 - Cooling rate, porosity, segregation
 - Heat treat modeling for properties
 - FEA modeling for performance
 - NDT indications or modeled locations

- Questions
 - Conservative simplifications?
 - Testing level required?
 - Standard?



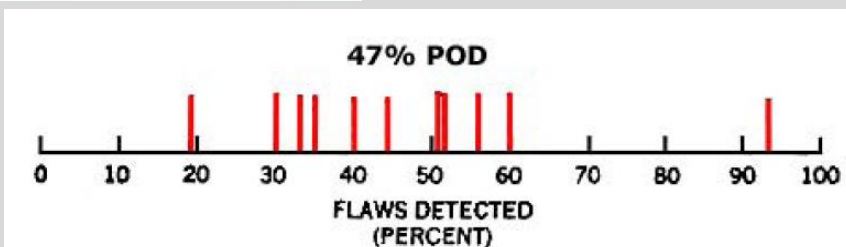
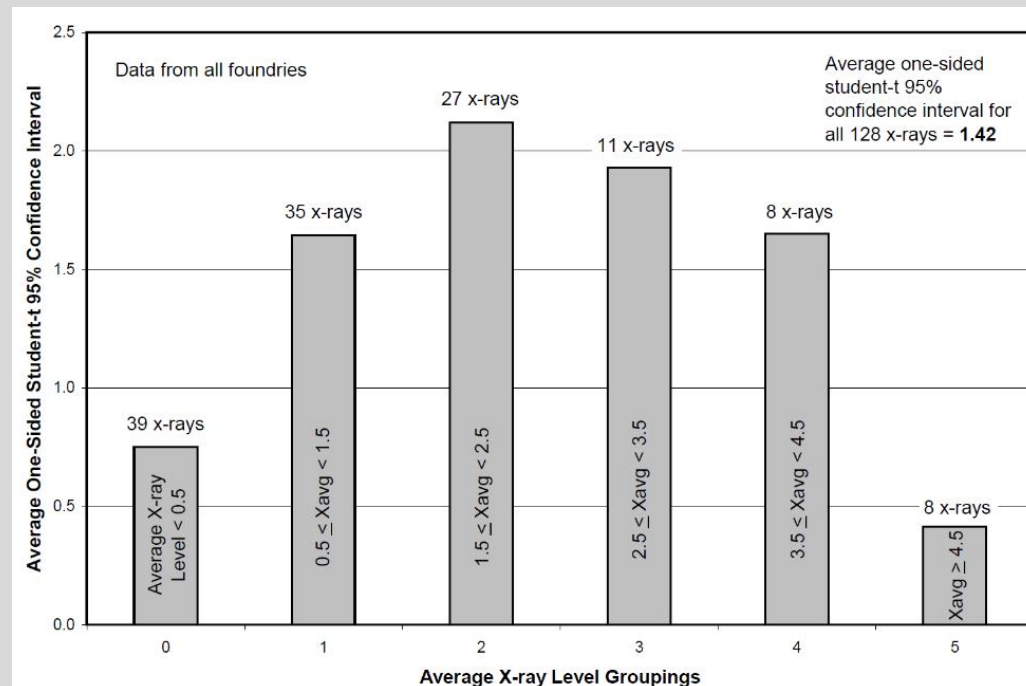
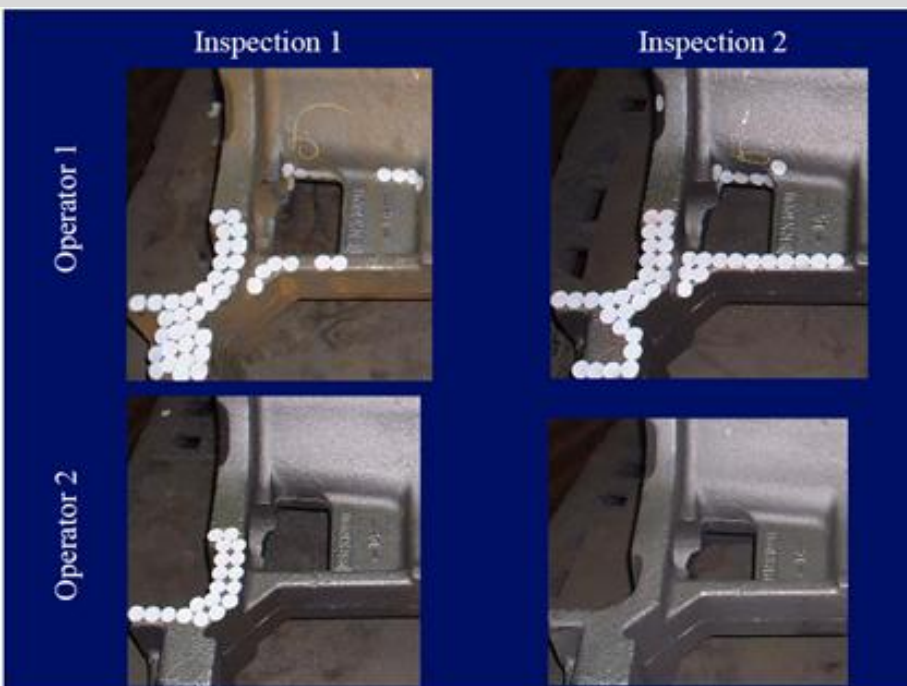


