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Leveraging NNSA's investment in Geometry and Meshing to Solve Critical AM Problems; e.g. Path Planning, Chris Kozuch

It has been determined that the most advantageous structural system for pressure pads manufactured by silicone-based bead extrusion is that of a cross-hatch pattern in which successive layers are offset by the bead radius. However, creating this structure for arbitrary 3D shapes poses a significant challenge with respect to path planning. To address this, the computational simulation team at Sandia National Laboratories has sought to leverage the geometry and mesh tools of CUBIT, a finite element mesh-generation software toolkit, to develop a path planning capability that could produce this type of structure. The result was marked success for structured geometries as well as promising progress for unstructured geometries.

Advanced/Additive Manufacturing of Energetic Materials, Alex Tappan

Sandia National Laboratories has been researching small-scale detonation and combustion on a variety of energetic materials, including high explosives, thermites, pyrotechnics, and intermetallics. A critical aspect of this research involves the question, "how do you make small samples to study them?" As such, we have applied techniques such as physical vapor deposition and inkjet printing to produce these small samples. This talk will present details of this work and how these techniques have allowed investigation of detonation phenomena in vapor-deposited films of explosives at sub-millimeter scales.

Direct Write Electronics-Embedded Sensing, Adam Cook

Understanding the mechanical response of LENS microstructures using Direct Numerical Simulation, Joe Bishop

The microstructure resulting from the LENS process is vastly different than the microstructure of the wrought material with respect to grain size, grain morphology, and texture. In order to understand the impact of these microstructural differences on the macroscale behavior of the host structure, we perform a series of Direct Numerical Simulations (DNS) in which the microstructure is embedded directly within a macroscale structure. High-performance computing resources are used to model the macroscale structure with a finite element mesh of sufficient refinement to also resolve the microstructure. An FCC crystal-plasticity model is used to represent the grain-scale physics. The DNS simulations of both the LENS and wrought materials are compared with analogous simulations that use the material properties obtained from homogenization theory.

Microstructure, phase, and composition of stainless steel 304L made by LENS TM, David Adams

Mechanical Response of Additively Manufactured 304L Across a Wide Spectrum of Loading Conditions, Mike Maguire

Additive Manufacturing of Porous Materials, David Robinson

Additive manufacturing is heralded by mechanical engineers as a new path to load-bearing structures that use material very efficiently. The emerging field also has promise in chemical engineering, where there is a ubiquitous reliance on randomly packed powders in chemical reactors, battery and fuel cell electrodes and separator membranes, separation columns, filters, and other devices that manipulate fluid flow and ion transport. In cases where randomly arranged materials have been replaced by deterministically fabricated devices with optimized geometries, major performance and efficiency improvements have been achieved. Notable examples can be found in gas chromatography, microfluidic medical devices, and recently emerging "3D battery" structures. However, such improvements are not widespread because the appropriate fabrication techniques are not available in most situations.

The key technology gaps are:

(1) Limited access of additive manufacturing techniques to the 1-100 µm length scale, especially for inorganic materials. Dimensional control on this length scale is often needed for efficient fluid-solid contact.

(2) Lack of parallelism in technologies that do exist, which typically involve a rastered laser or extruder. For a given part volume, build times by rastering become very long as feature size decreases.

The goal of our project is to develop efficient, scalable manufacturing methods for porous chemical engineering devices, relying on several key Sandia technologies:

(1) Nanoporous powders of well defined particle and pore size that can be sintered through mild chemical or thermal treatments

(2) Photochemical methods that permit metal deposition a plane at a time, without relying on rastering

(3) Small-scale platforms for high-throughput characterization of filters and separation columns

(4) Imminent acquisition of state-of-the-art powder-based 3D printers for inorganic materials.

We are working to deliver, as a proof of principle, a sub-millimole scale hydrogen-deuterium separation column that achieves much more sharply defined separations at a much lower pressure drop than a similarly sized packed-powder column.

Metrology Artifacts for Additive Manufacturing Process Characterization, Bradley Jared

Metrology artifacts and processes exist for subtractive manufacturing where part geometry and surface finish are commonly inferred through machine metrology procedures. These methodologies prove inadequate to characterize the performance of additive manufacturing processes and equipment, however, since additive geometries are an outcome of the positioning accuracy of material placement, the physics of the material deposition process at each material location, the deformation from residual material stresses, and the cumulative errors of the build process. Work has been performed to develop a family of metrology artifacts which address these deficiencies and are useful for a range of additive processes in assessing minimum feature resolution, relative accuracy of form and size, surface texture, and anisotropies associated with part orientation or workspace location. Design details will be presented as well as performance data from both plastic and metal additive processes.

