Contract No:

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SR19016 – Characterization of AM Materials for SRTE Service

SRNL-STI-2020-00369

Facility Need

SRS and NA-123 have procured and installed an Arcam A2X electron beam melting (EBM) Powder Bed Fusion (PBF) (E-PBF) 3D printer. This equipment is ideally suited to print Titanium alloys, Cobalt-Chrome, and several Inconel alloys. A decision was made to develop operating experience with the best characterized and easiest material to work with, consequently, Ti-6Al-4V was selected based on vendor recommendations. This alloy offers many desirable attributes such as lower density than stainless steel (~4.6 g/cc vs. 8 g/cc), higher yield strength (775 MPa vs 290-480 MPa), and modest ductility (~12-15%) in the as-printed condition with increasing ductility in the as-heat treated condition. 3D printing and additive manufacturing offer an opportunity for increased complexity, reduced weight, and reduced part count with appropriate design and fabrication implementation. Titanium alloys are susceptible to hydriding and are not suitable for direct tritium contact, however, they are suitable for tooling and incidental contact. This project develops the knowledge base of AM Ti-6Al-4V for use in the tritium facility as tooling and fixtures for incidental tritium contact.

Potential Benefits

- ☑ Cost Reduction
- ☑ Defect Reduction
- ☑ Error Reduction
- ☑ Mission Diversification
- ☑ Mission Viability
- ☑ Obsolescence Solution
- ☑ Process Optimization
- ☑ Safety

Project Summary

This project addresses several issues and challenges for the use of AM produced components in the tritium facility. It will evaluate the effect of low level hydrogen and tritium exposure on the mechanical and chemical characteristics of Arcam A2X Electron Beam Powder Bed Fusion Produced (E-PBF) Ti-6Al-4V by printing tensile samples (Figure 1) and testing them in the as printed, machined, and hydrogen exposed conditions. Hydrogen uptake will be measured using an Eltra Hydrogen-Oxygen-Nitrogen analyzer. Hydride response will be measured using a Seiffert's apparatus and determining the effects of various surface treatments on the hydriding susceptibility. Tools, fixtures, and other objects will be deigned and printed for use in the AM lab and tritum facility and for other groups that support the tiritum mission.

SR19016

Status

Started in FY19 terminated after FY20

Technology Readiness Level

Start of FY20: 2
End-of-FY20Forecast: 3
End-of-FY20 Actual: 3

Financial

FY20 Project Cost: $137,447
Cumulative Total Project Cost: $286,856
FY20 Authorized Amount: $210,000 reduced mid year to $160.803

Credits

Principal Investigators: Paul Korinko & John Bobbitt
Facility Engineering Co-Lead: Brandon
Contributor: T. Hubbard, S. Scott, K. Shanahan

Milestones/Findings/Accomplishments

Project Milestone	Expected End	Actual End
Attend MS&T 19 and present results	10/31/19	10/31/19
Determine effects of thermal exposure	3/31/20	8/30/20
Attend AM CJOWOG	1/31/20	1/31/20
TMS 2020	3/31/20	3/31/20
Develop CoCr tooling	9/30/20	OBE
Characterize CoCr tensile properties	9/30/20	OBE
Arcam User’s Group in Sweden	9/30/20	OBE
Required year-end summary report	9/18/20	9/18/20

OBE—Overcome by events

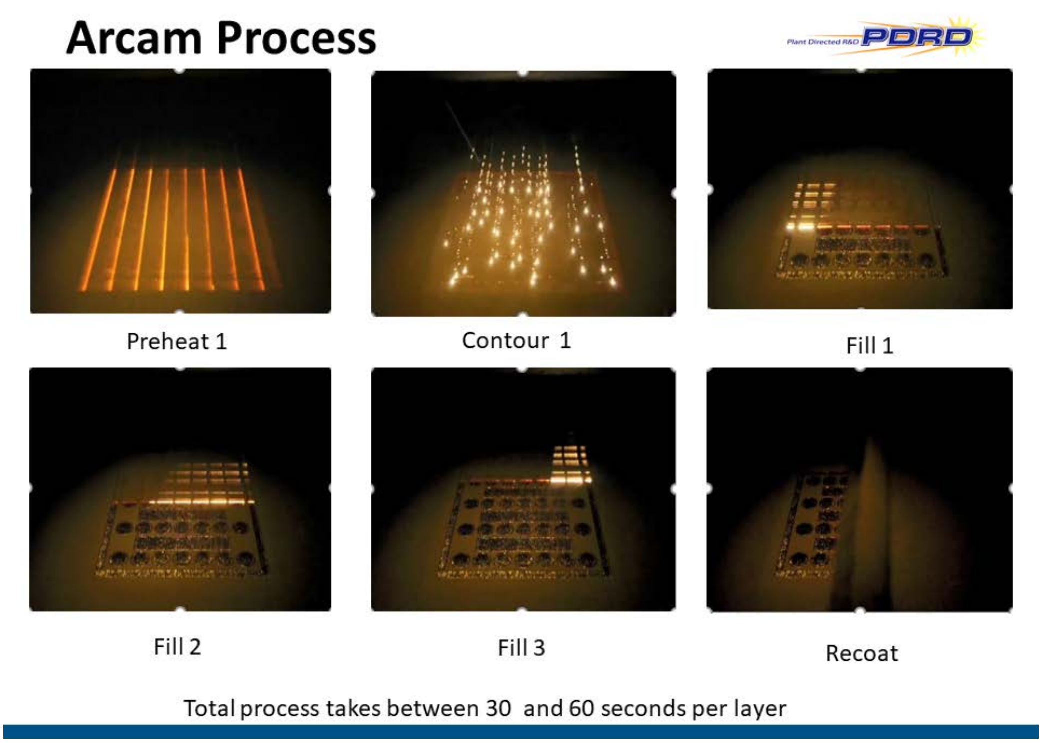

Figure 1 The EB-PBF process is a multi-step process as shown above.

