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EXPERIMENTAL STUDY OF FORMING RENE95 ALLOY PARTS BY LASER CLADDING

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ABSTRACT

In this paper, experimental study of forming metal parts by laser cladding Rene95 alloy powder was reported. The influence of main process parameters, such as laser power, scanning speed and laser beam diameter, on the thickness, width and the angle of the laser cladding track was investigated. The microstructures of laser cladding parts were studied and compared with those of common casting parts. The obtained Rene95 metal parts formed by laser cladding are dense and of high strength.

Keywords: Laser cladding, Rene95 alloy, rapid prototyping

1. INTRODUCTION

The working principle of forming metal parts by laser cladding is similar to that of Rapid Prototyping. The three-dimensional CAD model of the part is developed in computer, the CAD model is then sliced into a series of 2D planar layers. The computer obtains the instructions of the scanning track for each layer and controls the movement of the NC table. The metal powders are delivered into the laser melting pool by a powder feeding apparatus. Laser energy melts the metal powder. The melted metal powder becomes the cladding layer and combines either with the substrate materials when cladding the first layer or with the previous cladding layer after the first layer has been formed. The cladding layer combines with the substrate material or with other cladding layers metallurgically. After cladding a layer, the laser head rises a height equal to the thickness of the next layer, then clads the following layers until the whole part is finished. The final 3D metal part is obtained after some post processing such as mechanical machining of the metal parts.

The main difference between laser cladding forming and other rapid prototyping is that the parts formed by laser cladding are very dense. Its density can achieve and exceed the parts manufactured by casting or forging.

Rene95 is a kind of high-temperature alloy. In aviation industry, Rene95 alloy powder is used to manufacture the turbine dish of aviation engines. Currently, the traditional method for manufacturing such turbine dish is to form the green product by powder metallurgy first, then machine the green product to the final product. The cost of manufacturing turbine dish using this method is very high because the powder is very expensive while the waste of the alloy material is very large. Laser cladding forming is a promising method for the manufacturing of turbine dishes. Experimental study of laser cladding forming was carried out to explore the optimal process conditions.

2. EXPERIMENTAL APPARATUS

The schematic diagram of the experimental apparatus is shown in Fig. 1.

The laser used in the experiments is a 5KW RS850 CO_2 laser. The JPSF-I powder feeder uses N_2 to deliver the powder material. The powder nozzle has a special construction. The Ar shade is coaxial with the powder stream. The Ar shade restrains the powder stream so that the powder stream can be both thin and straight. This design can improve the precision of laser cladding and can prevent the powders in laser pool from oxidation.

3. EXPERIMENTAL MATERIALS

The substrate material is A3 steel. Before laser cladding, the rust on the substrate is removed using sand-paper and the oil dirt is removed using eradicator. The powder material used in laser cladding is Rene95. Its grain is 100 to 200 mesh. Its chemical compositions are shown in Table 1.

Before laser cladding, the powder has to be parched at 110°C for two hours in a vacuum drying cabinet in order to remove the hydrosphere in the powder.

4. PARAMETER OPTIMIZATION

The technology of laser cladding forming is to manufacture 3D parts by cladding a series of thin layers. In order to clad a good 3D part, one must ensure high quality cladding of every layer. For each cladding layer, the thickness, width and angle of the cladding track are the most important. In laser cladding, laser power, laser scanning speed and laser beam diameter are the major process parameters. The influence of the process parameters on the thickness, width and angle (Defined in Fig.2) of the cladding track is studied in order to find the optimal process parameters for laser cladding.

The designed laser beam scanning tracks are shown in Fig. 3. Process parameters such as laser power, scanning speed and laser beam diameter are changed systematically to find the optimal process condition.

The temperature of the substrate material will rise during laser cladding. In order to reduce the influence of temperature rise of the substrate material during laser cladding, the first three cladding tracks are not used for measurement. It is supposed that the temperature of the substrate stabilizes after the first three laser cladding tracks.

After laser cladding, the middle section of the cladding track is cut with wire cutting. The cutting is vertical to the substrate surface and the cladding track. The thickness and the width of the cladding track are then measured using calipers.
The experimental results showing how laser power, laser scanning speed and laser beam diameter affect the cladding thickness and cladding width are shown in Fig. 4, 5 and 6.

Laser power relates directly with the heating energy of the powder. The larger the laser power, the larger the thickness and width of the cladding track. Scanning speed reflects the time of laser heating of the powder. The higher the scanning speed, the smaller the thickness and the width of the cladding track.

From Fig. 4, 5, and 6., it is seen that the thickness and width of the cladding track are proportional to the laser power when laser scanning speed and laser beam diameter are kept unchanged. The thickness and width of the cladding track is inversely proportional to the scanning speed when laser power and laser beam diameter are kept constant. When laser power and scanning speed are fixed, the thickness of the cladding track is inversely proportional to the diameter of laser beam, but the width of the cladding track is proportional to the diameter of laser beam.

The angle of the cladding layer is defined in Fig. 2. The influence of laser power, scanning speed and laser beam diameter on the angle of cladding track is as following.

When the scanning speed and laser beam diameter are fixed, the angle of the cladding track will decrease if laser power increases. The thickness of the cladding track increases with the increase of laser power, which tends to decrease the cladding angle. In the same time, the width of the cladding track increases with the increase of laser power, which tends to increase the angle of the cladding track. Because the angle decrease due to the increase of cladding thickness is larger than the angle increase due to the increase of cladding width, the angle of the cladding track decreases with the increase of laser power.

