NSRP RA Project: 2018-454-013 Scaling Up 3D Printed Steel Castings

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All Panel Meeting

Castings in Shipbuilding

- Castings in Shipbuilding
  - High cost
  - Long lead times
  - Casting manufacturing issues
- Friction Stir Additive Deposition (FSAD) Process utilized by MELD Manufacturing Corp
  - AM solution on scales relevant to shipbuilding

MELD Manufacturing Method

- MELD is a solid-state process, meaning the material does not reach the melting temperature during printing

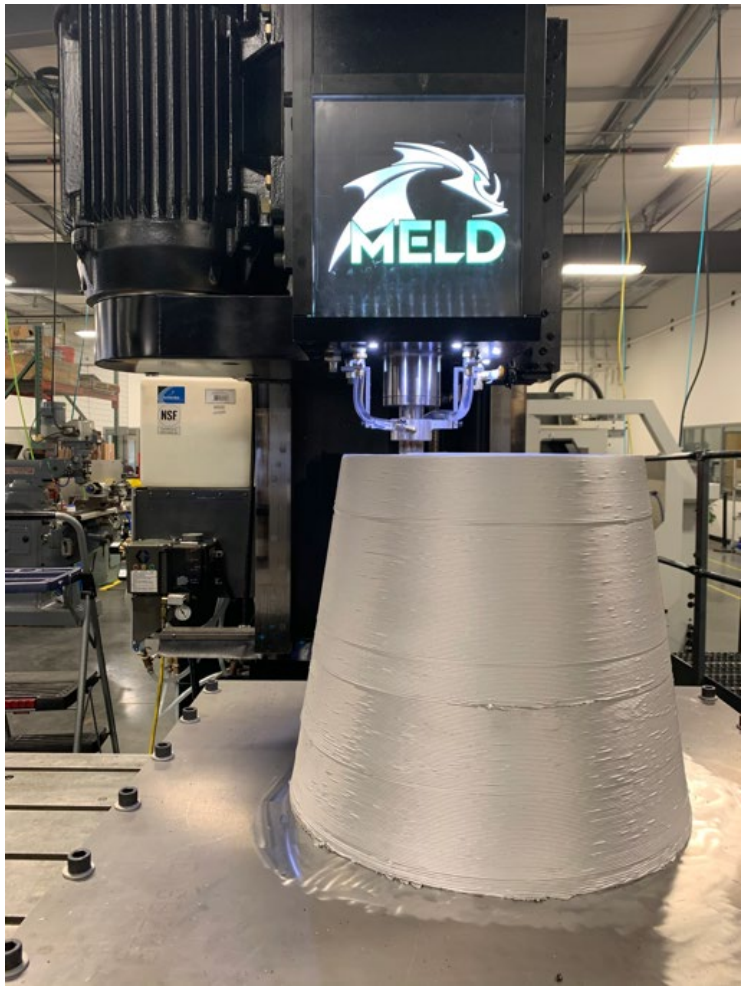
- MELD is able to produce high-quality wrought materials
  - Low residual stress
  - Full density
  - Not susceptible to porosity, hot cracking, or other common problems of melt-based technologies