NDT Tasks and Questions

- Tasks
 - Develop NDT standard that are related to performance
 - Lengths/areas that can be used to support design minimums
 - Standard code type packages of first article and audits
 - Indications and performance
- Questions
 - LEFM (Linear Elastic Fracture Mechanics)?
 - Linear/non-linear, cracks, RT/UT, welds?
 - Solidification measures, microporosity?
 - Fatigue?
 - Factors



Overcoming NDT Gage R&R





Variability/Reliability





Steel Design Survey

SME, ASME, FD&E, MMPDS, NCSEA, AISC, AISI, AIST and FIA
<https://www.surveymonkey.com/r/steelcastdesign>

1. What major end market(s) are you involved in?
2. What type of components do you design?
3. What percentage of your designs are steel?
4. What are the major design factors considered in your designs? (Please rank order as appropriate.
5. What type of products are commonly used in your designs? (check all that apply)
6. Where do you get the material properties for the materials you design?
7. How do you evaluate or test your designs?
8. When multiple manufacturing options exists for a steel component, how do you decide (casting, forging, weldment, machining)?
9. Many designs are variations of legacy components. What are the typical challenges for a new casting design that you wish could be solved?
10. What engineering software do you use?
11. Contact information



How You Can Help

- Continue participating
- Trials (communication & speed)
- Key properties, codes and handbooks
- Quality factors
- Key partners

Acknowledgment

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Thank you!

Diana David
Steel Founders' Society of America (SFSA)
ddavid@sfsa.org
815-676-6536

Frank Peters
Iowa State University (ISU)
fpeters@iastate.edu
515-294-3855



Year 1 Activities

- Research priorities
- Initial program goals

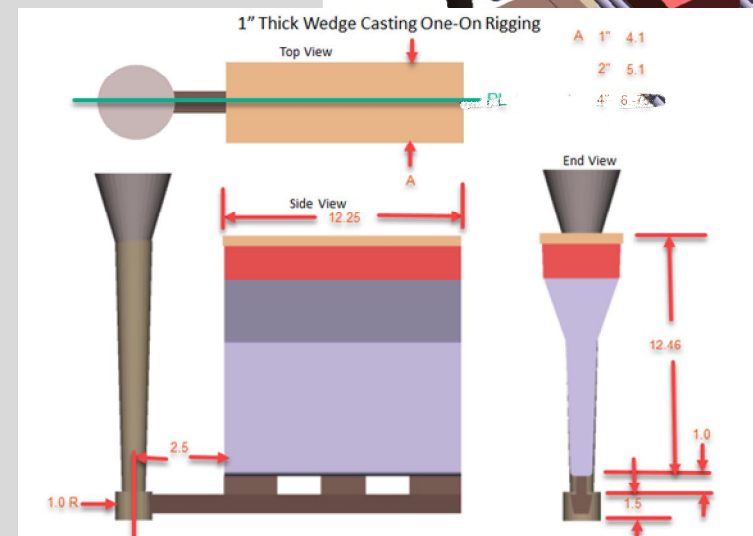
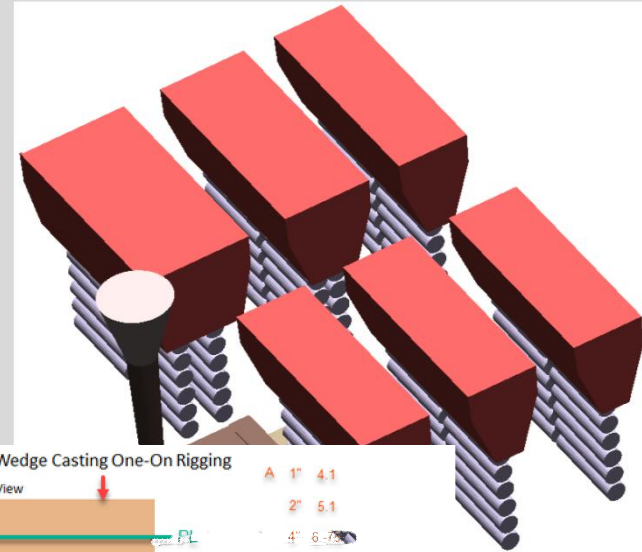
David Poweleit
Steel Founders' Society of America
(SFSA)
email: poweleit@sfsa.org



