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The Influence of Ring Inside-Laser Coaxial Powder Feeding Process Parameter on Forming

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Abstract. This experiment uses the shower nozzle of the ring laser inside-laser coaxial powder feeding for single channel /layer, defocusing, and multi-channel lap cladding. This study investigates the influence of process parameters (such as the laser power) on forming size and surface morphology. In certain limits, the cladding layer height and width are in positive correlation with laser power and powder feeding rate, and in negative correlation with scanning velocity. When the lap coefficient is 50%, the forming quality is high.

Introduction

At present, the laser cladding on metal parts rapid forming technology is the research focus in the field of rapid forming. In forming manufacturing, high energy laser beam and melted material couple accurately. Metal material accurately, evenly, and stably gets into the laser spot, which is in dynamically scanning movements according to predetermined tracks. It mainly has the following advantages [1-5]: The interface is metallurgical combination, and the organization is very fine; The composition of cladding layers, dilute rate and cladding layer size are controllable and thermal deformation is small; It is easy to realize constituency cladding and process automation. The mainly used powder feeding way is outside-laser powder feeding with the existing direction problem, which limits parts accuracy in the manufacturing process. A new laser powder coupling rapid forming system is studied, based on the ring inside-laser powder feeding, which realizes the real sense of "laser powder coaxial". The ring laser spot surrounds powder spot, and powder utilization rate increases greatly, which can eliminate the influence of direction, and produce parts with high-quality surface. This paper researches the factors influencing laser cladding rapid forming, which would provide coaxial powder feeding cladding manufacturing with important reference.

Experimental Scheme

Circular inside-laser coaxial powder feeding processing principle is shown in Fig.1. The laser path system can produce ring focus laser beam of hollow pour cone, and the focusing system uses reflection focus; the hollow area is used to decorate the coaxial powder feeding tube, and metal powder vertically drops to the processing area.

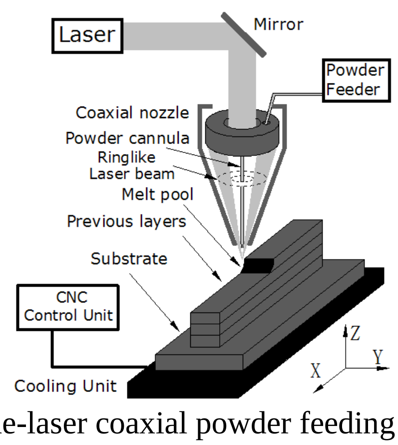


Fig.1. Circular inside-laser coaxial powder feeding processing principle

The experiment uses GS-TFL-10 KW CO2 gas laser with multimode. The alloy powder Fe313 is used for this experiment on the substrate, made of 45 steel, with thickness of 10 mm.

Experimental Results and Discussions

The influence of the laser power on the quality of the cladding layer. As shown in Fig .2, the scanning velocity= 6mm/s, powder feeding rate= 5.78g/min, gas load= 300L/h, laser spot diameter = 1.8mm, with the improvement of the laser power, the cladding layer height and width are increased.

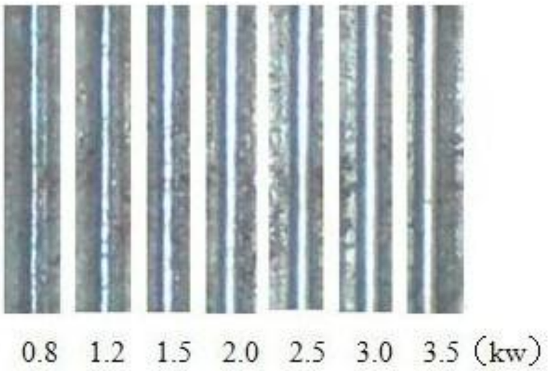


Fig.2. The surface morphologies of cladding layers with different laser powers

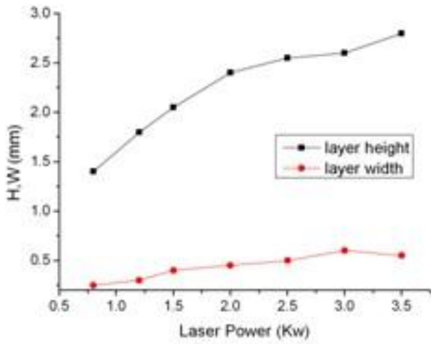


Fig.3. The influence of laser power on the surface of cladding layers

It is shown in Fig .3 that when the laser power is 0.8kw or 1.2kw, a large number of powder particles adhere to the cladding layer surface, and cladding layer height and width are small, as a result of the laser power being too low; Because the laser energy is not enough to melt metal powder, therefore the melting and forming rate of the metal powder is low, and the cladding layer surface roughness increases. With the increase of the laser power, in the unit of time the molten metal powder increases accordingly, which increases the forming width and height; On the other hand, due to the limit of powder feeding rate, when laser power is too high, it will increase the depth of molten pool; When the liquid metal surface tension can't compete with its gravity, the liquid metal will slide along the two sides to the lower until the molten pool becomes wider and shallower which will make both regain new balance, and the cladding layer height will decrease.

