Journal of Materials Processing Tech. 262 (2018) 75–84

Contents lists available at ScienceDirect

Journal of Materials Processing Tech.

journal homepage: www.elsevier.com/locate/jmatprotec

Process parameters optimization and mechanical properties of forming parts by direct laser fabrication of YCF101 alloy

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ARTICLE INFO

Keywords:
Direct laser fabrication
Fabricating stability
Mechanical properties
Parameter optimization

ABSTRACT

In this paper, the process parameters optimization and performance testing in direction laser fabrication were studied. Some critical parameters that affect the part properties and process stability were researched and discussed in detail. The results show that the parameters (power, scan speed, and powder feed rate) affect the track geometry, and then influence the quality of the cladding specimens. The z-axis increase quantity plays an essential role in fabricating stability. The defects caused by laser opening and closing can only weaken to a certain extent by uniformly distributing the position of laser power on. Crack and pore inside the forming, surface defects, and non-uniform microstructure must be avoided during the parameters optimize and process control, because these defects can cause the failure of the process. The surface morphology, crack and pore in cross-section, micro-hardness, wear resistance and strength were measured and analyzed to select or optimize the optimal process parameters. With optimizing process parameters, the stability of laser cladding process and mechanical properties of the part can be significantly improved.

1. Introduction

Direct Laser Fabrication (DLF) is an advanced manufacturing technology, which can build complex metal parts with full density and excellent mechanical properties directly from CAD files without using any modules or tools and consider the laser cladding shaping, as reported in Li et al. (2005). Because it is direct laser fabrication, it does not need replacement molds and jigs between different processes and work steps in the process of fabricating. So it does not need to be mad mold design, performance analysis, and manufacturing, and can save maintain and repair cost of molds and jigs, etc. The applications of this technology have been widely researched and successfully introduced into manufacturing industry for the direct fabricate of the part and dies, and for use in surface repair and modification. Pi et al. (2011) reported laser cladding of a three-dimensional metal sample with a smooth surface with suitable process strategies under the open-loop system. Abioye et al. (2015) applied direct laser metal deposition for functionally graded Ni-Ti microstructures synthesized. Zhang et al. (2007) showed the fully dense and near-net-shaped metallic parts to be directly obtained using laser cladding technology under optimal processing parameters. Williams and Lavery (2017) summarized many research community of different laser cladding applications, namely the welding, cladding, additive layer manufacturing, micromachining and microstructure modification of BMG substrates. Ray et al. (2014) applied laser cladding for improving the service life of lateral rolls about high-temperature wear and corrosion. Complex and heterogeneous parts highly appreciate this process. In their study, the methods of optimized process parameters can be used to better optimize the process parameters to obtain a good performance part using laser cladding technology to fabricate. So, the process parameters optimize is very important to reduce the defects and improve the quality. Transmission nut of EPB system of the car is cold-forging first, and then fabricates in machining. The molds performance requirement is high, the cold-forging process is complex, the mold design is time-consuming and the die-life is short. Therefore, it led to high manufacturing cost and long manufacturing cycle. The influence of process parameters (inherent parameters and the sending powder form is powder-bed) on the specimen quality were investigated by Calignano (2018); Sing et al. (2018) and Fatemi et al. (2017). The sending powder form is powder-bed which is more conductive to the fabricating of complex parts. And transmission nut is similar to thin wall and step-hole part. Compared with the powder-bed fusion process, the coaxial powder feeding has higher efficiency and lower cost. So this paper hopes to research the laser cladding process parameters and apply in the manufacture of

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https://doi.org/10.1016/j.jmatprotec.2018.06.023
Received 18 January 2018; Received in revised form 15 May 2018; Accepted 18 June 2018
Available online 20 June 2018
0924-0136/

transmission nut to reduce cost using laser cladding technology.