Year 1 Activities

Properties of Sound Material

- Alloys: WCB and ASTM A958 8630 Class 115/95
- Perform static testing (samples from wedges)
 - Section thickness: 1", 2", 4"
- Materials produced by several foundries
- Solidification modeling
- Tensile tests and microstructural analysis





Year 1 Activities

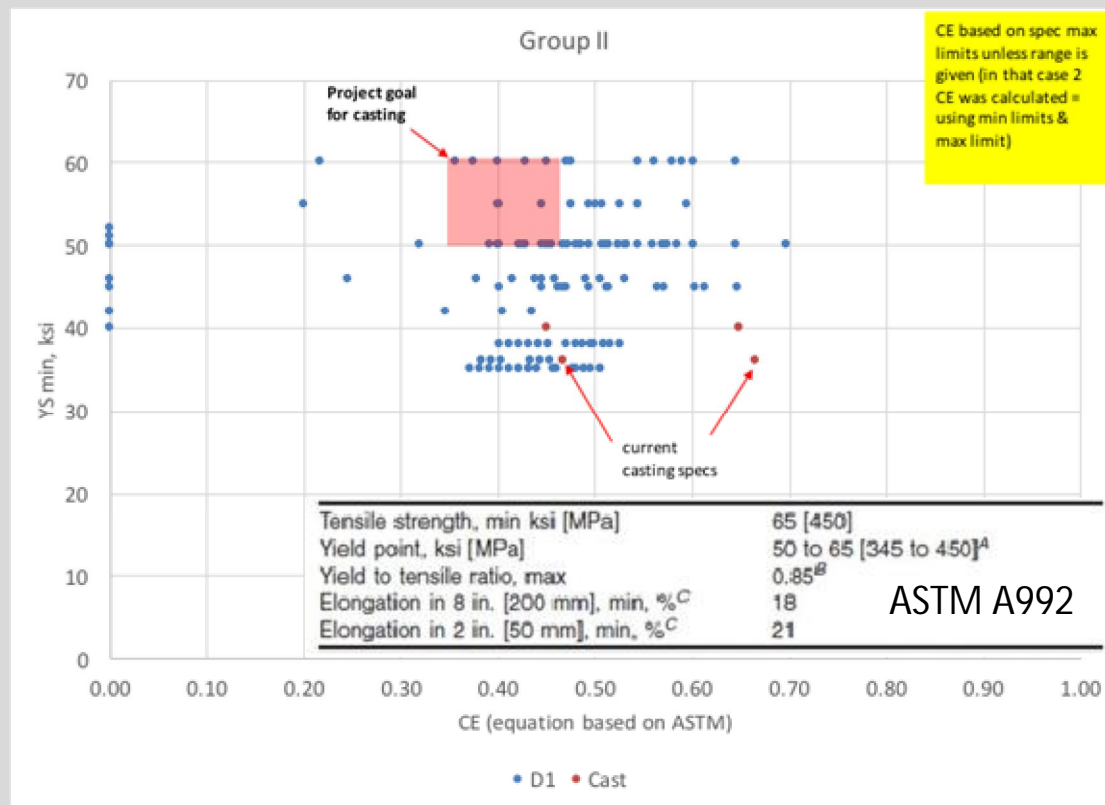
Building Construction & DOD

Prequalify Cast Steel Grades:

