Composition Control in Direct Laser Deposition

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Introduction

Laser engineered net shaping (LENS™) is a solid freeform fabrication process that has the capability of producing functionally graded material (FGM) components by selectively depositing different powder materials in the melt pool at specific locations in the structure during part build up. The composition in each layer of an FGM is dependent upon the degree dilution between the substrate and powder materials. Thus, a detailed understanding of processing parameter-dilution relations in this new fabrication process is essential for composition control for fabrication of FGMs.

Procedure

A study of the effects of LENS™ processing parameters (laser power, travel speed, and powder mass flow rate) on dilution was conducted for deposits of H-13 tool steel and copper powder on H-13 tool steel substrates. Single pass line builds were made under a wide range of processing conditions, and the resultant dilution was measured using image analysis techniques. The melting efficiency and laser transfer efficiency were also determined for each case. Laser transfer efficiency was determined using a Seebeck calorimeter, while melting efficiency was determined using metallographic methods.

Results and Discussion

When varying a single processing parameter while holding all others constant, dilution was found to increase with increasing laser input power and travel speed and decrease with increasing powder mass additions into the melt pool. Methods of predicting dilution in single pass LENS™ deposit were developed from knowledge of LENS™ process efficiencies and material thermophysical properties. Two potential modeling approaches are presented. The first is based on a simple power balance and utilizes both the transfer and melting efficiency values. The second model only requires

use of the transfer efficiency and is based upon the Rosenthal heat flow solutions and SOAR weld optimization program developed at Sandia Laboratory. Good correlation was shown to exist between experimentally measured dilution and dilution calculated from the models.

Conclusion

The results of this research provide two potential methods for composition control of functionally graded deposits made by direct laser deposition.