MELD L3 Model Machine

MELD Manufacturing Method

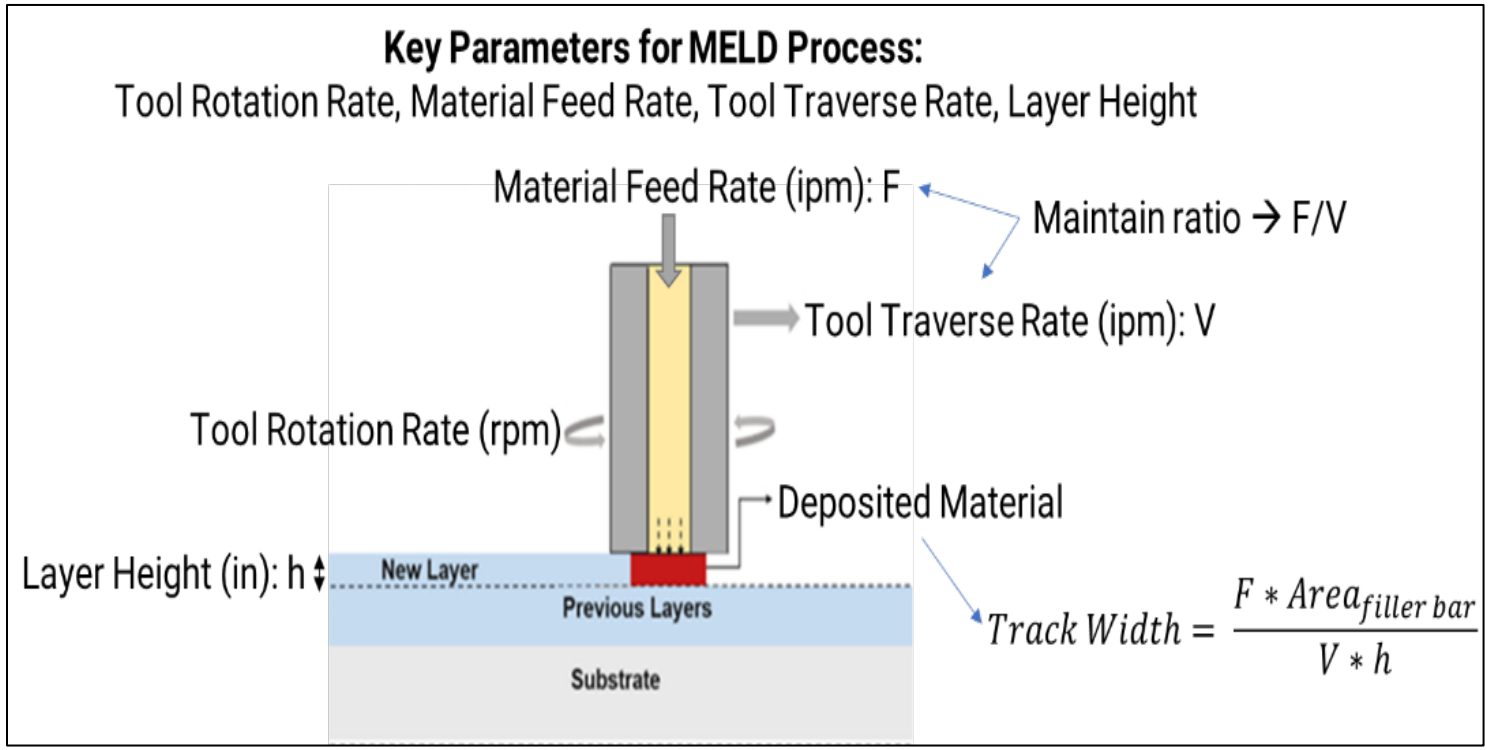
Relevance to Shipbuilding:

- Open air operation allows for scaling up
- Solid metal input reduces danger of powder metal
- No melting means all alloys can be used
- Fully dense parts have wrought and forged properties
- Used for 3D printing and repair