- Develop new cast carbon grade with 50 ksi min YS and max CE of 0.47% or 0.45% for thickness > 2"
- Plot shows YS-CE of common cast carbon steel grades vs wrought steel grades (prequalified in AWS D1.1)

**Data points based on spec limits and not actual data*

- Fatigue testing/properties
- Cast-fab and Production welding





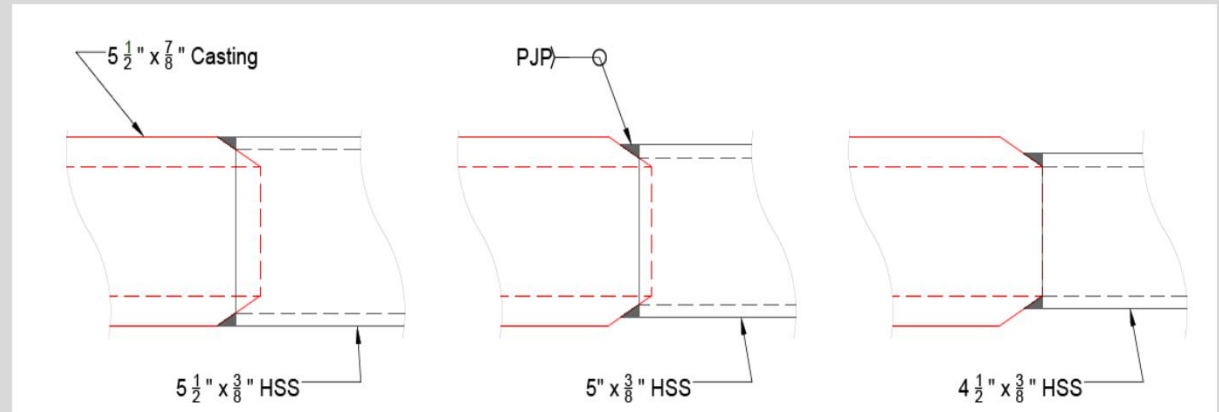
Year 1 Activities

Building Construction

Weld Interface Detail

Prequalify weld joint of cast to mill tubes:

- Minimum Cast Quality
- WPS as developed
- Different interface locations



Match: Outer Diameter (OD)

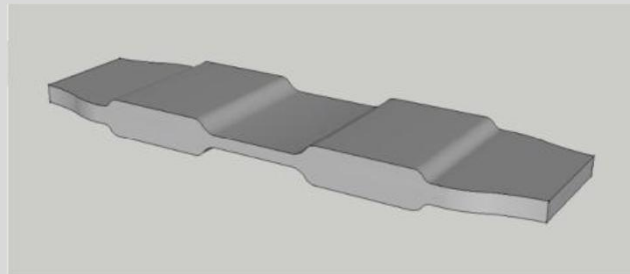
Centroid

Inner Diameter (ID)

Full Size Casting Test Demonstration

Casting Quality Effect on Performance:

- Surface finish
- Shrink Porosity
- Gas Porosity
- Inclusions
- Welding





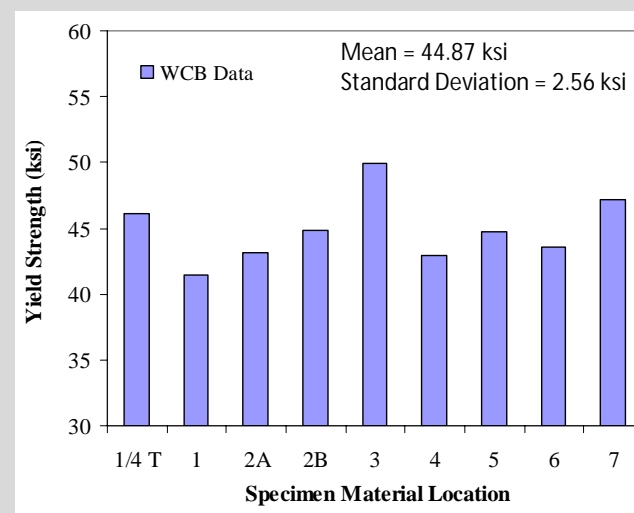
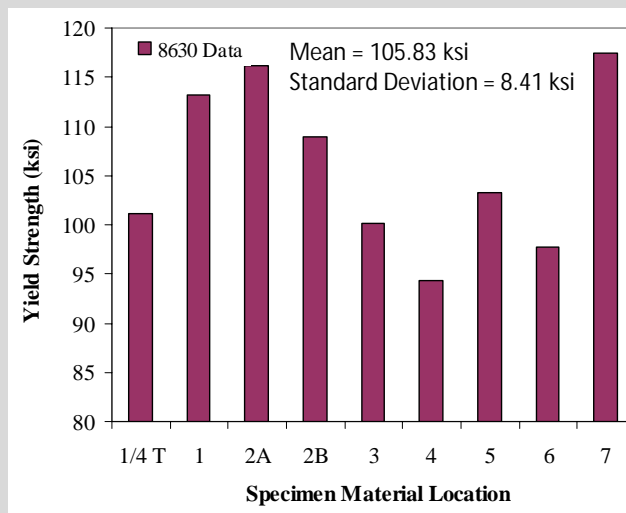
Year 1 Activities

