

Qualification Requirements for Additive Manufacturing Processes – Phase 1 of 3

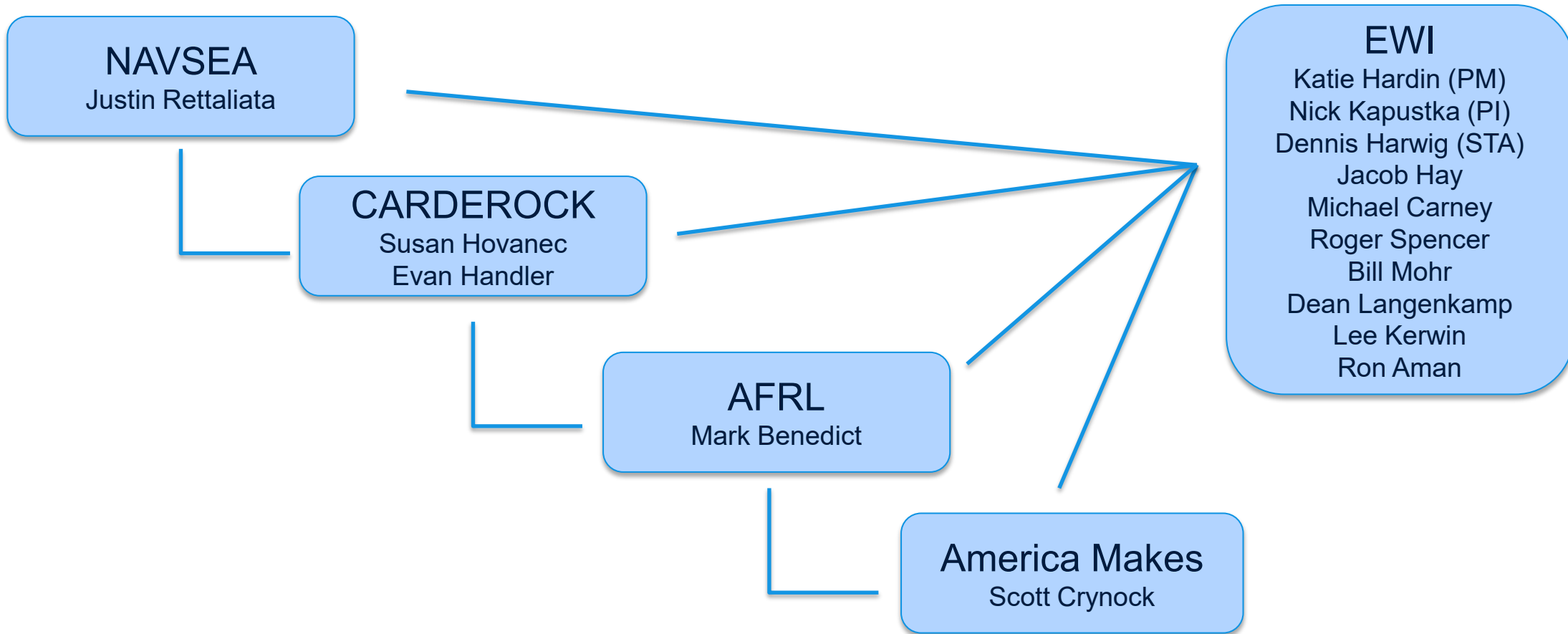
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Project Team



