Space Technology Research Grants

Control of Variability in the Performance of Selective Laser Melting (SLM) Parts through Microstructure Control and Design

Completed Technology Project (2015 - 2018)

Project Introduction

The high variability and low repeatability of metal parts produced using Additive Manufacturing (AM) represent a major barrier in getting AM into the mainstream. Efforts to characterize (and eventually reduce) variability start by predicting the microstructure and performance properties of AM parts. In this proposal, we propose a Phase Field Modeling to characterize the microstructure evolution in Selective Laser Melting (SLM) given the temperature history. The majority of works in the literature focus on predicting the thermal history, and none of these works capture microstructure evolution. In contrast, we will experimentally characterize the thermal history using a custom integrated monitoring system, and then use Phase Field Models to computationally predict the microstructure of the fabricated part. Furthermore, we will capture one layer of uncertainty by modeling the temperature history as a time-based stochastic process with measurement errors. Next, we will conduct systematically designed experiments to validate the predicted microstructures, and identify key process parameters and higher order interactions that significantly contribute to the variability of the microstructure. The outcome of these experiments will be used to construct a Response Surface Model to optimize process parameters (e.g. laser power and scanning speed) such that we achieve desired properties while keeping variability at a minimum and increasing repeatability. The proposed framework will be validated using Nickel Titanium Shape Memory Alloys as a model material that is both highly applicable in aerospace applications and whose macroscopic properties are very sensitive to small variations in process parameters and microstructures. The key aspects of innovation in this project lie in proposing a phase field model-based novel approach to characterize microstructure evolution in SLM, and further integrating this with stochastic processes and uncertainty quantification models to identify and control variability sources. This will represent a major contribution to the existing literature on modeling SLM processes which solely focuses on predicting the thermal history. Furthermore, the outcomes of the project will be used to build a repository of process parameters and material properties for NiTi SMAs, and will contribute to increasing the MRL for the Selective Laser Melting of SMAs from its current TRL 1 to TRL 3.

Anticipated Benefits

This will represent a major contribution to the existing literature on modeling SLM processes which solely focuses on predicting the thermal history. Furthermore, the outcomes of the project will be used to build a repository of process parameters and material properties for NiTi SMAs, and will contribute to increasing the MRL for the Selective Laser Melting of SMAs from its current TRL 1 to TRL 3.

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Primary U.S. Work Locations and Key Partners

Organizations Performing Work	Role	Type	Location
Texas A&M University	Lead Organization	Academia	College Station, Texas

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Texas A&M University

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

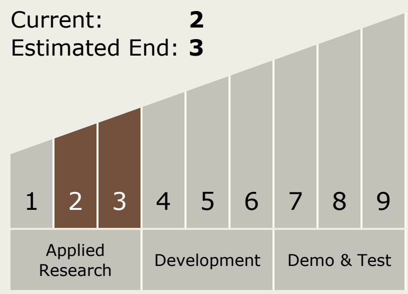
Hung D Nguyen

Principal Investigator:

Alaa Elwany

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  └ TX12.4 Manufacturing
    └ TX12.4.2 Intelligent Integrated Manufacturing

Target Destination

Foundational Knowledge