Task: Data generation by Numerical Modeling to support ML assisted alloy design and FSW-AM processability

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What is the outcome or accomplishment? (1-2 short sentences describing it and why it is transformative; 50-word maximum suggested)*

A Coupled Eulerian-Lagrangian (CEL) finite element (FE) model is developed using the plastic deformation concept to simulate the additive friction-stir deposition (AFSD) process. The model can predict the time-dependent temperature and stress distribution inside the deposition layer, the substrate, and the tool, depending on the three major parameters— tool rotation speed, tool traverse speed, and material deposition rate.

What is the impact? (1-2 simple sentences describing the benefits for science, industry, society, the economy, national security, *etc.*; suggested 50-word maximum)

Numerical modeling of the thermo-mechanical behavior of the AFSD process at various processing parameters can generate useful process outcomes rapidly and cost-effectively, which are difficult to achieve experimentally. It also acts as a convenient method to optimize the input parameters for processing high-entropy alloys. This research can generate a large set of data for developing a robust machine learning model to predict the critical traits in AFSD and characterize the quality and strength of the AFSD processed parts.

What explanation/background does the lay reader need to understand the significance of this outcome? (1-2 paragraphs that might include, for example, more on who, when, where; NSF's role; support from multiple directorates/offices; what makes this accomplishment unique; additional intellectual merits; or broader impacts such as education, outreach, or infrastructure improvement that are integral to this outcome; suggested 150-word maximum)

The study is accomplished by developing a multi-physics-based FE model using aluminum alloy (AA 6061) as the feedstock and substrate material and conducting collaborative experiments using the MELD L3 machine. The Johnson-Cook plasticity model is used to model the large plastic deformation, and Coulomb's Friction Law is implemented to address the friction effect between the material-substrate contact interface. The FE model is validated by comparing the numerical results for temperature with the experimental results. The experimental results for temperature distribution and layer geometry are obtained by collaborating with Dr. Guo and his students at

LSU, which show a good agreement with the modeling results. The tensile and fatigue properties of the AFSD-processed steel parts are also characterized by FE modeling using ANSYS. The AFSD-processed parts show higher strength than that of the conventionally fabricated parts due to refined equiaxed microstructure. The overall study can establish an engineering knowledge base on predicting the AFSD process outputs in large quantities and potentially leads to developing a robust machine learning algorithm for comprehending material flow behavior in the process along with the performance of the processed parts.

Chowdhury Alam is working on his finite element simulations under the supervision of Dr. Shafiqur Rahman at the Louisiana Tech University.