Open Air Printing

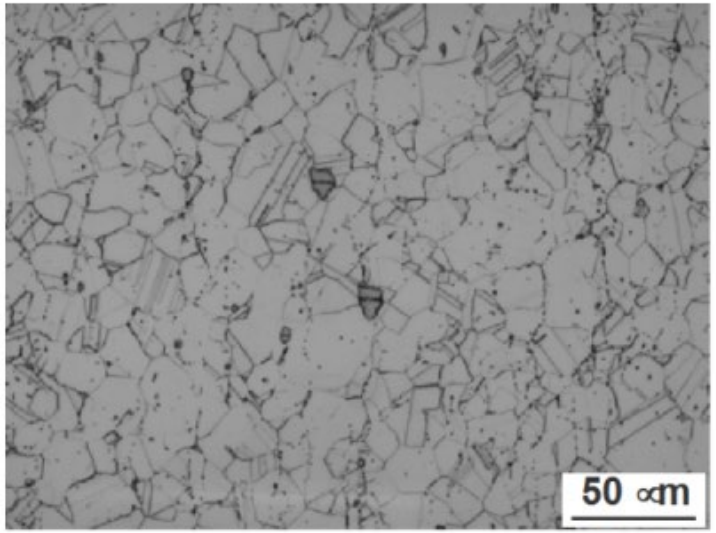
FSAD/MELD Process



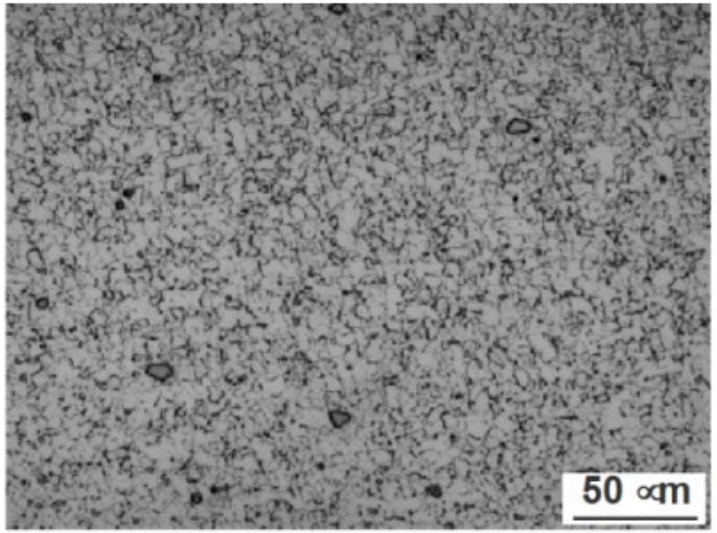
- The MELD process is performed by passing the filler material through the hollow rotating tool (stirring tool).
- Frictional heating creates robust metallurgical bond.
- Subsequent layers are created by raising the tool by the desired layer height.

Enhanced Physical Properties

- MELD Process refines grain sizes through the stirring process.
- Creates increased strength properties, wear resistance, and corrosion resistance.

