Characteristics of Laser Aided Direct Metal Powder Deposition Process for Nickel-based Superalloy

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Abstract

Laser additive direct deposition of metals is a new rapid manufacturing technology, which combines with computer aided design, laser cladding and rapid prototyping. The advanced technology can build fully-dense metal components directly from CAD files with neither mould nor tool. Based on the theory of this technology, a promising rapid manufacturing system called "Laser Metal Deposition Shaping (LMDS)" is being developed significantly. The microstructure and mechanical properties of the LMDS-formed samples are tested and analyzed synthetically. As a result, significant processing flexibility with the LMDS system over conventional processing capabilities is recognized, with potentially lower production cost, higher quality components, and shorter lead time.

Keywords : Laser Metal Deposition Shaping (LMDS); Nickel-based alloy components; Layered direct fabrication; Microstructure and property

1. Introduction

Laser additive direct metal deposition is an extension of the laser cladding process in that it allows three-dimensional parts directly from a 3-D CAD model to be built by cladding successive layers on top of one another in pre-determined vector paths. Development of this process has brought tremendous interests among the rapid prototyping industry as well as the tool industry [1]. The process can be utilized in many promising fields such as net shaped solid metallic parts, functionally graded materials, cellular solids, in-situ alloying parts, and parts with conformal/internal features [2]. With the ability of one-step manufacture, the technology can greatly reduce the lead-time and investment cost of module and die design, the fabrication of hard or rare metal components, the repair of refractory and costly components, etc [3].

2. Technical Experiments

Recently, a promising rapid manufacturing system called "Laser Metal Deposition Shaping (LMDS)" is being constructed and developed with flying colors by Shenyang Institute of Automation Chinese Academy of Sciences. Fig. 1 shows the experimental setup for laser direct deposition experiment. Experimental setup is primarily composed of four components: energy supply system, motion control system, powder delivery system, and computer control system. These components have their specified functions, but work in association with each other. Only in this way can the three dimensional object be achieved successfully.

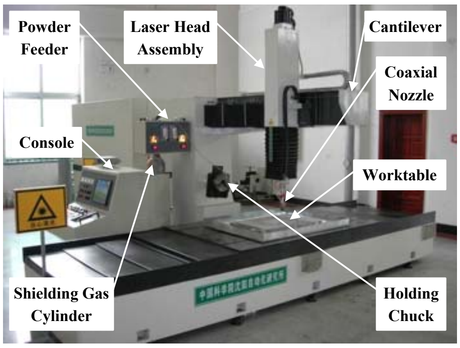

Fig. 1. Components of the LMDS setup.

The experimental material for laser direct deposition experiment is Ni60A alloy whose powder size is about 200 mesh. The substrate used for multi-layer laser cladding is A3 steel plate with the dimension of 200 mm×200 mm×10 mm.

3. Microstructure Analysis

Through LMDS setup, a thin-wall part used for microstructure analysis and property examination was deposited layer by layer. Fig. 2 shows the longitudinal cross-section area of the thin-wall part under a low magnification of 60× by SEM. The structure of several uniform layers is illustrated. For each layer two regions are recognized: the deposition region and the remelting zone. The orientation of the dendrite of the deposition region always follows the direction from the bottom to top of each layer and slightly toward the scanning direction. The other fact about grain orientation is that the new dendrites always nucleate at the sites of the dendrites from the former layer and inherit their orientation. It is found in Fig. 3, the close-up view of the remelting region, that the microstructure of the remelting region tends to become featureless and prevent the dendrites of the new layer form inheriting the orientation of those in the previous layer.

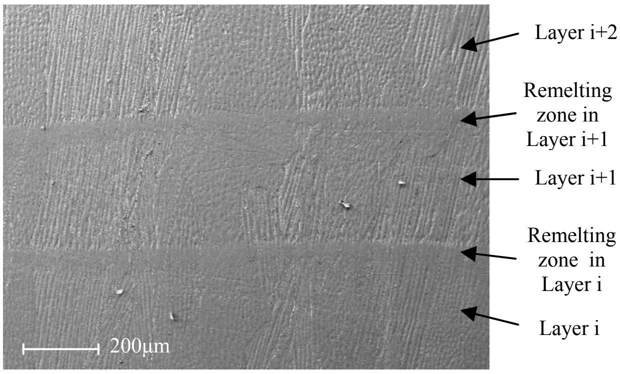

Fig. 2. SEM morphology of the longitudinal cross-section area of a multi-layer Ni60A part.

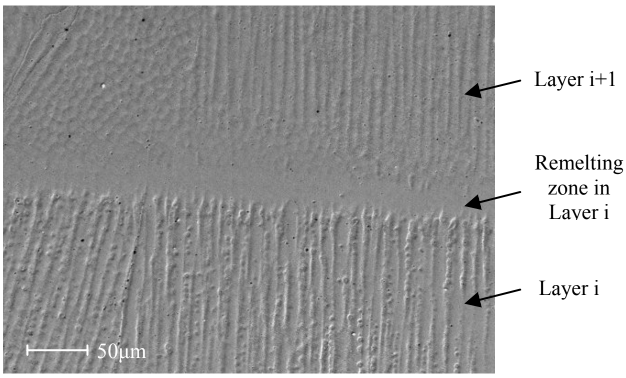

Fig. 3. Close-up view (200×) of the remelting region between two adjacent layers.

4. Mechanical Properties of the Parts

The uniaxial test was conducted for the thin-wall part using tensile tester. For the thin-wall part, the specimens are prepared so that the tensile directions are varied both parallel and perpendicular to the scanning directions of the layers.

The tensile test was carried out with the specimens broken in the middle position. As illustrated in Fig. 4, a large number of dimples with various shape and size are distributed on the fracture surfaces, which indicates that the fracture characteristic of as-formed Ni60A samples is the ductile fracture behavior. The mechanical properties of the tensile samples loaded with the different tensile directions are listed in Table 1.

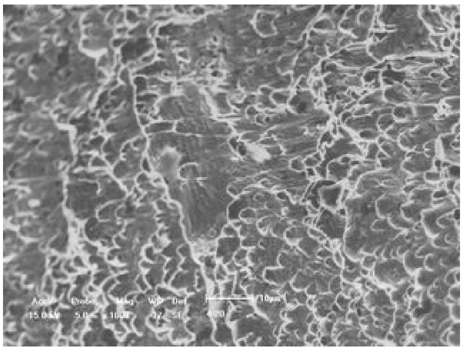

Fig. 4. SEM morphology (1000×) of tensile fracture surface of formed sample.

Table 1. The mechanical properties of as-deposited Ni60A part

Material	Yield Strength (MPa)	Ultimate Strength (MPa)	Elongation Percentage (%)
Deposited Ni60A (Parallel)	385	572	9.6
Deposited Ni60A (Perpendicular)	224	338	18.5

5. Conclusions

A direct laser metal deposition process has been incorporated into the LMDS setup. A direct laser metal deposition process has been incorporated into the LMDS setup, and then a thin-wall Ni60A part was successfully fabricated by this technology. There is no crack or porosity formed in the part and the dendrites oriented from the bottom to the top of each layer with slightly toward the laser scanning direction. The tensile test results for Ni60A samples show that the mechanical property of the deposited part is anisotropic and affected by the microstructure distribution. Finally, a number of metal parts had been produced using the LMDS setup.

6. References

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