Project Overview

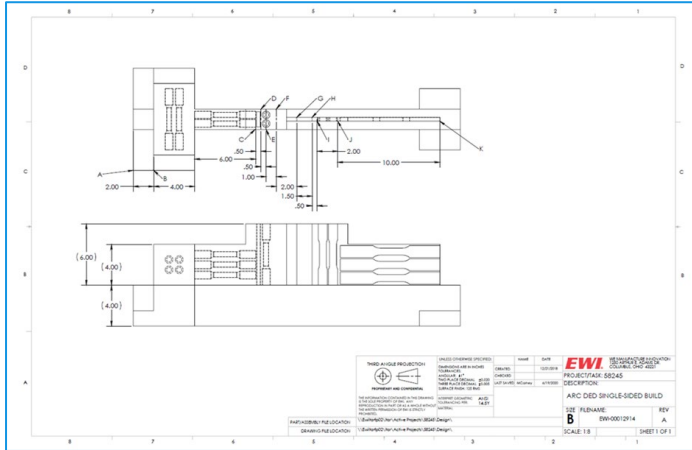
- **Problem Statement:**
 - Metal Additive Manufacturing (AM) process implementation is impeded by a lack of prescriptive qualification and fabrication standards.
 - Detailed requirements are needed for a wide range of metal powder bed and DED AM processes and build feature/scale applications.
 - Implementation is needed to support shipbuilding systems, supply chains, and platform sustainment.
- **Objectives:**
 - Leverage past initiatives and per NAVSEA priorities; develop additional procedure qualification schemes, support process requirements, and pertinent fabrication requirements to improve Technical Publication impact.
 - Support NAVSEA/Carderock who will directly implement methods and requirements via revisions/updates to:
 - NAVSEA Technical Publication – Requirements for Metal Powder Bed Fusion Additive Manufacturing
 - NAVSEA Technical Publication – NAVSEA Process Requirements for Metal Directed Energy Deposition Additive Manufacturing
- **Project Benefits:**
 - Develop, demonstrate, and transition prototype qualification and fabrication requirements for:
 - Mini and curved standard qualification build (SQB) design (full scale and subscale SQBs completed in prior investigations)
 - Procedure requirements for electron beam powder bed fusion (EB-PBF), electron beam DED (EB-DED), powder laser DED (PL-DED), and gas tungsten arc (GTA)/plasma arc (PA) DED processes
 - DED nondestructive evaluation (NDE) requirements - ultrasonic inspection calibration and test requirements for build sensitive microstructure
 - Procedure requirements for support processes (thermal management, active cooling) to support lights-out automation
 - Transition qualification requirements and representative data to AM Naval manufacturing base and supply chains

Background

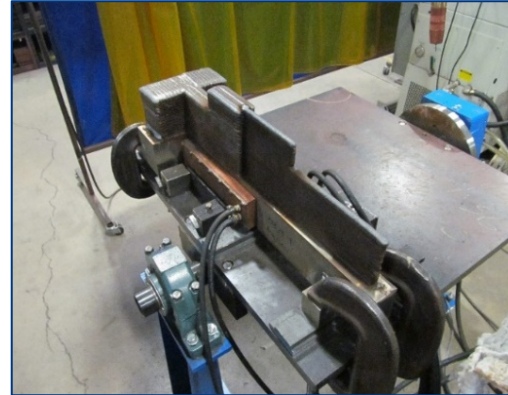
- EWI has completed three projects to support procedure qualification scheme development and drafting of NAVSEA metal AM Technical Publications.
 - Procedure qualification schemes for gas metal arc (GMA) and wire laser DED processes
 - Scheme (SQB design, NDE procedure map, property specimen test matrix, and qualification records for each process, procedure, & build application combination)
 - SQBs were designed for full scale (~> 5 mm) and subscale (~2 – 5 mm) features.
 - Single-sided integrated build platform (SS-IBP) and nonintegrated build platform (SS-NIBP)
 - Double-sided integrated build platform (DS-IBP) and nonintegrated build platform (DS-NIBP)
- Need mini SQBs for processes with features approximately < 2-mm bead width
- Need procedure and fabrication requirements for additional AM (EB-PBF, EB-DED, GTA/PA DED, etc.) and support (NDE, thermal management, active cooling) processes