From the experimental results above, the laser power 2.5kw is the best forming power under the experimental conditions. The forming width is stable, and surface smooth precision is high.

The influence of the scanning velocity on the quality of the cladding layer. The surfaces of cladding layers are shown in Fig.4, with different scanning velocities, and powder feeding rate= 5.78g/min, laser power = 2.5kw, gas load= 300L/h, laser spot diameter= 1.8mm. The canning velocity is 5, 6, 7, 8, 9, 10mm/s respectively.

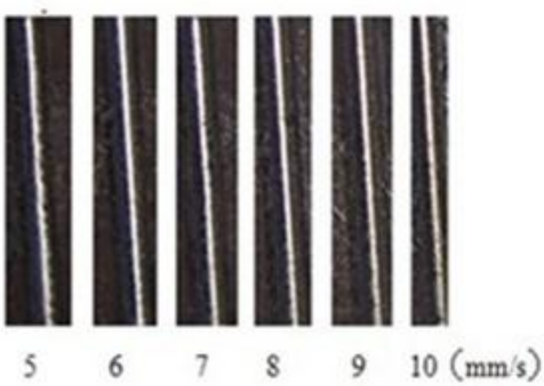


Fig.4. Cladding layer surfaces with different scanning velocities

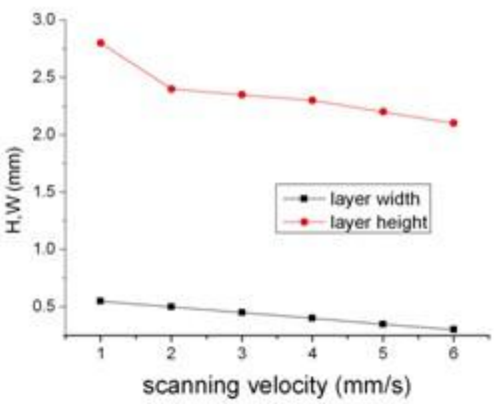


Fig.5. The influence of scanning velocity on the surface of cladding layers

With the scanning velocity increased, the cladding layer height and width are reduced(as shown in Fig .5). When the scanning velocity is slow, it has a significant influence on the cladding layer height and width; when it is higher than 9mm/s, the forming height changes to slow down. The laser energy and powder supplement both led to this change trend: When the laser power is constant, along with the scanning speed increased, the interaction time of laser beam and powder reduces, so the energy metal powder absorbs reduces. Heat transmitts through the width direction, which makes more than half of the melting temperature area reduce; At the same time the substrate surface absorbs fewer laser beams, so the cumulative total energy reduces; Therefore the cladding layer will narrow down; On the other hand, with the scanning velocity increased, the supplement of metal powder in molten pool will be reduced, so the cladding layer height will decrease.

The influence of the laser spot diameter on the quality of the cladding layer. As shown in Fig .7(powder feeding=3g/min, laser power=2.5Kw, scanning velocity=6mm/s), when the other parameters are constant, the cladding layer width increases with the defocusing increased, and gradually turns gent; There is an approximately linear relationship between defocusing and cladding layer width, so increasing the defocusing can improve the speed of forming. Along with the increase of the defocusing, the laser power density decreases; when the laser power density is lower than some critical value, powder can't be fully molten, the cladding layer surface become coarse, and the forming precision reduced. As shown in Fig .6, when the laser spot diameter is 7 mm, the cladding layer surface is rough; when the laser spot diameter is 4mm, good cladding layers can be gotten, and the focal depth of laser can get 14mm.