Tensile specimens were exposed to atmospheres of varying hydrogen content (0, 1%, 3%) under varying temperatures (up to 200 °C) and tested for changes in their mechanical properties. No discernable effects of hydrogen exposure under the conditions studied were observed. Figure 2 displays an example of the changes in tensile test performance between hydrogen- and argon-exposed samples with surfaces in the as-printed and machine-finished conditions.

Hydriding of the samples requires a highly clean sample surface. An as-machined surface requires a temperature of over 410°C to initiate hydriding, a surface that has been immediately ground, cleaned, and inserted into a test cell will hydride at about 360°C, while activating the surface by heating the sample in vacuum to 550°C and then cooling it prior to introducing hydrogen results in absorption occurring at about 250°C. The expectation is that the high temperature vacuum treatment allows the surface oxygen to diffuse inward to produce a metallurgically clean surface that is more active. The results from the pressure-volume-temperature testing, Figure 3, support the effects that were observed from the mechanical property testing where no effects were observed after heating in hydrogen at 200°C for up to 10 weeks. These results further suggest that if the oxide is stable, it may reduce the likelihood for tritide formation in low tritium contamination areas and for non-critical tooling applications.

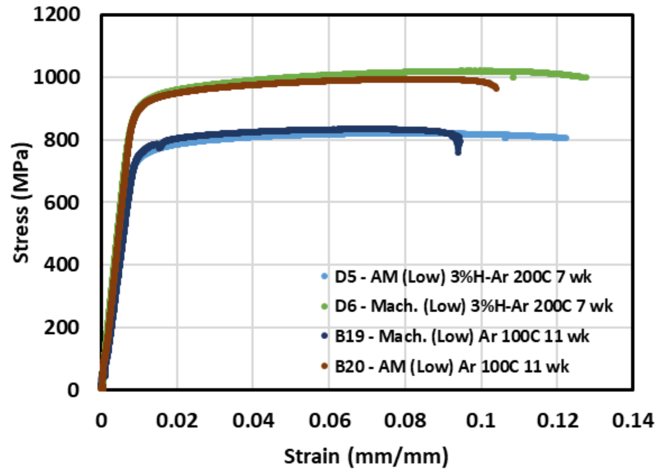

Figure 2 Tensile test comparison of hydrogen and argon exposed samples in the as-printed and machined conditions.

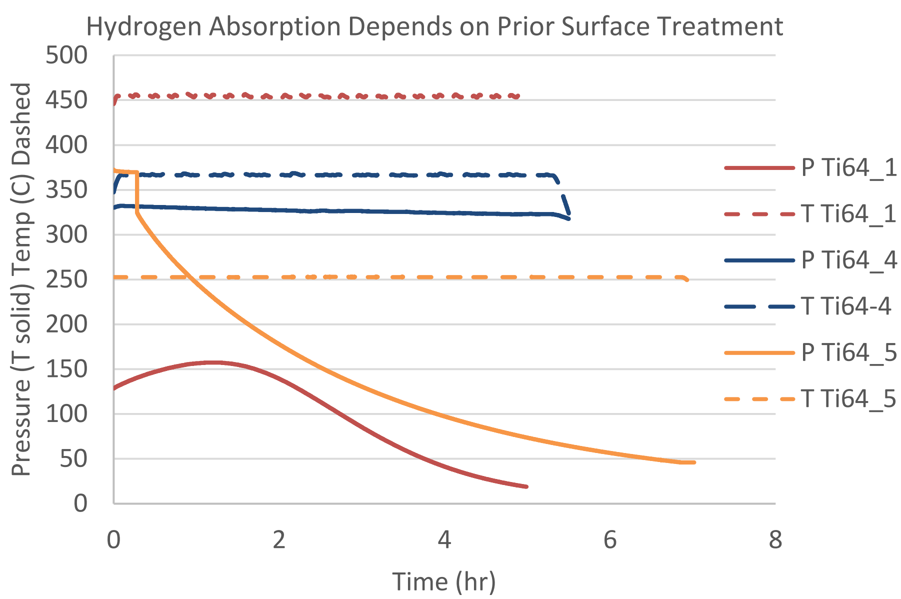

Figure 3 Hydride temperature depends on the surface treatment.

Proposed Future Work

- Expose AM and wrought Ti64 coupons to low levels of tritium to see if they hydride.
- Develop tooling and applications for Co-20%Cr alloys since it will be more tritium and hydrogen resistant while still being an electron beam powder bed fusion processable alloy.
- Conduct low and high level of hydrogen saturation tests for mechanical properties.