Qualification Build Scheme Requirements Outline

Design



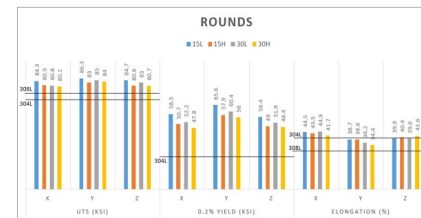
Build



Machine



Block Tensile Results



EWI

Property Test

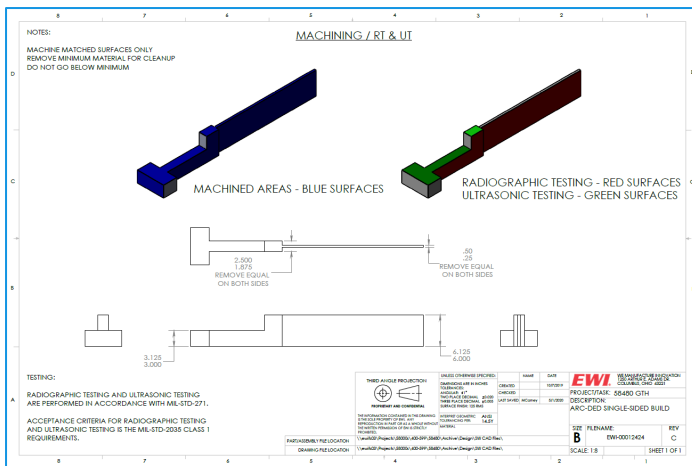
Report

Environment			
Track Building	Building	Environment	Other
Control	AC	Humidity	Controlled
Construction	200	Altitude	Sea Level
File Date	2012-11-15	Time	10:00
Name	3100-001-001-001	Version	1.000

Material Properties (per ASME B7.1)			
Description (Material, Surface, Condition)	Specimen Name	User	Version
Material	316L	316L	1.000
Surface	Polished	Polished	1.000
Condition	As Supplied	As Supplied	1.000
Material of Manufacture (Mfg. Name)	Material of Manufacture	Material of Manufacture	Material of Manufacture
Material of Manufacture (Mfg. Name)	Material of Manufacture	Material of Manufacture	Material of Manufacture

Data Table		Waveform	
Specimen No.	Material	Amplitude	Phase
1	316L	100	0
2	316L	100	0
3	316L	100	0
4	316L	100	0
5	316L	100	0
6	316L	100	0
7	316L	100	0
8	316L	100	0
9	316L	100	0
10	316L	100	0
11	316L	100	0
12	316L	100	0
13	316L	100	0
14	316L	100	0
15	316L	100	0
16	316L	100	0
17	316L	100	0
18	316L	100	0
19	316L	100	0
20	316L	100	0

NDE



Technical Plan – Phase 1

The objectives of Phase 1 of this project are to develop and support the following tasks:

- Task 1 – Mini SQBs and Test Specimen Designs
- Task 2 – EB-PBF Build Layout, Test Array and Demonstration Build
- Task 3 – Support with Development of the PBF Technical Publication
- Task 4 – EB-DED Procedure Qualification Scheme and Demonstration Builds
- Task 5 – PL-DED Procedure Qualification Scheme and Demonstration Builds
- Task 6 – Support with Development of the DED Technical Publication
- Task 7 – SQB NDE Requirements
- Task 15 – Reporting
- Task 16 – Project Management and Communication

Task 1 – Mini SQBs and Test Specimen Designs

Lower deposition rate processes, primarily PL-DED, build at significantly lower rates with finer resolution than other DED processes. Mini SQBs are required in order to allow for the qualification of low deposition processes in a timely manner.

- Task Summary:
 - Mini SQB Design (Harmonized with Full Scale and Subscale)
 - Single-sided integrated flat build platform (SS-IBP)
 - Single-sided non-integrated flat build platform (SS-NIBP)
 - Double-sided integrated flat build platform (DS-IBP)
 - Each will have
 - Standardized build platform
 - Standardized build geometry
 - NDE test map
 - Property test specimen matrix

