LA - 19-EPSCoR -0019

Integrated Computational and Experimental Optimization of Materials and Methods for In-Space Manufacturing of Lightweight Metal Alloys (ISM-LMA)

Louisiana Board of Regents

NASA MD: STMD
Center: MSFC

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This collaborative research effort, designed to study additive manufacturing processes using lightweight metal alloys for in-space manufacturing applications, is led by Dr. Jonathan R. Raush (Science-I) of the University of Louisiana at Lafayette with collaborators at Louisiana State University and Louisiana Tech University. The project includes strong support from NASA Marshall Space Flight Center, NASA Johnson Space Center, and alignment with critical NASA Space Technology Mission Directorate roadmap objectives (TA 12.1.2, 12.4.1, 12.4.2). The team conducting the research has expertise in additive manufacturing, fused deposition modeling, , material thermal-physical property measurement, computational methods including CALPHAD and Phase Field modeling, and advanced materials characterization including electrostatic levitation and x-ray diffraction techniques .

The overall project goal is to support NASA's vision of developing in-space manufacturing capabilities, as well as to support Louisiana's top research priorityâ€"Advanced Manufacturing & Materials. Sustainable, long-duration human spaceflight missions require on-demand manufacturing capabilities that provide solutions for fabrication and repair of components, electronics, consumables, tools, and structures. The most promising additive manufacturing method available for in-space manufacturing is the fused deposition modeling process. During this process, green bodies are fabricated with metal powder laden polymer composite feedstock. After a de-binding process, sintering is performed to increase metallic part density. One key technical challenge associated with fused deposition modeling of metallic parts is how to consolidate the loosely packed alloy powders into a dense structure as trapped voids and defects in the sintered parts can significantly degrade the mechanical properties of the manufactured part.

Thus, the primary technical objective of this proposal is to produce robust and high strength fused deposition modeled aluminum parts with minimum porosities. The research will couple theoretical and experimental studies while developing qualified material databases and simulation tools, in order to understand the multiple physics governing the fused deposition modeling sintering process for achieving dense aluminum parts. In this study, we will focus on high strength Al-7xxx series alloys, for which zinc is the major alloying element and, in particular, will plan to accomplish the following tasks: 1) Generate a database of thermo-physical properties for the experimental alloys, including melting range, density, surface tension, and viscosity etc., using advanced experimental techniques such as Electrostatic Levitation and thermodynamics based calculations. 2) Develop a thermodynamic-based model using the data NASA's Physical Sciences Informatics System to simulate the alloy microstructure evolution and predict the properties of printed parts. The model will use the phase-field approach, which will capture the effect of particle size, temperature, pressure, interface energies, composition, surface tension, and their influence on the formation and coalescence of the microstructures. 3) Certify as-built samples through metallurgical, mechanical, and material characterization. As-built samples should achieve comparable levels of relative density and mechanical performance as compared to wrought samples. 4) Conduct in-situ X-Ray diffraction testing to capture the dynamic sintering process to assist process optimization. 5) Design and prepare samples for potential microgravity studies on the International Space Station.