CONF-9605172--1
SAND--96-1293C

Laser Engineered Net Shaping (LENS) for the Fabrication of Metallic Components

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Introduction

Solid Free Form Fabrication is one of the fastest growing automated manufacturing technologies that has significantly impacted the length of time between initial concept and actual part fabrication. Starting with CAD renditions of new components, several techniques such as stereolithography and selective laser sintering are being used to fabricate highly accurate complex three-dimensional objects using polymeric materials. Coupled with investment casting techniques, sacrificial polymeric objects are used to minimize costs and time to fabricate tooling used to make complex metal castings.

This paper will describe recent developments in a new technology, known as LENS™ (Laser Engineered Net Shaping), to fabricate the metal components *directly* from CAD solid models and thus further reduce the lead times for metal part fabrication. In a manner analogous to stereolithography or selective sintering, the LENS™ process builds metal parts line by line and layer by layer. Metal particles are injected into a laser beam, where they are melted and deposited onto a substrate as a miniature weld pool. The trace of the laser beam on the substrate is driven by the definition of CAD models until the desired net-shaped densified metal component is produced.

Fabrication

The system consists of a Nd:YAG laser, a controlled atmosphere glovebox, and a computer controlled positioning system. A schematical representation of the LENS™ process is shown in Fig. 1. A solid substrate is used as a base for building the LENS™ object. The laser beam is focused onto the substrate to create a weld pool in which powder particles are simultaneously injected to build up each layer. The substrate is moved beneath the laser beam to deposit a thin cross section, thereby creating the desired geometry for each layer. After deposition of each layer, the powder delivery nozzle and focusing lens assembly is incremented in the positive Z-direction, building a three dimensional component layer additively. To insure that a uniform deposition was achieved for each layer independent of direction, a specialized powder delivery nozzle and powder feeder have been developed. The addition of these items has served to provide an extremely robust process.

Our research in the first year was to demonstrate the role of the processing parameters for thin walled geometries. The process variables considered were: component velocity, laser irradiance, Z-axis increment, and powder volumetric flow rate. The results of these experiments suggest that, for the process region considered, the two most significant factors associated with this process are the component travel speed and the laser irradiance. In fact, analysis of this data for the Ni-based super alloy 625 has shown that there is a linear relationship between the layer build-up height and total volumetric exposure. The volumetric exposure is the ratio of the laser irradiance to the component travel speed. A graph of these experimental results is shown in Fig. 2.

After determining the LENS™ parameters for a material, a hollow geometry is typically fabricated. Figure 3 is a picture of an H13 tool steel thunderbird (which has similar LENS™ parameters as the 625 alloy). The tallest geometry we can build in the LENS™ platform is 6 inches. For this geometry and material, the dimensional variance along Z is only 0.002 inches for the wingspan section of the thunderbird.

From our understanding of the LENS™ parameters, solid geometries were fabricated. With a solid geometry, understanding the hatch spacing (line by line spacing) is critical for building 100% dense components. Figure 4 shows a housing built out of 316 stainless steel. This part is very accurate in X and Y dimensions but the build height needs better control. The error is X and Y is less than 0.005"; however, Z can vary by as much as 0.125". By understanding the thermal properties along with the LENS™ parameters, we should be able to control the Z height.

Mechanical Properties

Initial mechanical test specimens show the LENS™ processed stainless steel components to have high strengths, with ultimate tensile strength = 115 ksi, and good ductility (elongation = 30-50%). Further studies of stainless steel and other materials will give a clearer picture of the materials' properties.

Preliminary work with H13 tool steel shows that it is readily possible to make components with a hardness value of 59.3 (Rockwell C).

Sensor Development

Although this process has proven to be very robust, a significant amount of work remains to develop the LENS™ process for operation in a manufacturing environment. The current system operates as an open-loop system, that is, it depends solely on the reliability of the laser and other system components to reproduce a given result. Preliminary results from current experimentation suggests that improvements can be made in process reliability by implementation of sensors for monitoring the process and providing a response signal for closed-loop process control. Continuing research efforts are aimed at further developing the LENS™ process to establish an extremely robust process. This will provide manufacturers with a method to fabricate metallic components directly from a CAD solid model.

