Department of the Navy SBIR/STTR Transition Program

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Topic # N171-090
Understanding Additive Manufacturing Solidification Profile Effects on Material Inhomogenieties, Defects, and Qualification
Applied Optimization, Inc.

WHO

SYSCOM: ONR

Sponsoring Program: Office of Naval Research Code 33 Sea Warfare and Weapons

Transition Target: Office of Naval Research (ONR) Future Naval Capabilities (FNC) Program Enterprise Platform Enablers (EPE) Quality Metal Additive Manufacturing (Quality Made), EPEFY17-03

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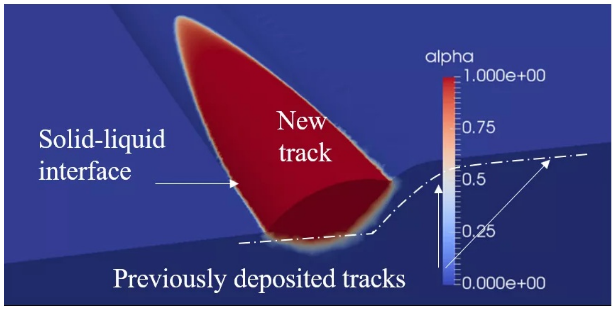

Other transition opportunities: Employment of AM leads to more innovative designs, and are capable of meeting an ever-increasing demand for components for the Navy, Air Force, Army, and Marine Corps. Navy AM qualification processes are applicable for commercial manufacturing and maintenance applications.

Notes: Picture: Applied Optimization Additive Manufacturing Simulation

WHAT

Operational Need and Improvement: A solidification science-based additive manufacturing (AM) model is required that relates the melting/solidification profile of metals/alloys to the metal/alloy microstructure during additive manufacturing (AM) processing. An integrated computational materials engineering (ICME) framework to model phenomenologies associated with melting/solidification profile is required. This ICME should model influences of the generation of microstructural inhomogeneities on defects as a function of power, speed, and materials for a given AM process, as a function of build depth. Process parameter correlation with different materials via ICME should be employed so that defect and inhomogeneities can be minimized, part property variations within the component can be minimized, and the part's performance can be qualified.

Specifications Required: As-built microstructure data is leveraged as input to phenomenological models in order to predict the mechanical anisotropy. Methodical experimentation using scaled part geometries is employed to calibrate the ICME models and create material, processing, and microstructure property relationships for 316L and IN625.

Technology Developed: AO is developing an Integrated Computational Materials Engineering (ICME) solidification science-based additive manufacturing (AM) framework for multi-scale, microstructure modeling, employing thermodynamic and kinetic models and a cellular automata (CA) framework. The dynamics of solidification interface velocity will be modeled using interface response function theory to predict the inhomogeneities caused by phase selection phenomena. The evolution of the solidification front will be traced within the CA grid to predict the solidification grain growth and orientation and the sub-grain morphology and texture. The thermodynamic and kinetic modeling will be combined with melt-pool scale residual stress predictions to assess the susceptibility to solidification or liquation cracking. The AM solidification profile and melt-pool physics data will be utilized to predict the occurrence or mitigation of defects such as buckling, keyhole, porosity, and lack-of-fusion.

Warfighter Value: Additive Manufacturing (AM) is a disruptive manufacturing process that enables reliable and cost-effective low volume manufacturing to increase Fleet readiness. Technology development is required to reduce the time and cost associated with deploying qualified/certified AM metallic components for use in Naval Air, Sea, & Ground platforms.

WHEN

Contract Number: N68335-18-C-0534 **Ending on:** April 17, 2020

Milestone	Risk Level	Measure of Success	Ending TRL	Date
Apply ICME tools to metal AM processing, to predict design and processing parameter limits	Low	Prototype demonstration of ICME	TRL-4	3rd QTR FY19
Validate ICME tools and predictive analysis capabilities by comparing the physical, metallurgical and mechanical properties of 2 different metals	Med	Surface roughness and dimensional accuracy of the AM component and model are correlated	TRL-5	4th QTR FY19
Perform mechanical test on AM component	Med	Correlation between test and model	TRL-5	4th QTR FY19
Perform component fatigue test for evaluation and comparison	Med	Correlation between test and model	TRL-5	2nd QTR FY20

HOW

Projected Business Model: The Additive Manufacturing (AM) team at Applied Optimization, Inc. (AO) focuses on research and development in metallurgy and metals processing. AO plans to work with government and Department of Defense (DoD) prime contractors to develop viable solutions to complex problems in the area of metal additive manufacturing (3D printing metal) in order to meet DoD AM component performance requirements.

Company Objectives: Since 1995, Applied Optimization, Inc. (AO) has collaboratively developed innovative solutions in material science to address the technical challenges for industry, NASA, and the DoD. Offering the right balance between critical thinking and non-conformity, AO's team of scientists, engineers, mathematicians, and software developers strive to further the understanding and state-of-the-art of additive manufacturing (AM), materials processing. AO intends to leverage the DoD SBIR program to develop software capabilities that optimize AM process parameters, mitigating defects in build parts and processes.

Potential Commercial Applications: AM is maturing and has increasing applicability in manufacturing, worldwide. Quality control of AM parts is critical when facilitating the transition of AM components into critical applications. AO's technology has broad applicability in aerospace, automotive, and medical commercial industries

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