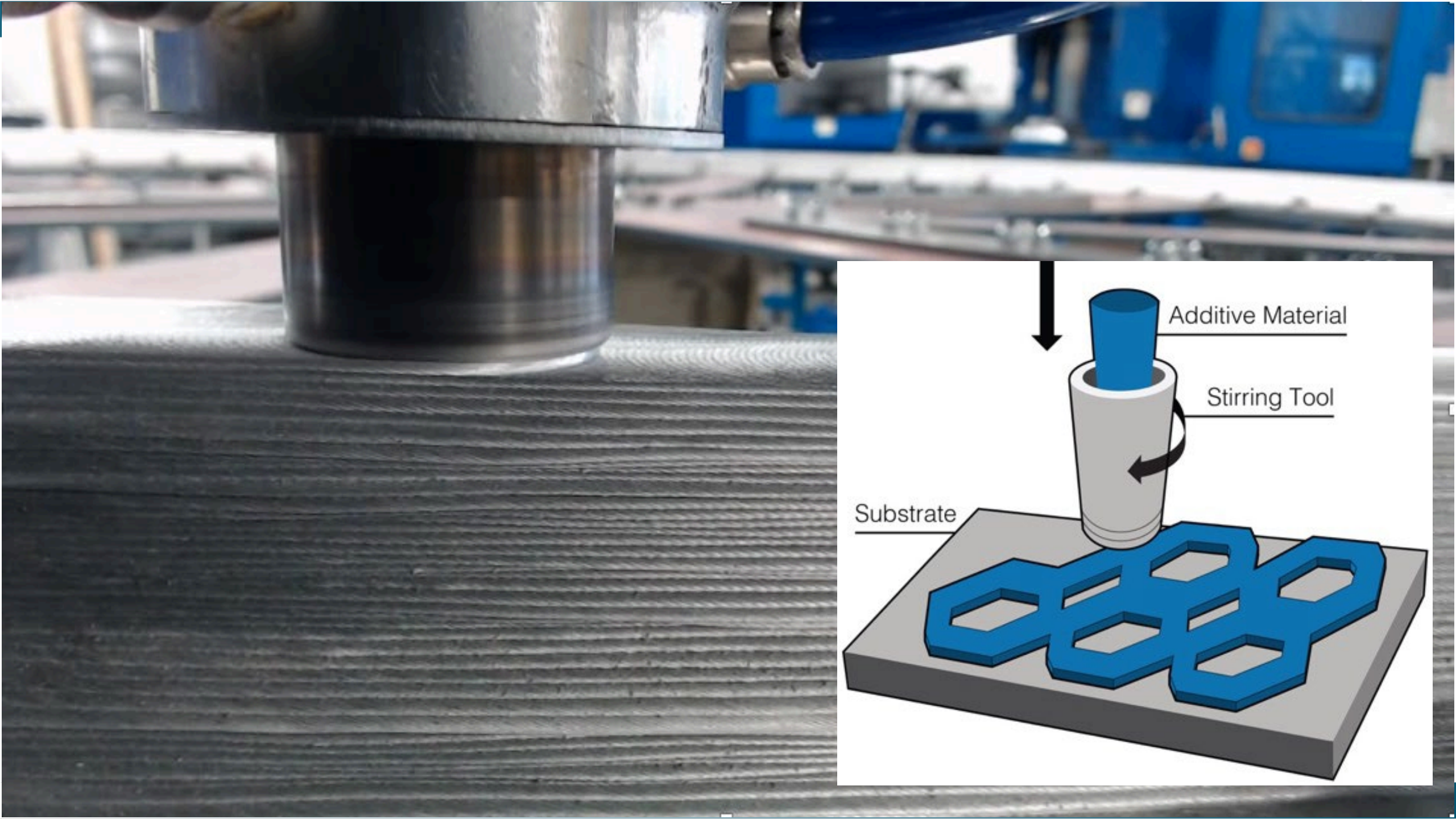


Inconel 625 - Filler material
Average grain size: ~ 12 ∝m



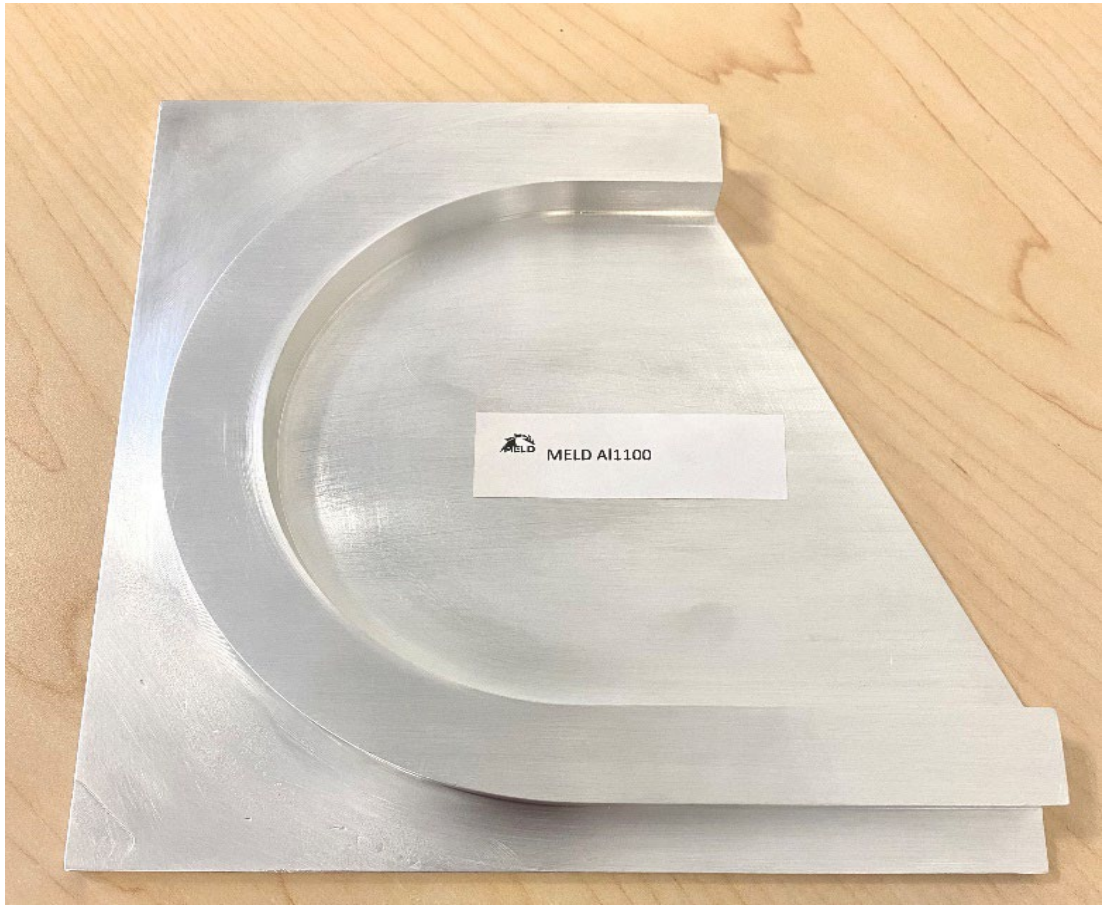
Inconel 625 - MELDed material
Average grain size: ~ 5 ∝m