Powder Safety for Additive Manufacturing: Evaluating Powder Combustibility, Aaron Hall
Powder safety is a complex issue facing the additive manufacturing community. Evaluating a specific powder's combustibility is critical to implementing safe and effective powder handling procedures. Evaluating powder combustibility is challenging and test results can be difficult to interpret. Standard test methods for determining power combustibility will be reviewed. The meaning and interpretation of combustibility test data will be discussed. This presentation will raise awareness regarding power combustibility testing and powder safety.

AM Product Realization, The New Reality, Larry Carrillo
The physical differences and steps needed between parts conceived and fabricated using traditional methods and parts made using additive manufacturing is easy to see in most cases without intense scrutiny. Nonetheless, there are important steps in the production style that must be addressed before we are able to select, design, define, fabricate, test, inspect, and procure parts made using AM technologies. Using a team based approach, SMEs from the different impact areas will research, discover and resolve differences, shortcomings and inconsistencies between the way that the complex has used traditional manufacturing methods and the way that we seek to deploy AM. This presentation will discuss some of the apparent inconsistencies and incongruities between traditional fabrication methods and AM and propose different ways that the complex might employ to overcome hurdles.

Service Bureau Lessons Learned, Abe Sego
The proliferation of 3D printing information is intense. However, the accessibility of high quality, timely, and affordable printing services within the NSE is moderate at best. Implementing a balance between a centralized service bureau and localized solutions (3D printers for every office) can be the answer to technology accessibility and more wide-spread acceptance within the NW design community. SNL has established a 3D printing center of excellence that is enabling design teams like never before, but we still have a long way to go. This talk will highlight SNL's center of excellence successes and opportunities.

Additive Manufacturing for the B61-12 Actuator and Pulse Battery Assembly, Nic Leathe
The Actuator and Pulse Battery Assembly (APBA) housing has been the focus of an additive manufacturing and adaptive topology optimization (ATO) feasibility investigation. Through the implementation of the ATO code and the characterization of boundary conditions, the APBA PRT has developed models of optimized geometry designed to minimize the weight of the

component while increasing the stiffness. The generated designs are able to accomplish these goals while producing a unique, organic looking geometry.

AM Applications In Neutron Generator Tooling, Nathan Fuller

While additive manufacturing processes are in a perpetual state of development, there are many excellent applications for current technologies in tooling development. Through AM, tooling engineers can make great strides in reducing overall costs and lead times while significantly increasing the quality of their product. This presentation will discuss how the Neutron Generator Tooling Team has realized substantial cost and lead time savings while increasing the quality of production tooling through the use of additive manufacturing.

Topology Optimization Algorithms: Challenges and Opportunities, Josh Robbins

Advances in additive manufacturing technologies allow designers to explore new complex designs based solely on performance specifications rather than manufacturing limitations. To leverage this new flexibility, next generation designs must be treated as performance-based optimization problems rather than heuristics-based design processes. Successful application of performance-based optimization requires leading-edge research in large-scale constrained shape and topology optimization to develop algorithms that can efficiently handle large sets of design variables and performance specifications in a wide variety of physical settings. This talk will i) identify and describe some of the existing challenges in topological optimization, ii) present ongoing work in abstract optimization techniques that will ultimately enable the application of general first- and second-order optimization algorithms for topology optimization with arbitrary physics, and iii) present recent examples of topologically optimized components generated using newly developed computational tools.

Function-based Design Enabled by Adaptive Topology Optimization and Additive Manufacturing, Brett Clark

The combination of Topology Optimization (TO) and Additive Manufacturing (AM) has the potential to fundamentally transform the way design is done. Employing TO in the design process will force modeling and simulation to direct design rather than just validate design. For this to become a reality the design environment must naturally incorporate TO and make it feasible & accessible to use, addressing issues such as the scale of TO output, extraction of shape from the data, smoothness of the results, interface back to CAD, and ultimately enabling interaction between the designer and the optimizer. This presentation will describe Sandia's vision for developing such a design environment and report on progress along that path.