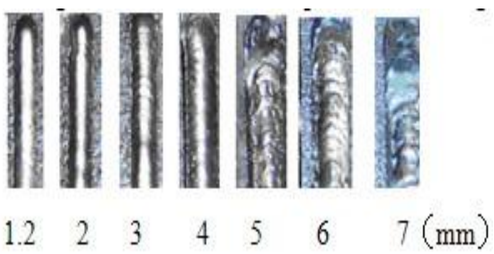


Fig.6. Cladding layer surface morphologies under different spot diameters

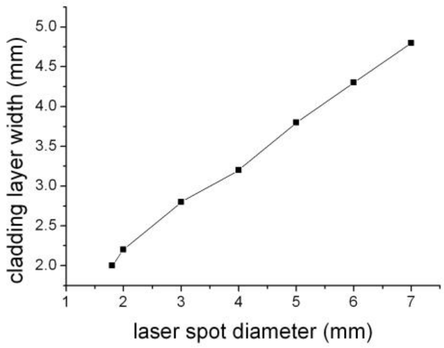


Fig.7. The relationship between laser diameter spot and cladding layer width

The influence of the powder feeding on the quality of the cladding layer. Stable powder feeding rate is the key factor to good forming,and the two pipes carrying gas to feed powder satisfies this need, in this experiment.

NO.1 NO.2 NO.3 NO.4 NO.5 NO.6 NO.7 NO.8

(a)(The surface morphologies of the molten way)

(b)(The profile morphologies of the molten way)

Fig.8. Cladding layer surface morphologies with different powder feeding rates

In this experiment, laser power=2kw, scanning velocity=5mm/s, laser spot diameter=1.8mm, gas load of 300L/h. Because of the unclosed-loop, in the forming process, the z axis increment is artificially regulated. The amount of cladding layers and powder-feeding quantity are shown in Table 1, and the cladding layer morphologies are shown in Fig .8.

Table 1.Single- channel multilayer cladding process parameters and forming parameters

Powder feeding rate (g/min)	Scanning layer	Height (mm)	Width (mm)	Number
0.96 (3)	10	1.24	1.48	1
1.28 (4)	8	1.5	1.58	2
1.59 (5)	8	1.72	1.66	3
3.00 (6)	8	1.88	2.08	4
3.48 (7)	8	2.24	2.16	5
4.58 (8)	8	2.32	2.48	6
4.86 (9)	8	2.5	2.66	7
5.78 (10)	8	2.68	3.0	8

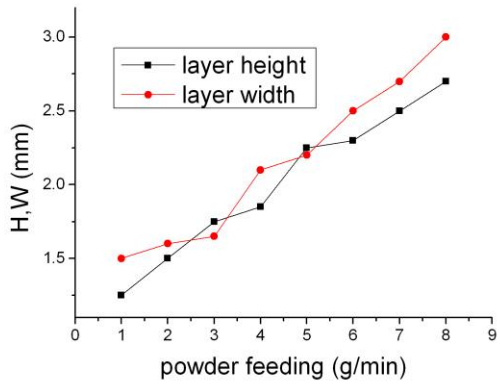
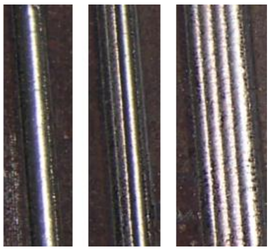


Fig.9. The influence of powder feeding rate on the surface of cladding layers

It is shown in Fig.9: In a certain range, when the powder feeding rate is relatively slow,the forming height is susceptible to the change of the powder feeding rate; However, when the powder feeding rate is more than 3.48g/min, the forming height increases slightly with the scanning velocity increased. The width increases with the increase of the powder feeding rate.

The influence of the overlapping quantity on the quality of the cladding layer. The energy distribution of the ring laser is that energy on both sides of the laser spot is high, and energy is even in the center. Therefore, in the single layer cladding process, the metallurgical combination between both sides of the molten pool and substrate is good, and it is not prone to turn out defects. In the experiment, the lap coefficient is 33%, 50%, 67% respectively, and the experimental result is shown in Fig.10.When the lap coefficient is 67%, the latter cladding layer is higher than the former cladding layer; When the lap coefficient is 30%, there is an apparent "valley" between the two channels, and wave shape surfaces are formed; When the lap coefficient is 50%, the lap effect is ideal, and the smooth surface of the cladding layer is gotten.



67% 50% 30%

Fig.10. The forming surface precision with different lap coefficients

Conclusion

Process parameters of ring inside-laser coaxial powder feeding, such as laser power, powder feeding rate, and scanning velocity have significant influences on the single channel cladding layer surface morphology:

The cladding layer height and width are increased with the laser power improved; The laser power also has an obvious influence on the surface accuracy of cladding layers.

The cladding layer height and width are reduced with the scanning velocity increased; When it is greater than 9 mm/s, the change of the forming height slows down.

When the other parameters are constant, the cladding layer width increases with the defocusing increased, and gradually turns gent; there is an approximately linear relationship between defocusing and cladding layer width, so increasing the defocusing can improve the speed of forming.

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