Inconel Grain Size Example (MELD Manufacturing)


Additive Material
Stirring Tool
Substrate

Previous RA #2018-454: Scaling Up 3D Printed Castings

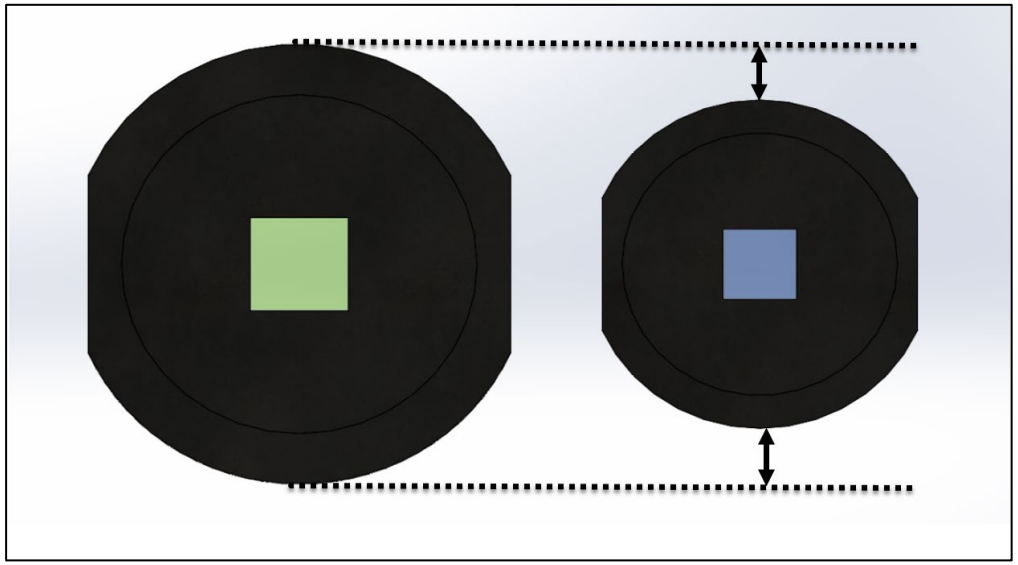
- Successfully demonstrated that scaled up MELD process:
  - Utilized larger-size aluminum feedstock materials
  - Increased deposition rate per pass
  - Maintained equivalent material quality
- Advanced Meld technology relevance to the shipbuilding industry magnitude.
- Current efforts aim to demonstrate the same scalability in steel alloys.