Conclusions

In summary, the LENS process has great potential for revolutionizing the fabrication of metallic components. We have demonstrated that near net shape, dense solid parts can be fabricated from stainless steel and nickel based alloys. Preliminary work shows that tungsten and H13 tool steel parts are feasible.

Acknowledgment
Work supported by the U. S. Department of Energy under contract DE-AC04-94AL85000

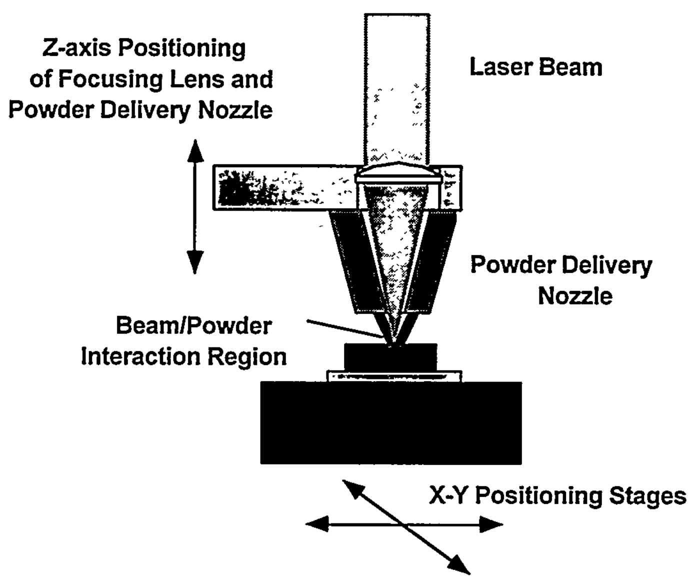

Figure 1. Schematic of LENS process.

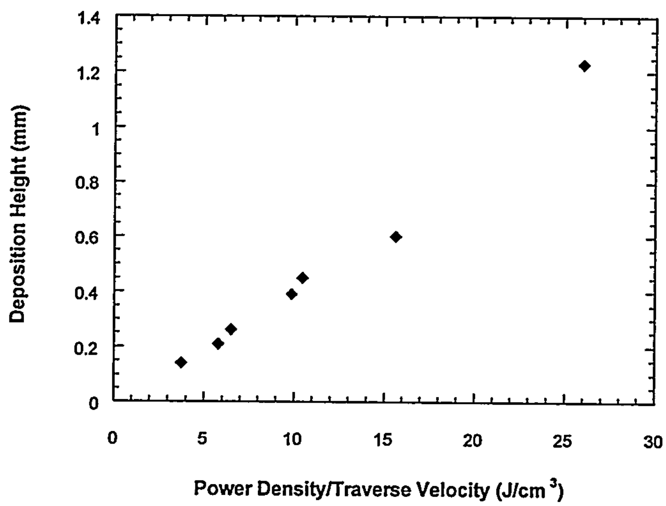

Figure 2. Build up height versus volumetric exposure for Ni-based alloy 625.

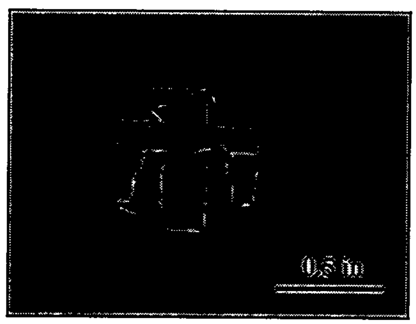

Figure 3. Thin walled component fabricated from H13 tool steel.

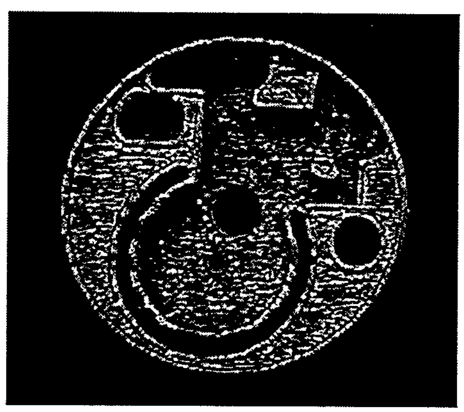

Figure 4: Solid component built from 316 stainless steel.

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