Information Technology

Finite Element Models for Electron Beam Freeform Fabrication Process

Potential applications are in the fabrication of short-run components, and repair and refurbishment of parts in the aerospace, automotive, power generation, and other industries.

Lyndon B. Johnson Space Center, Houston, Texas

Electron beam freeform fabrication (EBF^3) is a member of an emerging class of direct manufacturing processes known as solid freeform fabrication (SFF); another member of the class is the laser deposition process. Successful application of the EBF^3 process requires precise control of a number of process parameters such as the EB power, speed, and metal feed rate in order to ensure thermal management; good fusion between the substrate and the first layer and between successive layers; minimize part distortion and residual stresses; and control the microstructure of the finished product.

This is the only effort thus far that has addressed computer simulation of the EBF^3 process. The models developed in this effort can assist in reducing the number of trials in the laboratory or on the shop floor while making high-quality parts. With some modifications, their use can be further extended to the simulation of laser, TIG (tungsten inert gas), and other deposition processes.

A solid mechanics-based finite element code, ABAQUS, was chosen as the primary engine in developing these models whereas a computational fluid dynamics (CFD) code, Fluent, was used in a support role. Several innovative concepts were developed, some of which are highlighted below. These concepts were implemented in a number of new computer models either in the form of standalone programs or as user subroutines for ABAQUS and Fluent codes.

A database of thermo-physical, mechanical, fluid, and metallurgical properties of stainless steel 304 was developed. Computing models for Gaussian and raster modes of the electron beam heat input were developed. Also, new schemes were devised to account for the heat sink effect during the deposition process. These innovations, and others, lead to improved models for thermal management and prediction of transient/residual stresses and distortions.

Two approaches for the prediction of microstructure were pursued. The first was an empirical approach involving the computation of thermal gradient, solidification rate, and velocity (G,R,V) coupled with the use of a solidification map that should be known *a priori*. The second approach relies completely on computer simulation. For this purpose a criterion for the prediction of morphology was proposed, which was combined with three alternative models for the prediction of microstructure; one based on solidification kinetics, the second on phase diagram, and the third on differential scanning calorimetry data. The last was found to be the simplest and the most versatile; it can be used with multicomponent alloys and rapid solidification without any additional difficulty.

For the purpose of (limited) experimental validation, finite element models developed in this effort were applied to three different shapes made of stainless steel 304 material, designed expressly for this effort with an increasing level of complexity.

These finite element models require large computation time, especially when applied to deposits with multiple adjacent beads and layers. This problem can be overcome, to some extent, by the use of fast, multi-core computers. Also, due to their numerical nature coupled with the fact that solid mechanics-based models are being used to represent the material behavior in liquid and vapor phases as well, the models have some inherent approximations that become more pronounced when dealing with multi-bead and multi-layer deposits.

This work was done by Umesh Chandra of Modern Computational Technologies, Inc. for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-24598-1

Autonomous Information Unit for Fine-Grain Data Access Control and Information Protection in a Net-Centric System

Potential uses include cyber-security, smart grid, defense networks, and enterprise networks.

NASA's Jet Propulsion Laboratory, Pasadena, California

As communication and networking technologies advance, networks will become highly complex and heterogeneous, interconnecting different network domains. There is a need to provide user authentication and data protection in order to further facilitate critical mission operations, especially in the tactical and mission-critical net-centric networking environment. The Autonomous Information Unit (AIU) technology was designed to provide the fine-grain data access and user control in a net-centric system-testing environment to meet these objectives.

The AIU is a fundamental capability designed to enable fine-grain data access and user control in the cross-domain networking environments, where an AIU is composed of the mission data, metadata, and policy. An AIU pro-