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as of 04-Feb-2021

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STEM Degrees: 1 **STEM Participants:** 3

Major Goals: The main objectives of this proposal were to predict the damage accumulation and failure mechanism associated with high strain impacts in 1) additively manufactured specimens as well as 2) additively manufactured lattice structures.

The main aim of the first research was to characterize the plastic behavior, and as a result, microstructure changes of AM Inconel 718 under different deformation conditions (stress states, strain rates, and temperatures) using split Hopkinson pressure bar (SHPB) tests, and quantify the influence of thermal post-processes on its plastic behavior and microstructure.

The second research focused on the design, topology optimization, and characterization of quasi-static and in particular, dynamic load-deformation behaviour of additively manufactured metal structures. The energy absorption behavior, failure modes, localization of deformation, and densification of these lattice structures under quasi-static and dynamic loading conditions were studied.

Accomplishments: The instrument obtained through this grant was used to investigate the plastic deformation behavior and microstructural evolution of additively manufactured Inconel 718 super alloy when subjected to high-strain-rate (ranging from 2×103 to 5×103 s-1) loading conditions. In another research in collaboration with the Air Force Institute of Technology, this tool was used to study the mechanical properties and energy absorption characteristics of additively manufactured lattice structures.

In the first research, microstructure changes of AM Inconel 718 under different deformation conditions (stress states, strain rates, and temperatures) using split Hopkinson pressure bar (SHPB) tests were characterized, and

the influence of thermal post-processes on its plastic behavior and microstructure were quantified. Comparisons were made with TM Inconel 718. High strain rate compressions tests were conducted, using an SHPB, at strain rates of 1000 s-1, 1700 s-1, and 2200 s-1. Mechanical properties (yield strength and strain hardening rate) experimentally obtained by this investigation may be used not only as criteria and input for novel alloy development and/or material selection for various engineering applications but also as the data necessary to calibrate and validate constitutive equations implemented in material models. Such insight is also beneficial for adjusting the AM processing and post-processing parameters.

In the second project, in collaboration with AFIT, samples consisting of three different triply periodic minimal surfaces were fabricated from Inconel 718 through additive manufacturing methods, with relative densities ranging from 21.34 to 38.73%. Compression tests were accomplished at various strain rates utilizing a uniaxial compression testing machine and Split Hopkinson Pressure Bar to determine mechanical properties and plasticity model parameters of the lattice structures. The plasticity model parameters were extracted and implemented in the model. The model was able to predict the material response at high strain rates.

Training Opportunities: In all of the projects that have been conducted with this tool so far, graduate and undergraduate students were the key members of the research team and performed much of the research identified. This tool was used by different groups at the University of Alabama, including Allison's Group and Davami's Group. Currently, the PhD thesis of a student, Mr. Russell Rowe, has been defined on the impact properties of additively manufactured structures, where Russell is heavily using this tool for his research.

Undergraduate students, including female students, were also trained on the tool, and participated in the research as well. The outcome of this research encouraged one of the students, Ms. Bailee Gilbreath, to join one of the DoD sectors after her graduation, and now she is doing similar research in her career.

Some of the results of the research conducted with this tool have already been incorporated in a course taught by PI Davami, called Surface Engineering Techniques (ME 491) where the effects of the surface properties on the failure mechanisms of the structures are being studied.

In addition to the students here at UA, a student, Lt Col Derek Spear, at the Air Force Institute of Technology in Ohio also benefitted heavily from this tool in his dissertation.

Results Dissemination: So far a paper titled "Comparison of High Strain Rate Mechanical Properties of Additively and Traditionally Manufactured Inconel 718 Samples" have been presented at the SCITECH conference (AIAA Scitech 2021) and two other papers, including one in collaboration with the Air Force Institute of Technology are about to become submitted.

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Other Collaborators:

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