C. Continuous Ultrasonic Welding for Solid State Rapid Prototyping

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Introduction

Continuous Ultrasonic Metal Welding (USMW) has been demonstrated as a technology for rapid prototyping in aluminum. An additive manufacturing technology, Ultrasonic Consolidation (UC) employing a metal tape lay up approach, in which a solid laminated aluminum structure is produced according to the geometry supplied as an input file, is described.

In additive manufacturing processes a part is produced, using a CAD file as input, by continuously joining a featureless feedstock material to previously deposited material, to produce objects of random geometry. This is a major welding engineering challenge, because the weld geometry, and hence parameters, are constantly changing.

Most additive manufacturing techniques rely on liquid phase joining techniques. In the Ultrasonic Consolidation process discussed here, a solid state joining process is employed. Extensive welding parameter development and testing was required to establish a set of procedures that could be used to automate the generation of machine code to automate the production of parts on a USMW rapid prototyping machine. Peel tests, metallographic testing, and laser vibrometry were employed in the development.

Designed experiments in which weld speed, force, and amplitude were varied were conducted to establish baseline parameters for inclusion the UC system. Peel tests were used to identify optimum parameters, as resistance to delamination is the critical performance criteria in an object produced via metal lamination. Peel tests were conducted at vary stack heights, as peel test performance varies with the number of laminate layers already deposited. Metallographic examination was employed to evaluate characteristics, for example, interlaminar defects, that could be related to welding conditions. Laser vibrometry was used to evaluate the mechanical behavior of a part during build.

These data were used to define parameters for weld initiations and terminations, and to vary weld regimes for high aspect ratio features in which part vibration can impede the joining process. A maximum tolerable part motion value was identified. Power supply output was measured on line, and a minimum energy density associated with successful joining identified.

USMW can be used as a rapid prototyping technology for production of aluminum components. In addition to the research described above, an automated rapid prototyping system was designed and demonstrated. The software system used to decompose CAD files into layers and generate machine code was implemented successfully employing the results of the experimental work.