Heavy Section Mechanical Properties

Characterize mechanical properties and microstructure of heavy section castings

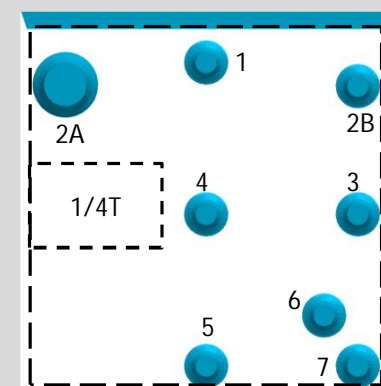
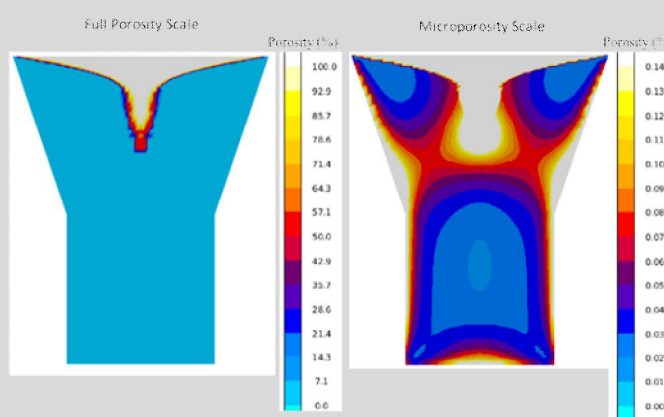
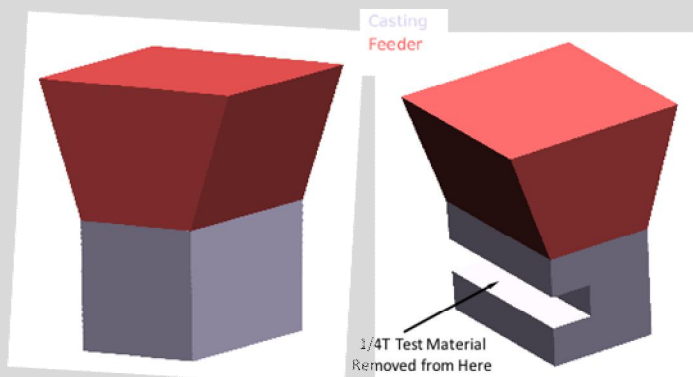
Preliminary analysis on:

- WCB and 8630
- 4" Y-blocks sectioned for tensile testing



Default Boundary Condition Assumes Hot Topping and Good Feeding

Numbering Scheme in Cross Section





Year 1 Activities

Investment Casting

Background: Recent inquiries concerning mechanical properties in investment casting

- 4330 CVN at RT:
 - Investment cast ~10 ft-lbs
 - Sand casting ~20 ft-lbs

Evaluate the difference between investment and sand casting

- Confirm difference in properties between casting processes
- Consider as a quality factor?
- Identify root cause and means to improve properties