As a new manufacturing method, the process parameters optimize and control in laser direct fabrication processing has been widely studied for researchers and different scientific research teams. By measuring the property of the parts under various process parameters in the manufacturing process, the specific influence rules of the particular parameters on the parts were studied. Song et al. (2016) studied the influence of scan speed on specimen properties during laser cladding. They showed that a rational high scan speed is beneficial to enhance the high hardness (7.6 GPa) and high elastic modulus (136.8 GPa) of the Ti6Al4V coating and to obtain 60–400 nm grains. He et al. (2013) studied the influencing rule of scanning pattern on the edge collapse of solid parts. The results showed that the molten pool starts to collapse as the inclination angle increases to about 25°–32° in the inside-to-edge scanning pattern. Gao et al. (2014) investigated the influence of laser re-melting on geometry and overlapping pores of cladding coating. The results showed that re-melting process is an effective method to improve the surface smoothness and remove the overlapping pores easily. Sun et al. (2010) studied the effect of scan speed on parts properties. The results indicated that the volume of retained austenite in the alloyed layer increased, micro-hardness and wear resistance increased with the increase of scan speed. Ocelík et al. (2012) tested few specially designed strategies about the beginning and the end of the laser track overlapping in the same area. They found that the 'Gradient powder' and the 'Variable defocus' set-ups are the best methods to ensure a suitable cladding in Start/Stop zone and at the Start/Stop zone, the morphology of the clad track is irregular. Riquelme et al. (2016) optimized the process parameters to improve the cladding track properties. The results showed that the focused manner is optimal laser focus and the smaller distance between the laser lines can get a smaller melted and heat affected zone. Arias-González et al. (2017) researched the suitable processing parameters to generate phosphor bronze coatings. With the hardness improved 56% compared with cast bronze, they proposed the results as a method to create a substitute bronze surface in an area of a shaft. Wang et al. (2017) investigated the effects of energy distribution on characteristics (tensile, residual stress, hardness and microstructure properties) using a series of thin-walled parts which were produced with different laser parameters. The results showed that the ultimate tensile strength of the specimens paralleled to scan speed present is higher than the perpendicular specimens, while the elongation has a contrary case. Zhang et al. (2017) studied the effects of N_2 addition in shielding gas on microstructure evolution and localized corrosion behavior of weld. The results proved that the microhardness of the heat affected zone slightly increased when adding 2% N_2 in pure Ar shielding gas. Yadaiah et al. (2016) investigated the characteristic difference between a self-protective atmosphere of argon and open atmosphere during laser welding. The results showed that the weld bead dimension of self-protective atmosphere decreased 40% (maximum) and the penetration depth increased 29% (maximum), compared with the open atmosphere.

Although many researchers are studying some main issues in laser cladding processes, and have achieved some results, there still some parameters which are important in fabricating and controlling part processes need to study. They are mainly focused on studying the influence of process parameters which caused by instruments and equipment on the forming parts. The cladding processes are rarely studied, like scanning and lap joint modes, trajectory planning and cladding sequence and process planning. In actual cladding process, some systematic error cannot be eliminated. It can only be weakened or eliminated by subsequent process design. Therefore, this paper focuses on the trajectory planning and cladding sequence, hoping to reduce the system errors in manufacturing process.

On the bases of these studies, this paper focuses on optimization process parameters (the vertical lift, scanning paten, lap joint modes, cladding sequence and other parameters) of the part in laser cladding. The objective of this paper is to optimize the process parameters which can reduce cracks and pores, improve the performance of the forming parts. This paper discussed the influence rules between the qualities of the forming parts and laser cladding parameters, studied the value of the vertical lift to verify its effect on the stability of cladding process, and also studied the process parameters to verify its effect on the internal defects and metallurgical bonding strength.

2. Experimental procedure and setting

2.1. The open-loop system of DLF

The hardware part system of the open-loop system for DLF process consists of a 500 W YLR-500 optical fiber laser, a powder feeder, a laser cladding head with a coaxial powder nozzle, a water cooler, and a KUKA robot. The laser is continuous multimode optical fiber; wavelength is 1020 nm, the spot diameter is 2 mm, laser beam quality is 8mard■mm, and good stability is very propitious for the demand of DLF process. The powder feeder is made of RAYCHAM for conveying powder metal material in laser cladding system. KUKA robot has six freedom degrees with a laser cladding head at the actuator of the sixth freedom degrees. In this study, the fourth freedom degree and fifth freedom degree were fixed, the sixth freedom degree as can as possible to ensure approximately 90°. During the manufacturing process, the YCF101 alloy was conveyed to the molten pool through the laser beam, the solidified into a single channel, multichannel, multilayer, forming parts respectively. The circular coaxial powder nozzle shows in Fig. 1.

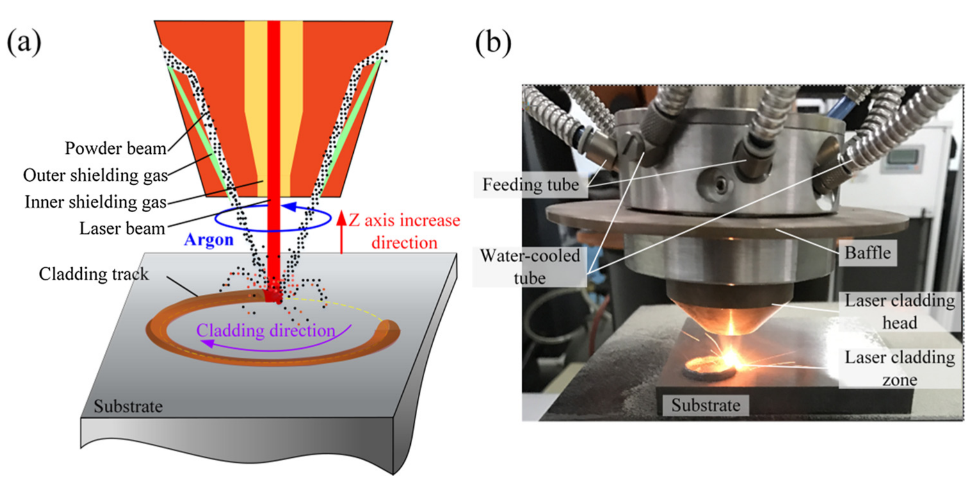

Fig. 1. Circular coaxial powder nozzle for DLF process.