Previous RA #2018-454: Scaling Up 3D Printed Castings

Increased Deposition Rate

- Larger Tool/Nozzle
  - 33% increase in tool diameter
- Larger feedstock opening
  - Increased from (3/8)" square bar to (1/2)" square bar
- Deposition increase of 355%
  - Maintained equivalent material properties



Stirring Tool Nozzle

Project Objectives

Four Key Objectives

1. Determine metallic alloy for nozzles to print with higher yield steel material
2. Establish parameters necessary to achieve high yield steel deposition
3. Validate that material properties of printed test coupons meet NAVSEA standards
4. Document details of MELD process to improve products to improve future FE simulation

Description of Project Roles

GD NASSCO

- Project Lead

MELD Manufacturing

- Develop technology required to print high-strength steel

NAVSEA

- Physical and Metallurgical testing of MELD coupons

HII

- Project collaboration and assistance

Altair

- Develop report summarizing MELD design constraints and process analysis

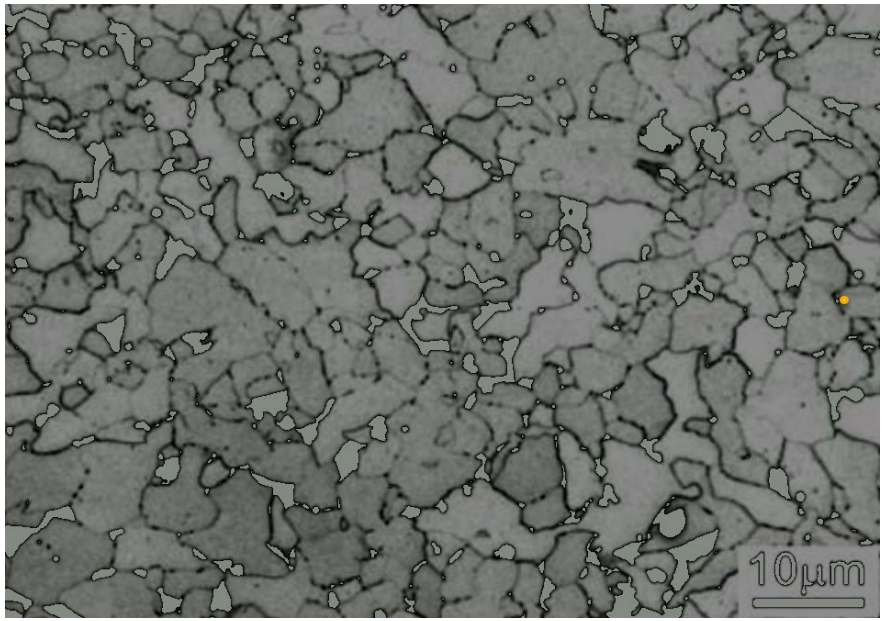
ABS

- Regulatory body review of project results

Testing Plan

Materials Testing at Carderock

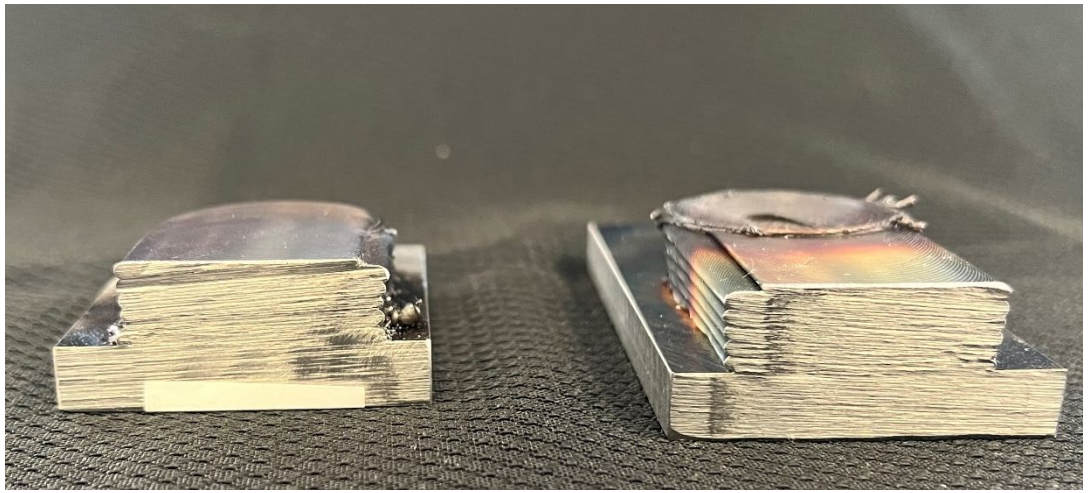
1. Tensile Testing
   - 9 Total samples (X, Y, Z)
2. Metallography (hardness testing on samples prior)
   - 6 Total samples (X, Y)
3. Charpy Impact Testing
   - 6 Total Samples (X, Y)
4. Chemistry
   - 3 Total Samples