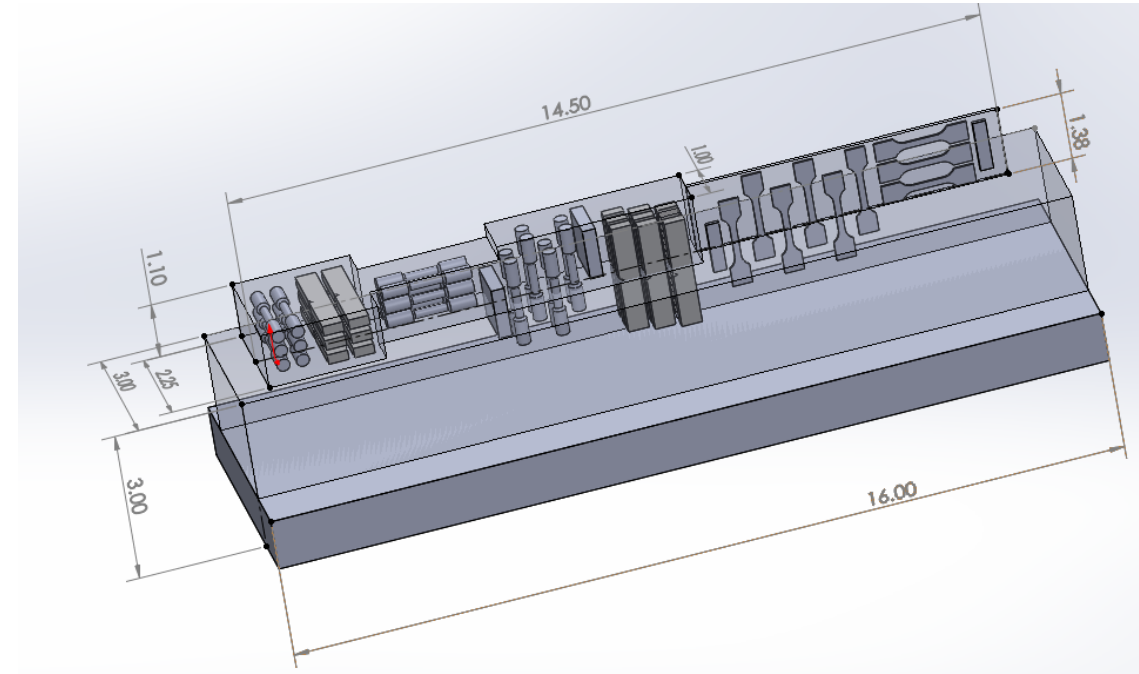
Task 1 – Progress

Updated mechanical test specimen selection and design is in process.

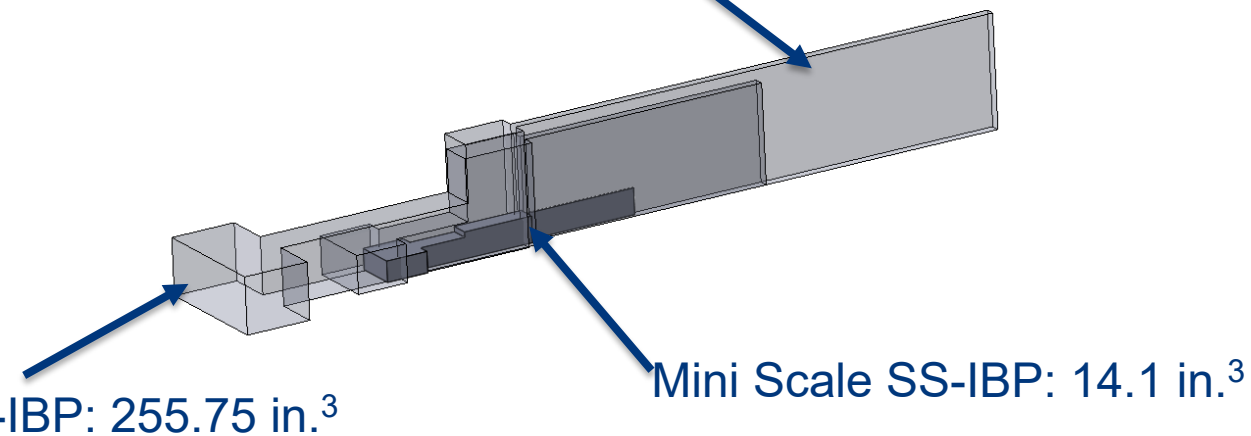
- Current Mini SS-IBP design eliminates bend specimens to reduce build volume but increases number of tensile specimens accordingly.
- Minimized tensile specimen size per ASTM E8 and ½ size CVN specimens where applicable
- Significant height and resultant volume reduction

Finalize

- Current specimen layout
- Size shape vs expected machine build volume (16 in. Acceptable)



