I/UCRC Executive Summary - Project Synopsis	**Date**: October 2020
Center/Site: NA/ISU	
Tracking No.: Predicting Mechanical Behavior	**E-mail :** ajtemple@iastate.edu
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Center/Site Director: NA/P. Collins	**Type: (Continuing)**
Project Leader: Andrew Temple	**Proposed Budget**: NA

Project Description: Although microstructure is process sensitive, it is the "material state" that governs the properties, and any fundamental physical relationship should be process-agnostic. If these relationships are truly process-agnostic, then composition-microstructure-property relationships can be exercised for any new additive manufacturing (AM) process or process variation that emerges in the future.

Experimental plan: Ti-6Al-4V was obtained from three unique AM processes – laser hot-wire (LHW), selective laser melted (SLM), and electron beam additive manufactured (EBAM). The post-build and post-heat treatment microstructures were tensile tested, characterized using SEM, and quantified using MIPAR Image Analysis. Descriptive statistics and machine learning (ML) tools were applied to the microstructure, composition, and mechanical property data to guide the development of a physics-based constitutive stress-strain model for AM Ti-6Al-4V.

Related work elsewhere: Traditional strain hardening equations (e.g., Ludwik, Hollomon, Swift, and Voce) are entirely empirical, with fitting parameters that are not rooted in the underlying physics. Kocks and Mecking previously developed a physics-based constitutive strain hardening equation for single phase, polycrystalline, cubic materials. This work has been extended to include hexagonal close packed materials.

How this project is different: Previous work has proven it is possible to predict yield strength for AM Ti-6Al-4V based on composition, microstructure, texture, and dislocation density. Recent developments suggest that Kocks-Mecking (KM) storage and annihilation coefficients are likely dependent on the underlying "material state", and the stress-strain behavior of AM Ti-6Al-4V can be predicted beyond the yield point.

Milestones for the current proposed year: Completion of microstructure characterization and quantification, determination of storage and annihilation coefficients for other titanium alloys.

Deliverables for the current proposed year: Demonstrate the predictive accuracy and precision of a process-agnostic, physics-based constitutive stress-strain model for Ti-6Al-4V. Hypothesize, analyze, and quantify the microstructure and defect structure dependence of the storage coefficient in the KM model.

How the project may be transformative and/or benefit society: An in-depth understanding of process-agnostic microstructure-composition-property relationships will be developed for both elastic and plastic stress-strain behavior. This will enable the accurate and precise prediction of tensile properties like yield strength and ultimate tensile strength for AM Ti-6Al-4V, while also serving as a framework upon which additional predictive stress-strain models can be built for other AM alloys.

Research areas of expertise needed for project success: MIPAR Image Analysis software for microstructure feature quantification; heat treatment with the Gleeble 3800 for precise control of the thermal conditions (i.e., programmed temperature and heating/cooling rates).

Potential Member Company Benefits: The understanding of process-agnostic microstructure-composition-property relationships as they relate to the underlying "material state". Enables the potential to demonstrate applicability of the predictive stress-strain model to a wide variety of AM materials.

Progress to Date: Determination of storage and annihilation coefficients for the KM model. Generation of a synthetic stress-strain curve using only three material properties – (E, YS, and k1). Process-agnostic prediction of ultimate tensile strength within 5% for Ti-6Al-4V produced via three unique AM process.

Estimated Start Date: Spring 2020	**Estimated Knowledge Transfer Date**: Spring 2021

The Executive Summary is used by corporate stakeholders in evaluating the value of their leveraged investment in the center and its projects. It also enables stakeholders to discuss and decide on the projects that provide value to their respective organizations. **Ideally, the tool is completed and shared in advance of IAB meetings to help enable rational decision making.**