Intelligent Adaptive Machining Fixtures (IAMFix R ) for Castings

(Presented at SFSA Spring Leadership Meeting in St. Louis)

3.15 PM May 4, 2016

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5. IAMFix Framework and Methodology
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PDA – Who We are?
(CAGE 4C5H6)

• In the Chicago area for over 22 years – Pioneered CAE applications in metal casting since early 90s.
• Has been a provider of technological and engineering solutions in the Military, Transportation, Medical Devices and General Engineering for metal, plastic, composite and rubber components.
• Member of DMDI-Digital Manufacturing & Design Innovation, a Mfg. Hub created by UI Labs-Chicago/DOD.
• Member of Youngstown-OH’s Printed Sand Core Project, America Makes, providing support for Casting Process Design and Modeling Validation
• Member of American Lightweight Materials Manufacturing Innovation Institute (ALMMII) – LIFT – Lightweight Innovations for Tomorrow
• SME Support for Rubber, Plastic, Casting and Composites
• AFS’s Exclusive Casting Design and Sourcing Solution Provider to Casting Users and Manufacturers in North America.
• Partnership with various Metal Casters, 3D Printing, RP and Tooling Providers and A2LA accredited Materials Test Laboratory.

• Memberships:
  • American Foundry Society – AFS
  • National Defense Industrial Association – NDIA
  • Association of the United States Army - AUSA
  • American Composite Manufacturers Association – ACMA
  • Society of Plastic Engineers - SPE
Background

• Manufacturing Innovation Institutes
  – DMDII – Digital Manufacturing and Design Innovation Institute – UI Labs – Chicago
  – AM- America Makes focusing on Additive Manufacturing, Youngstown, OH
  – LIFT – Lightweight Innovations for Tomorrow, Detroit, MI

• The work being presented is a Research project funded by DMDII – Digital Manufacturing and Design Innovation Institute, one of many Manufacturing Hubs being set up by US Government to develop Digital Threads between Design and Manufacturing to make US Manufacturing globally competitive.

• SFSA, along with AFS have been playing an important role to assist PDA with out reach to casting manufacturers and users with the outcome of this research project.

SFSA and PDA have been members and working in collaboration with DMDII on metal casting related initiatives!
# Team Structure & Contributions

**SFSA**
Professional Societies - workforce development & education

**PDA vendors:**
- **Casting Machining**

**Lead – Domain Expertise,**
demonstration article and commercialization

**ASU**
Co-PI
Software enabler tool and process development

**AFS**
Advisory
Review of technology; Workforce Development and Education

**SFSA**
Advisory
Review of technology; Workforce Development and Education

<table>
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<th>Organization</th>
<th>Role</th>
<th>Partner Contributions &amp; Responsible Tasks</th>
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<tbody>
<tr>
<td>PDA</td>
<td>Project Lead</td>
<td>Technology Demonstration, Guidance for the IAMFix framework development, Demonstration Article Machining and Validation</td>
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<tr>
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<td>Co-PI</td>
<td>Software enabler tool and process development</td>
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Project Goals

• Develop IAMFix R framework consisting of a patented software enabler with intelligent adaptive machining fixture for castings with piece to piece dimensional variability to eliminate or reduce the set up time for the 1st few operations which use as-cast surface and eliminate the scrap and rework due to mis-machining.

• Optimize machining stock with known variability.

• Demonstrate IAMFix functionality using a real demonstration article from PDA’s project archives of contract manufacturing.

Project Duration: 12 months, ends in July 2016
Potential Origins of Dimensional variability from piece-to-piece

- **Design Inherent**
  - Residual stress and distortion during solidification and subsequent processing, such as heat treatment.
- **Tooling Inherent**
  - Quality of tool and tooling mfg process and material, shrinkage rule in x,y and z directions
  - Wear and tear
  - Build up of chemicals
  - Core print clearances
- **Process Inherent**
  - Pour temperature and times
  - Mold and core making process and high temperature thermo-physical and mechanical properties
  - Quality of flask and parting line related issues
  - Buoyancy for large foot print castings
- **Rigging Related**
  - Parting plane and orientation
  - Gating & Risering
  - Chills and other feeding aids
- **Secondary Processing**
  - Shake out time and tumbling process
  - Riser and gate removal
  - Surface cleaning – blasting, grinding etc
  - Heat treatment cycle
  - Scaling for some alloys, etc etc…….
Current Predictive Techniques

Casting process Simulation for filling, solidification and residual stress / distortion at shake out

Effect of various molding and core types, pour temperature and times on dimensional variability
IAMFix Project Baseline

- Metal casting is over $30B market segment and the potential savings with proposed technology is in the machining cost attributed to set up time for large complex castings.
- Sand castings have dimensional variability from piece to piece, inherent to the manufacturing process and also driven by the geometry of the part.
- Machining raw sand castings and complex fabrications with variability requires pre-machining to qualify; leads to longer cycle times due to manual set up required for every piece in the machining fixture.
- Misalignment in machining results in scrap and/or rework.
- Optimize machining stocks
- DoD typically has smaller volumes, higher complexity and more machined features; it does not have adequate data for SPC;
- There is a need to find frameworks/technologies to eliminate pre-machining, reduce the machining cycle time and eliminate scrap/rework due to mis-machining by using digital qualification for each piece.
- This problem is not only specific to metal castings, but also to complex fabrications and cast-fab sub-assemblies.
## Program Metrics

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<th>Metric</th>
<th>Baseline</th>
<th>Project Goal</th>
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<tbody>
<tr>
<td>Set up time for the initial machining operations</td>
<td>Bench layout, pre-qualifying fixture use</td>
<td>80% reduction in set up time with IAMFix</td>
</tr>
<tr>
<td>Scrap due to mis-machining, estimated to be 1-2% in low volume</td>
<td>Castings don’t clean up and wall thickness violations</td>
<td>Estimated scrap 0% with the use of IAMFix</td>
</tr>
<tr>
<td>Re-work due to mis-machining, estimated to be 1-2% in low volume</td>
<td>Typically 1\textsuperscript{st} operation leads to mis-machining</td>
<td>Estimated scrap 0% with the use of IAMFix</td>
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Summary: What PDA is looking for?

- Examples of complex castings requiring pre-machining and/or high set up time.
- Collaboration for low volume high complexity casting machining optimization using IAMFix framework as a consulting service, than deploy, after customer sees the value!
- Feedback on Casting Dimensional Tolerance standard being used widely – ISO8062, AA?
- Teaming for future phases of the project

Acknowledgement: PDA acknowledge the funding support from DMDII and US DOD under DMDII project 14-07-03; collaborative support from our sub-contractor ASU – Design Automation Lab, and in-kind support of SFSA and AFS.
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