Subscale SS-IBP: 102.5 in.³

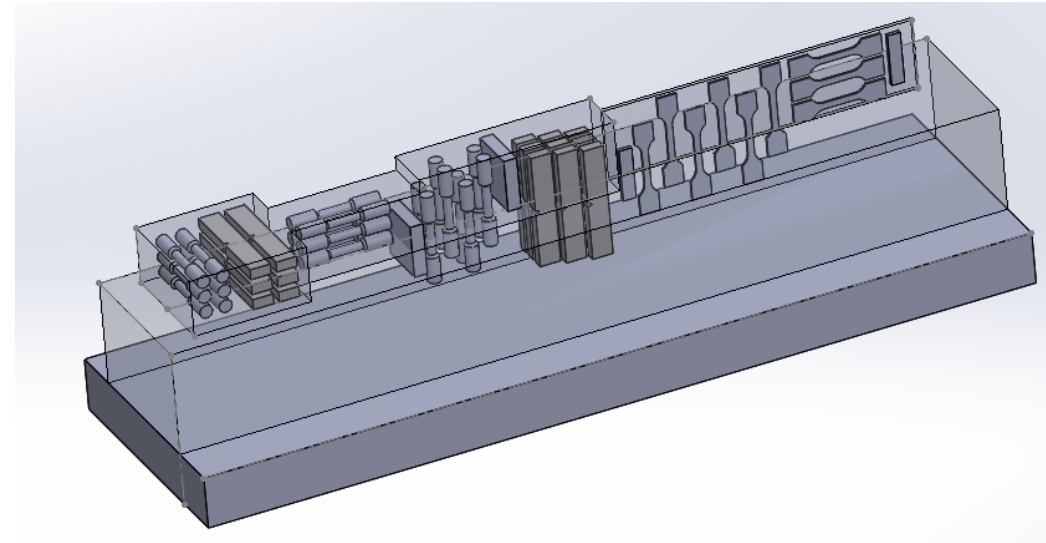


Full Scale SS-IBP: 255.75 in.³

Mini Scale SS-IBP: 14.1 in.³

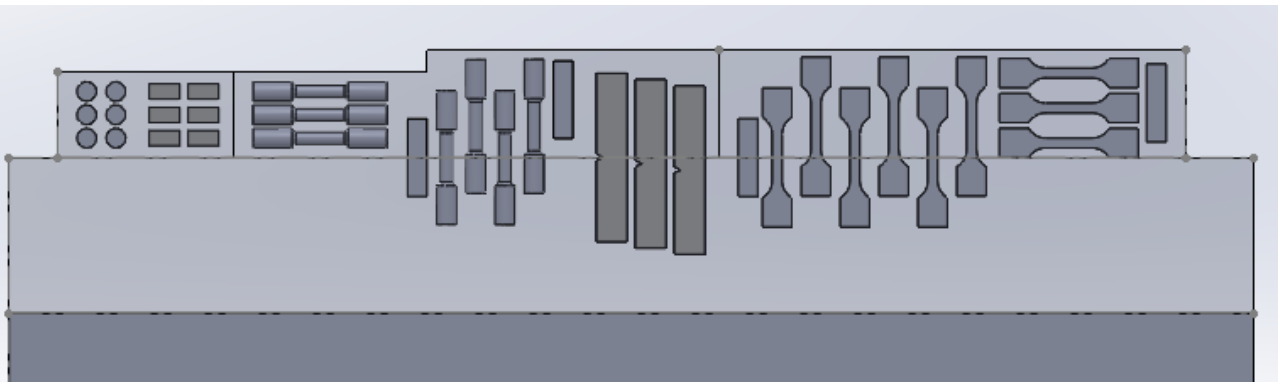
Task 1 – Next Steps

- Finalize specimen selection with NSWCCD
- Design Mini SS-NIBP and DS-IBP
- Finalize design, NDE plan and 2D drawings for all



Mini SS-IBP Specimens

- 6 – Y round deposition material tensile specimens
- 6 – Y ½ size CVN deposition material specimens
- 6 – X round deposition material tensile specimens
- 4 – Z round interface tensile specimens
- 4 – Z round deposition material tensile specimens
- 9 – Z ½ size CVN interface specimens
- 1 – Block cross section interface
- 1 – Block cross section deposition material
- 3 – Z flat interface tensile specimens
- 3 – Z flat deposition material tensile specimens
- 3 – X flat deposition material tensile specimens
- 1 – Thin wall cross section interface
- 1 – Thin wall cross section deposition material



Task 2 – Electron Beam – Powder Bed Fusion (EB-PBF) Build Layout, Test Array and Demonstration Build

Procedure qualification requirements need to be developed for the EB-PBF process for incorporation into the draft Technical Publication for Metal PBF AM. In this task the procedure qualification requirements for the EB-PBF process will be developed and demonstrated.