Initial AH36 Prints

- Initial high-yield material deposition has been successful

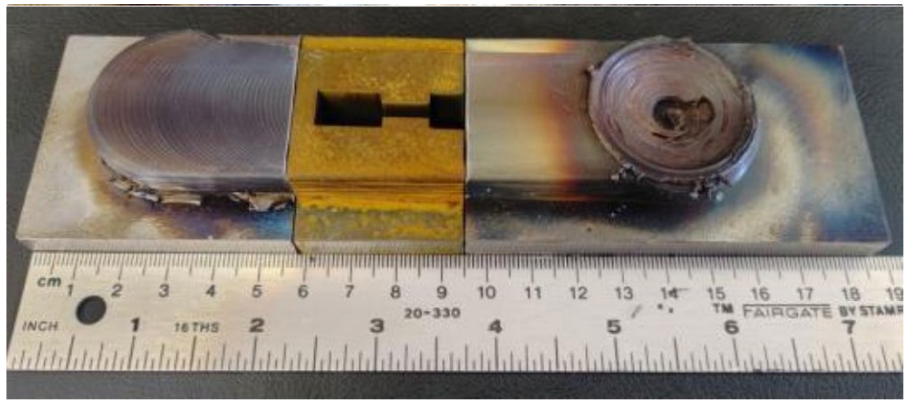
- Developing parameters for ideal AH36 deposition is necessary prior to test block creation and Tool Wear Study



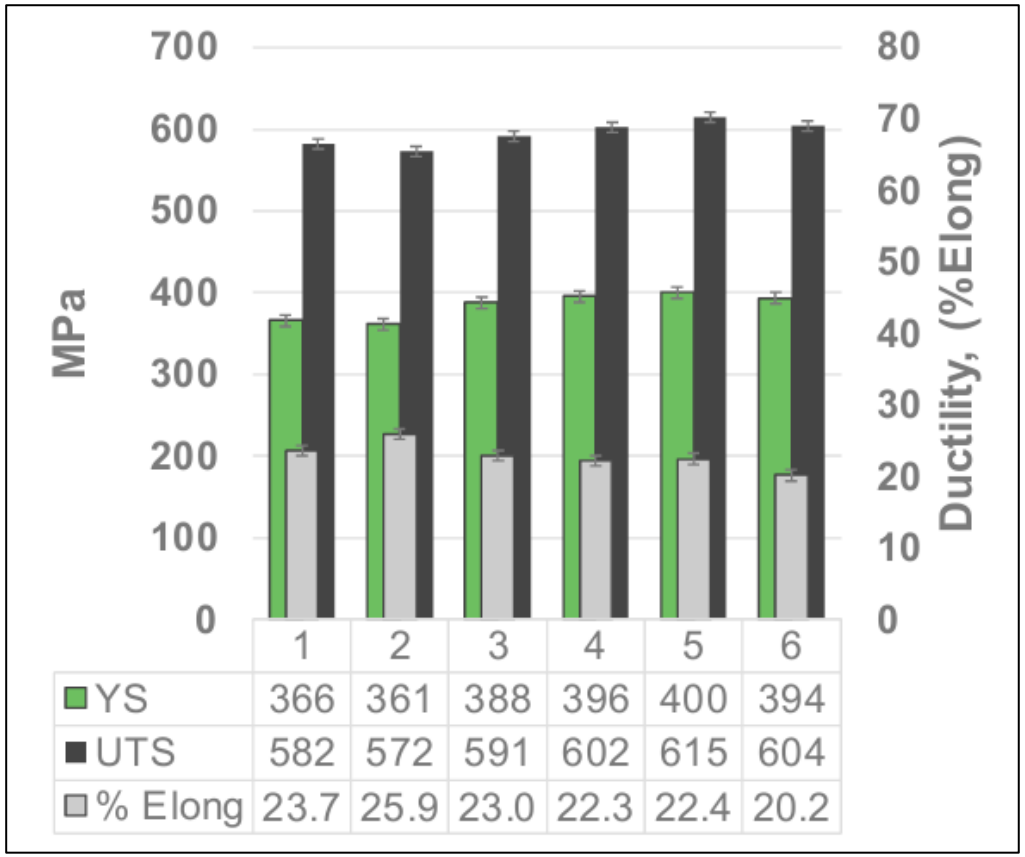
Print Samples from Initial Trials

AH36 Print Testing

- MELD is evaluating initial mechanical property and microstructure of samples
- Results show similar feedstock mechanical properties from small specimen tensile tests



