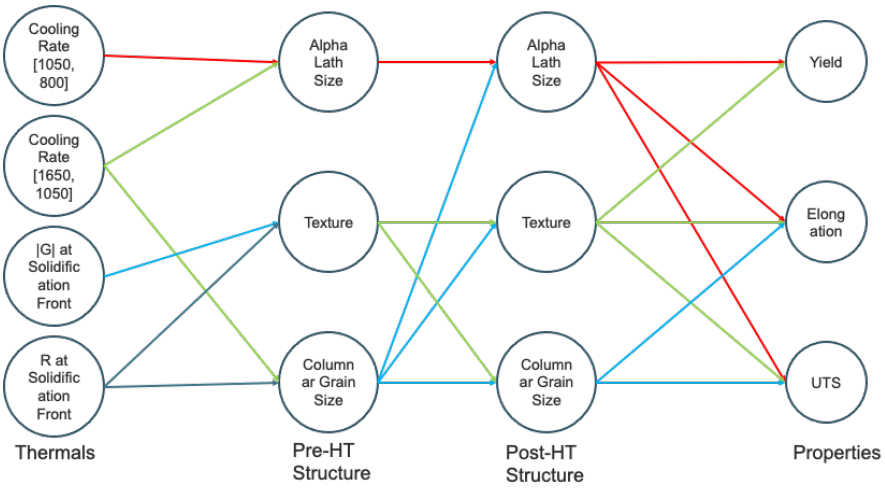
SUCCESS STORY

5001.003.002.001

Modeling system accurately predicts process parameters

Project reduces engineering and qualification cost for 3D printing aerospace legacy parts made from Ti64



An initial, illustrative architecture of a Bayesian Network that can connect process parameters to thermal features to microstructure to properties. Bayesian Networks support the inclusion of causal relationships and uncertainty quantification.

PROBLEM

Established causal, physics-based models that accurately predict the performance of additively manufactured (AM) parts should drastically reduce non-recurring engineering costs. Without these models, the development and qualification of AM processes and parts will continue to be done on a point basis, with each variant being treated independently. There is a high demand for more general approaches because of the significant cost associated with qualification/certification ($>1M per part).

OBJECTIVE

The purpose of this program was to develop a process, thermal, structure property (PTSP) model for single-pass Ti64 wall built with laser blown-powder directed energy deposition (DED-LB) that predicts alpha lath size, yield strength, and elongation as a function of process parameters. The goal was for the model to be explainable and include uncertainty quantification (UQ). The explain ability of the model was based on its ability to flow through a predictive network based on physical changes occurring through the build and post-processes. Namely, predictions flowed from build parameters to thermal features to structural properties to strength properties. Another goal was for the model to be assessed based on its accuracy in predicting the experimental measurements and by comparing its performance against an exclusively data-driven approach.

AMERICA MAKES TECHNOLOGY DEVELOPMENT ROADMAP

This project aligns to:

AM GENOME

ASTM PROCESS CATEGORY
Directed Energy Deposition

EQUIPMENT
RPMi557

MATERIAL
Ti64

TECHNICAL APPROACH

The program followed a proven data science approach. First, data from the Featured-Based Qualification (FBQ) ingested, assessed, and used as a basis for the draft data management plan. Second, a PTSP model was architected in collaboration with EWI's material science and structural integrity experts. Finally, the model was applied to the data, assessed, and deliverables generated. EWI was the sole participant in this project. The data acquired from the FBQ program was parsed and converted into a pandas data frame. Next, the data of interest associated with single pass walls was isolated, including process parameters, alpha lath size, and tensile testing results. Structural properties were tied to strength properties based on specimen ID and extraction location. Finally, basic data investigation was performed, including correlation analysis, pair plots, and data completeness checks. EWI followed its standard procedure for developing hierarchical hybrid machine learning models. The relationships in these models developed by EWI's AM, Material Science, and Structural Integrity Leads, as well as by observed correlations within the dataset. The process parameters and thermal history relationship leveraged EWI's multi-source Rosenthal model for time-efficient thermal predictions. Two methods were used to assess the model. First, standard leave-one-out cross-validation was used to assess the accuracy of the hierarchical hybrid machine learning model. Second, the model was compared against a baseline. The baseline was a single-level, exclusively data-driven regression model which links process parameters (e.g., laser power, layer thickness, contour speed) directly with tensile results (e.g., yield and tensile strength). Both modeling approaches were r^2.

ACCOMPLISHMENTS

The first highlight of this project was using data gathered from a previous America Makes Project 3011 FBQ program that studied the tensile properties of Ti64 DED-LD for different canonical feature types with different build strategies and process parameters. Because the project team was able to leverage previous data, this project accomplished all its tasks within a short time schedule. EWI proved that using a physics-based PTSP model versus the traditional process-property model development can accurately predict the outcome of a printed Ti64 wall structure. The EWI Windows GUI software program can be used to predict the yield and tensile strength with high confidence based on certain process parameters.

PROJECT END DATE

August 2023

DELIVERABLES

- Data Management Plan Presentation to AM Genome Working Group
- Final Written Project Report
- Project Data
- Virtual Presentation Windows Graphics User Interface (GUI)

FUNDING

$100,000 total project budget

PROJECT PARTICIPANTS

Project Principal:
Edison Welding Institute (EWI)

Other Project Participants:
NCDMM/America Makes

Public Participants:
U.S. Department of Defense