■ Task Summary

- Perform literature review to identify status of current qualification standards and essential elements
- Develop procedure qualification scheme for EB-PBF for incorporation into the Technical Publication
 - Build plate, standard build layout, NDE test map, specimen test array, procedure qualification test report form (PQTR)
 - Table listing essential elements and recommendations for Level 1 and Level 2 requalification
- Demonstrate EB-PBF scheme
 - Produce standard build
 - Testing per the NDE test plan and specimen test array
 - Document in PQTR form

Task 2 – Progress

- Literature review is near completion.
- EB-PBF procedure qualification scheme is being developed.
- Alloy 625 selected as the material for demonstration of standard build.

Task 3 – Support with Development of the PBF Technical Publication

The Technical Publication for Metals PBF AM has been issued. This Tech Pub includes requirements for L-PBF. The focus of this task will be to recommend requirements for incorporating the EB-PBF process into the Tech Pub, and to provide recommendations regarding the L-PBF content.

■ Task Summary

- Provide guidance on updates to the Technical Publication for Metals PBF AM to incorporate EB-PBF, accommodating important differences with L-PBF, including:
 - Source power
 - Bed temperature
 - Powder size
- Provide additional guidance on L-PBF for the Technical Publication for Metals PBF AM

Task 3 – Progress

- Technical Publication for Metals PBF AM is being reviewed and recommendations are being provided.

Task 4 – Electron Beam DED (EB-DED) Procedure Qualification Scheme and Demonstration Builds

EB-DED is a popular choice for AM parts from high value materials or with critical environmental requirements. Full scale SS-IBP and DS-IBP SQB's will be used to demonstrate this process.

■ Task Summary

- Review current industry standards and techniques regarding qualification of EB-DED processes
- Review support and adapt technical publication for qualification requirements of EB-DED
- Develop test report forms for the EB-DED process
- Set up EB-DED system, automated inter-pass temperature monitoring system with required fixturing
- Demonstrate qualification procedures in Sciaky EB-DED system by depositing full scale SQBs
- Evaluate builds by NDE and destructive methods per test specimen matrix

Task 4 – Progress

- Literature review is near completion.
- Table listing essential elements for the EB-DED process is being developed.
- Procedure qualification test report (PQTR) form is being developed.
- ER308L wire and 304L build platform have been selected for demonstration builds.
- Sciaky EB-DED system has been set up, and procedure development is being performed.

Task 5 – Powder Laser DED (PL-DED) Procedure Qualification Scheme and Demonstration Builds

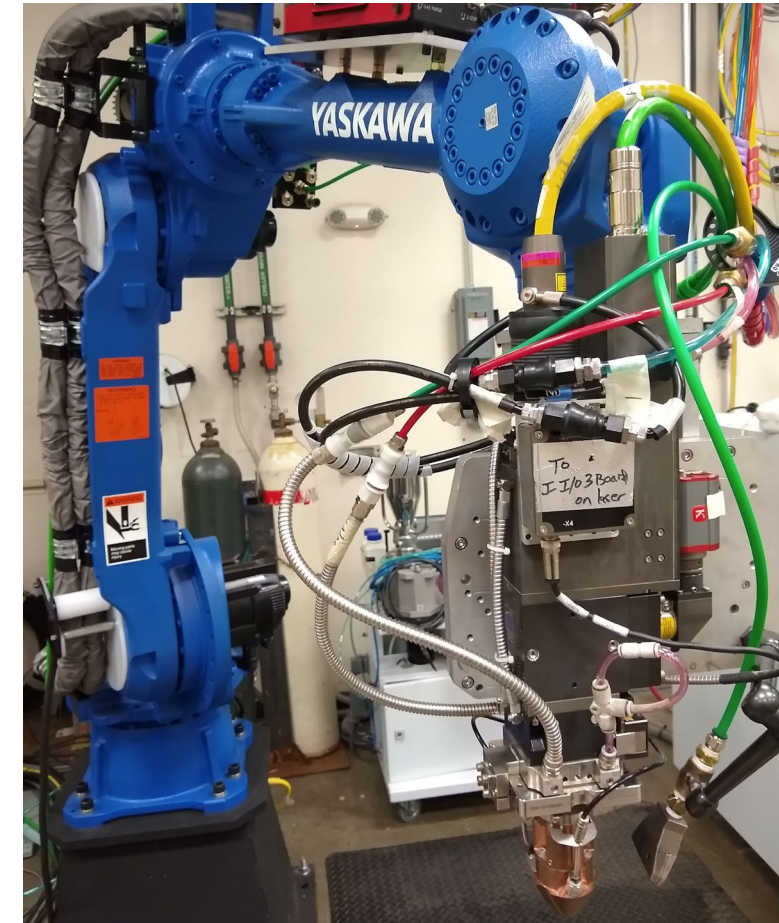
PL-DED is commonly used for AM parts that require fine resolution features but are too large to be built inside an L-PBF machine. PL-DED is also a common choice for repair and coating applications. Mini scale SS-IBP and DS-IBP SQB's will be used to demonstrate this process.