Sand Cast



Investment Cast





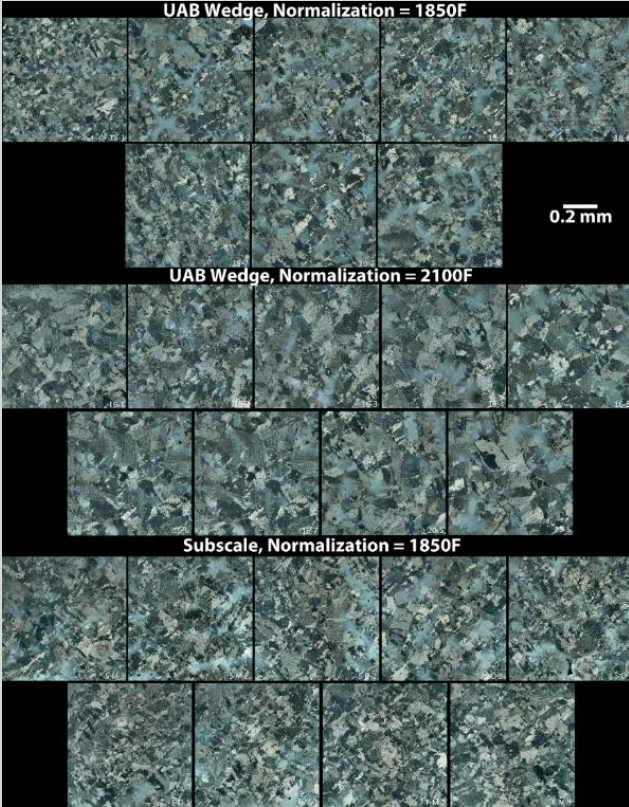
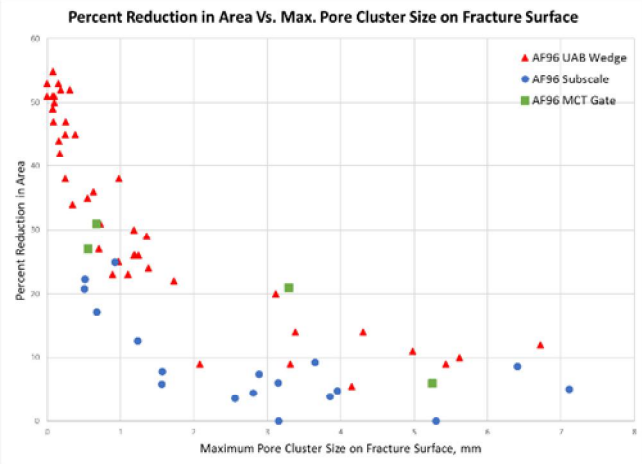
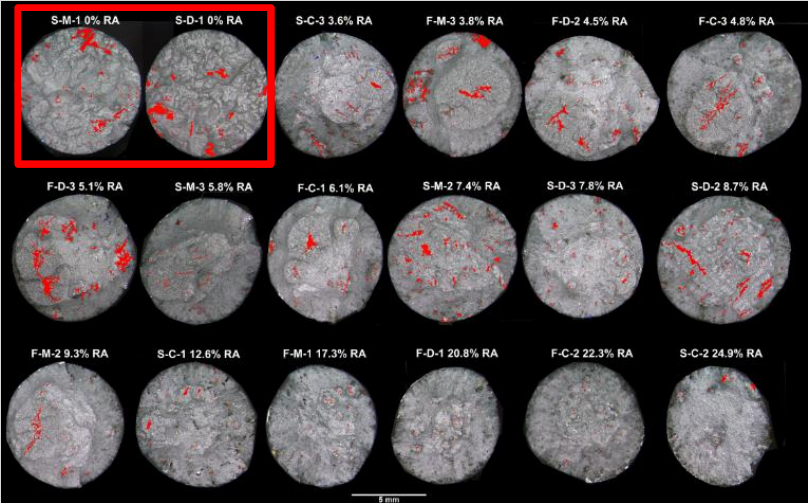
Year 1 Activities

AF96 Material Characterization

Evaluate how to further improve the ductility of cast AF96

Mechanical properties and microstructural characterization of several AF96 castings:

- VIM
- Subscale
- TARDEC Wedges
- M&T Runners
- Gen 4 Plate





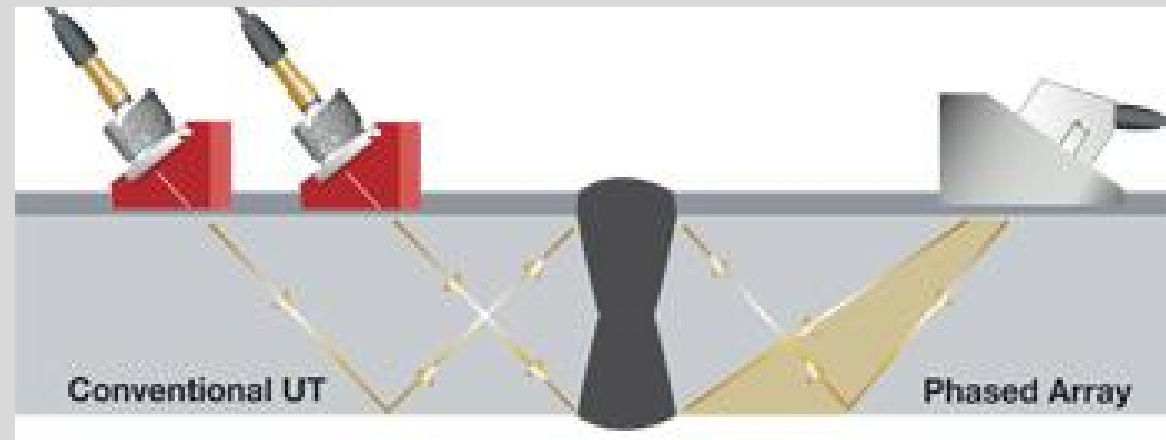
Year 1 Activities

Non Destructive Testing

Evaluate effect of NDT indications on properties (static tensile, fatigue)

Test Plan

- Alloys: WCB, 8630, AF96, HY80, HY100
- Specimen: weld plates and UA building construction specimen
- Procedures
 - Characterize surface – visual, scanning
 - MT & PT
 - CT and/or PAUT and/or RT



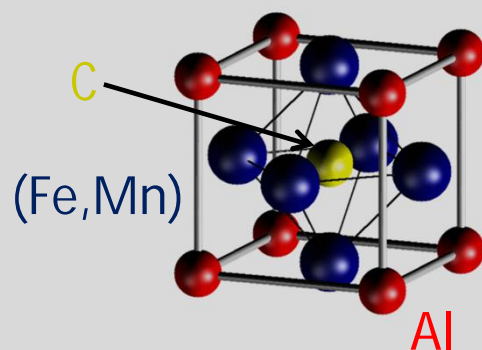


Year 1 Activities

FeMnAl

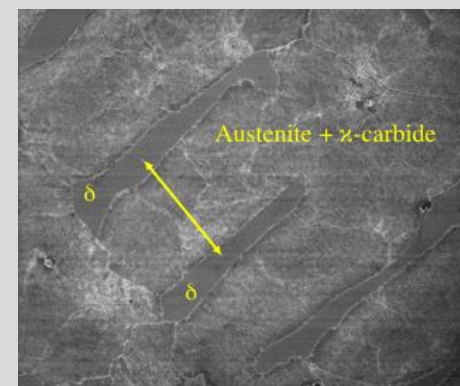
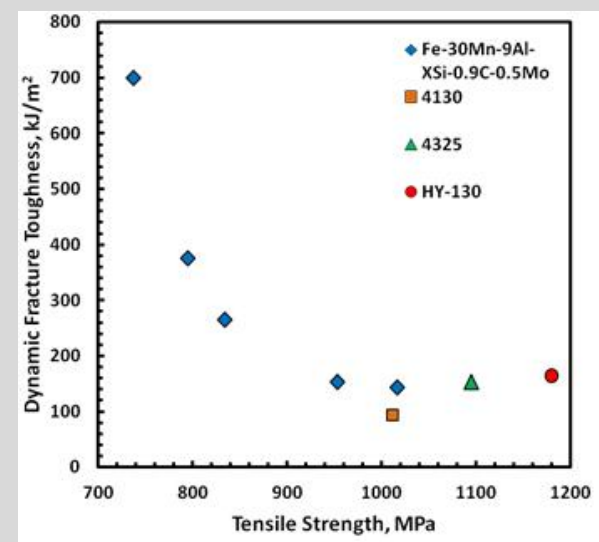
Develop the design and manufacturability of FeMnAl

- strength and toughness
- properties a function of age hardening



Experimental Trials:

- Melting and heat treatment studies using Y-block castings
- Thermomechanical processing: casting vs hot rolling
- Microstructural analysis
 - Segregation
 - Secondary phases
 - Grain size
 - Inclusions



As-cast microconstituents



Out Year Activities

- Leaking
- Tolerances
- Design tools (ANA, No Redesign)
- Cost
- Steel Casting Design Guide (for Building Construction)