Preliminary Print



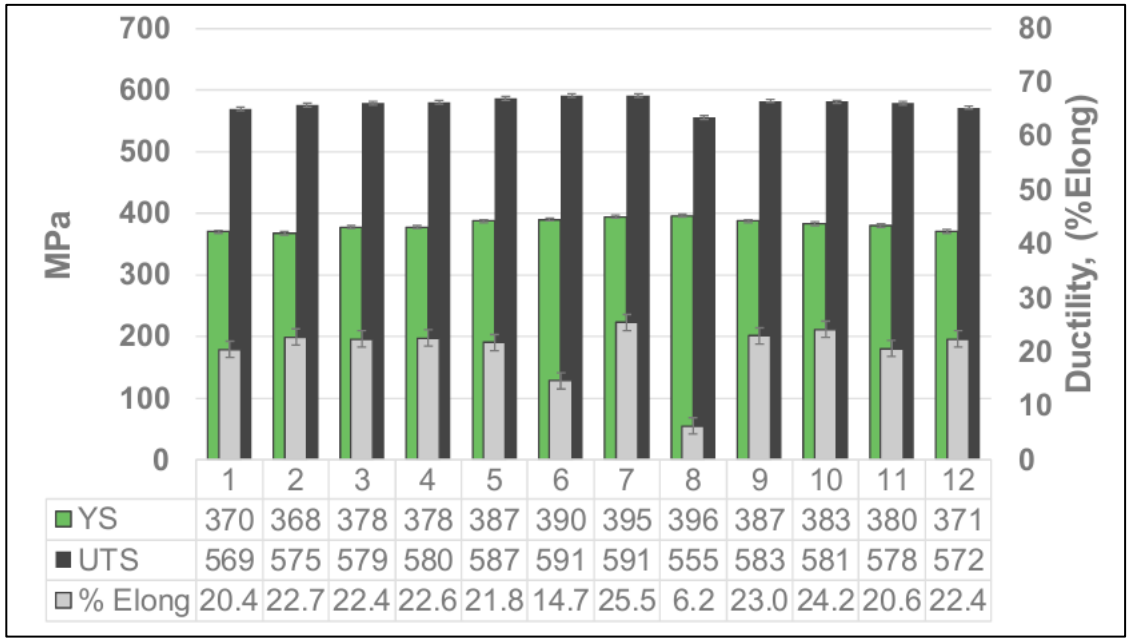
	1	2	3	4	5	6
YS	366	361	388	396	400	394
UTS	582	572	591	602	615	604
% Elong	23.7	25.9	23.0	22.3	22.4	20.2

Preliminary Sample Tensile Testing (Longitudinal Direction)

AH36 Print Testing

- Current testing has been longitudinal (direction of tool path) and through thickness (vertical) samples
- MELD is continuing parameter refinement and aims to develop multi-track builds for evaluation

Preliminary Print



	1	2	3	4	5	6	7	8	9	10	11	12
YS	370	368	378	378	387	390	395	396	387	383	380	371
UTS	569	575	579	580	587	591	591	555	583	581	578	572
% Elong	20.4	22.7	22.4	22.6	21.8	14.7	25.5	6.2	23.0	24.2	20.6	22.4

Preliminary Sample Tensile Tests (Through Thickness)

Project Path Forward

- MELD to optimize print parameters for the AH36 material and create blocks for testing
- NSWC Carderock will conduct a variety of material tests on specimens and report results
- Altair to compile plan with key parameters required to develop a model to simulate the MELD deposition process

Questions?