■ Task Summary

- Review current industry standards and techniques regarding qualification of PL-DED processes
- Review and create a table that lists essential elements for the PL-DED process
- Develop test report forms for the PL-DED process.
- Set up PL-DED system with automated inter-pass temperature monitoring system with required fixturing
- Demonstrate qualification procedures in PL-DED system by depositing mini scale SQBs
- Evaluate SQB's by NDE and destructive methods per test specimen matrix

Task 5 – Progress

- Literature review is near completion.
- Table listing essential elements for the PL-DED process is being developed.
- Procedure qualification test report (PQTR) form is being developed.
- Alloy 304 powder and build platform have been selected for demonstration builds.
- PL-DED system has been set up, and procedure development is being performed.
 - Motion system: Yaskawa Motoman robot
 - Laser: Trumpf TruDisk 6002
 - Optics: Trumpf powder feeding head
 - Powder Feeder: Medicoat Flowmotion



Task 6 – Support with Development of the DED Technical Publication

A new DED Technical Publication is currently in review, with arc as heat source and wire as the deposited material. This task aims to extend this document to additional heat sources such as laser and allow powder as a deposited material and additional configurations.

- Task Summary
 - Provide guidance on draft DED Technical Publication allowing additional DED methods and standard qualification build configurations
 - Compare to other industry standard documents

Task 7 – SQB NDE Requirements

AM parts and structures produced with wire and powder feedstocks are typically inspected using welding-based NDE specifications and acceptance criteria. While there are some similarities in flaw detection needs, building of additive DED parts can result in anomalies that are different from welding-based processes.

■ Task Summary

- Evaluate applicable NAVSEA and industry documents to baseline current NDE requirements for AM parts and structures produced with wire and powder feedstocks
- Determine if current NDE methods, techniques, and acceptance criteria are applicable for detection of discontinuities that may result in AM builds
- Identify technology gaps that may exist and recommend solutions. One common example is the need for appropriate calibration blocks for establishing ultrasonic testing (UT) sensitivity.
- Develop UT calibration block designs for single-sided and double-sided build platforms
- Task scheduled to begin Summer 2021

Task 15 – Reporting

- Final report at the end of each contract year to summarize all tasks and scope completed in that contract year
- Final report at the conclusion of the three-year contract
 - Documents background, objectives, approach, results and conclusions of work performed in each task/each year
 - Provides recommendations for further development of NAVSEA Technical Publications for DED and PBF AM

Technology Transition

- Develop, demonstrate, and transition prototype qualification and fabrication requirements for:
 - Mini and curved standard qualification build (SQB) design (full scale and subscale SQBs completed in prior investigations)
 - Procedure requirements for EB-PBF, EB-DED, PL-DED, and GTA/PA DED processes
 - DED NDE requirements - ultrasonic inspection calibration and test requirements for build sensitive microstructure
 - Procedure requirements for support processes (thermal management, active cooling) to support lights-out automation
- Transition qualification requirements and representative data to AM Naval manufacturing base and supply chains
- Support standards harmonization through participation in ASTM COE

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