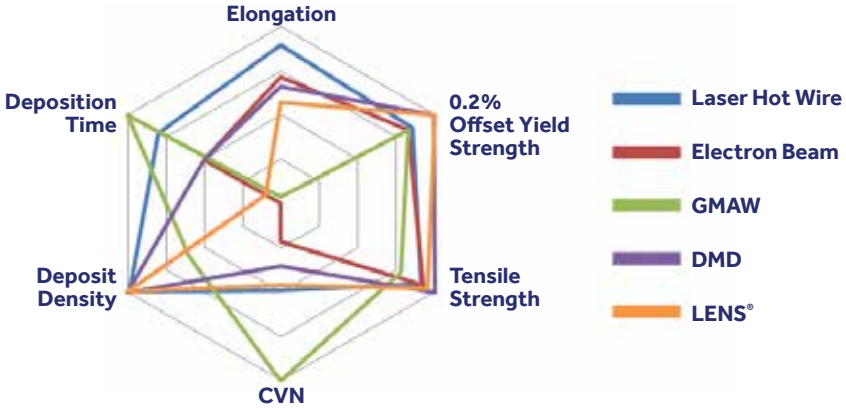
SUCCESS STORY

Additively Manufactured Maraging Structures Have Sufficient Hardness, Toughness, and Strength for Use in Die Cast Tooling Repair and Repurposing

Extending the Life of Steel Tooling with Additive Manufacturing



The spider chart shows the relative strengths of each additive manufacturing deposition process based on the results in this study for five categories: deposit density, elongation, yield strength, tensile strength, and Charpy v-notched toughness.

PROBLEM

High pressure die casting is a secondary manufacturing process in which molten metal is formed into a desired shape by allowing it to flow into a mold under externally applied pressure. The most common materials for manufacturing die casting tooling are AISI grade H13, H11, and modified versions of these steels. Maraging steels provide alternatives to medium- and high-carbon tool steels because they reduce the occurrence of quench cracking, while the high nickel content provides corrosion resistance. Maraging steels have a higher cost; however when applied as a low volume cladded layer, the higher cost is justified by improved performance.

OBJECTIVE

The objective of this project was to develop, evaluate, and qualify novel methods of rejuvenating and repurposing die cast tooling using additive manufacturing (AM). The goal was to determine the best method or combination of methods for reconstructive repair, selected on a case-by-case basis, yielding detailed documentation regarding the selection criteria and rationale.

TECHNICAL APPROACH

The project team was led by Case Western Reserve University and included Dante Solutions, Benet Laboratories, Delaware Dynamics, General Die Casters, Keystone Synergistic Enterprises, Lincoln Electric Company, Magma Foundry Technology, Nebraska Aluminum Casting, North American Die Casting Association, Sciaky, and Twin City Die Casting.

The testing for this study was conducted using H13 base metal blocks with varied deposition patterns. Tension testing, Charpy v-notched toughness testing, hardness testing, X-ray radiography, and metallography were performed on each sample. The following additive manufacturing processes were evaluated:

- Gas Metal Arc Welding (GMAW)
- Laser Hot Wire (LHW)
- Direct Metal Deposition (DMD)
- Laser Engineered Net Shaping (LENS®)
- Electron Beam Freeform Fabrication (EBF3)

Data collected was used to develop computer models for comparison.

AMERICA MAKES TECHNOLOGY DEVELOPMENT ROADMAP

This project aligns to:

VALUE CHAIN

ASTM PROCESS CATEGORY:
Directed Energy Deposition

EQUIPMENT:
Laser Hot Wire, Electron Beam Freeform Fabrication, Gas Metal Arc Welding, Laser Engineered Net Shaping, Direct Metal Deposition

MATERIAL:
Maraging Steel
H13 Steel

ACCOMPLISHMENTS

Based on the depositions conducted in this study, there are many acceptable deposition processes for additive tool repair and repurposing. From the mechanical testing, it appeared that additively manufactured maraging structures have sufficient hardness, toughness, and strength for use in die cast tooling repair and repurposing. The hardness of the deposit generally matched the hardness of tempered H13, which is the workhorse of the industry currently, while having higher strength, provided by the martensitic microstructure of maraging steels.

The CMM conducted on blocks post-deposition showed little distortion in the base material, even on an annealed H13 base plate. This is promising, since distortion in these experiments could have indicated the presence of residual stresses in the deposit which could increase the likelihood of cracking, especially during the thermal cycling of die casting.

For evaluating the deposit for structural integrity, the biggest factor was macroscopic voids and/or inclusions. The X–ray images showed that many of the deposition processes had some amount of porosity present. Since the surface of the deposit would be machined away to the final geometry, it is recommended to use this process as an opportunity to inspect each surface for porosity during and after machining.

LENS® (Laser Engineered Net Shaping) is a registered trademark of Sandia National Labs.

PROJECT END DATE

January 2015

DELIVERABLES

- Qualified best practices for welding and cladding repair of dies, including feed materials and recommended processing variables
- Mechanical properties of the AM materials, tested according to ASTM, ASW, and MIL specifications.
- Evaluation of rejuvenated tooling in reduction and performance benchmarking
- Specification for welding and cladding repair of dies prepared and submitted for consideration to standardization bodies i.e. ASTM and ASW
- Computer models that predict residual stress and distortion of H13 steel after deposition of steel by additive manufacturing

All downloadable deliverables are available to members of America Makes via the Digital Storefront.

FUNDING

$1.052M total project budget
($526K public funding/$526K private funding)

PROJECT PARTICIPANTS

Project Principal:
Case Western Reserve University

Other Project Participants:
Dante Solutions
Benet Laboratories
Delaware Dynamics
General Die Casters
Keystone Synergistic Enterprises Inc.
Lincoln Electric Company
Magma Foundry Technology
Nebraska Aluminum Casting
North American Die Casting Association
Sciaky
Twin City Die Casting

Public Participants:
U.S. Department of Defense
National Science Foundation
U.S. Department of Energy

4007 Qualification of Processes for Repurposing and Rejuvenation of Die Casting Tooling