When laser power and laser beam diameter are fixed, the angle of the cladding track will decrease if scanning speed decreases. The cladding thickness increases with the decrease of scanning speed, which tends to decrease the angle of the cladding track. In the same time, the cladding width increases with the decrease of scanning speed so that the angle of cladding track would increase. Because the angle decrease due to the increase of cladding thickness is larger than the angle increase due to the increase of cladding width, the angle of the cladding track decreases with the decrease of scanning speed.

When laser power and scanning velocity are fixed, the angle of the cladding track increases obviously with the increase of laser beam diameter. The cladding thickness decreases with the increase of beam size, which tends to increase the angle of the cladding track. The cladding width increases with the increase of beam size, which also tends to increase the angle of the cladding track. Therefore, the angle of the cladding track will increase sharply with the increase of laser beam diameter.

5. SAMPLE ILLUSTRATION AND MICROSTRUCTURE ANALYSIS

Using the optimized process parameters, very dense metal parts of Rene95 alloy with good dimensional precision was formed using laser cladding as show in Fig 7. The part is accurate, dense, and of high strength.

The microstructure of the casting and laser cladding parts of Rene 95 are show in Fig. 8.

From Fig. 8, it is seen that the separation distance of the once branch crystal in common casting is 200-300 microns. The separation distance in laser cladding is only 10-20 microns, more than 10 times finer. This indicates that laser cladding has the potential of getting higher quality Rene95 parts than common casting.

6. CONCLUSIONS

(1) Experimental studies revealed the relationship between cladding thickness/width/angle and major process parameters such as laser power, scanning speed and laser beam diameter as following:

When laser scanning speed and laser beam diameter are fixed, the cladding thickness and width are directly proportional to laser power and inversely proportional to scanning speed. When laser power and scanning speed are fixed, the cladding thickness is inversely proportional to laser beam diameter and the cladding width is directly proportional to laser beam diameter.

When laser scanning speed and laser beam diameter are fixed, the angle of the cladding track decreases as the laser power increases, but the rate of decrease is small. When laser power and laser beam diameter are fixed, the angle of the cladding track decreases as the scanning speed decreases, the decreasing rate is also small. When laser power and scanning speed are fixed, the angle of cladding track increases obviously as laser beam diameter increases.

(2) Comparing the microstructure of laser cladding with that of casting, the microstructure of laser cladding is finer an order of magnitude than that of common casting. This indicates that laser cladding has the potential of getting higher quality Rene95 parts than common casting.

(3) Through parameter optimizing experiments, compact metal parts with a definite precision and high strength were obtained.

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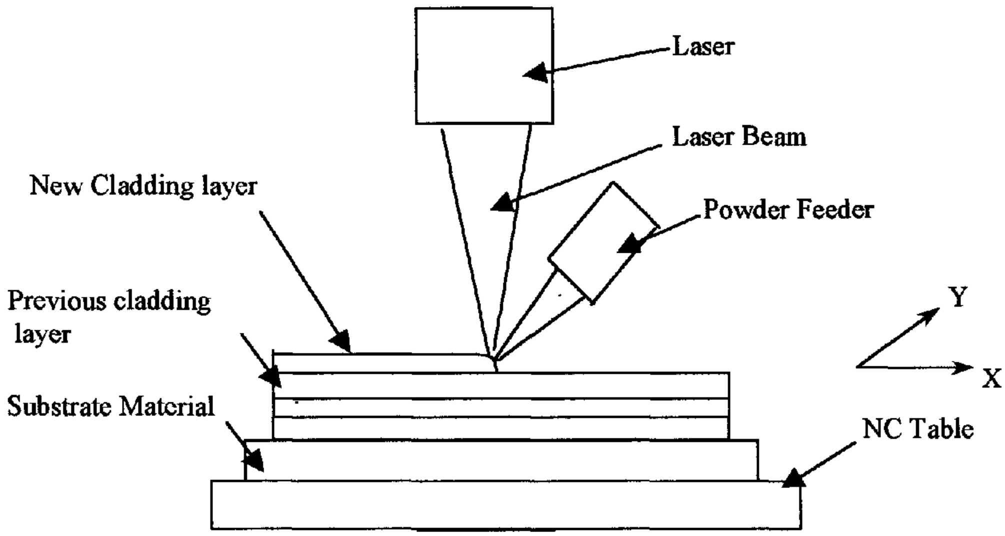


Fig. 1 The schematic diagram of the experimental apparatus

Table 1. Chemical composition of Rene95 alloy powder

C	Cr	Co	Al	Ti	Mo	W	Nb	Zr	B	Ni
0.04~ 0.09	12~14	7~9	3.3~ 3.7	2.3~ 2.7	3.3~ 3.7	3.3~ 3.7	3.3~ 3.7	0.03~ 0.07	0.006~ 0.015	other

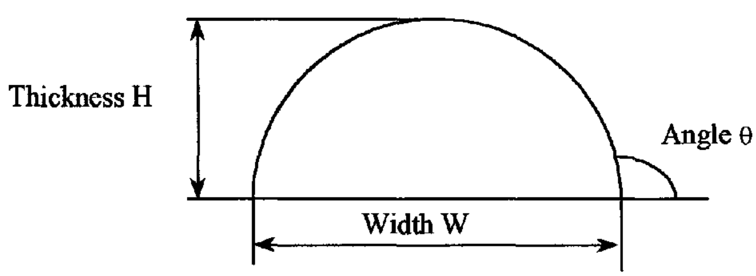


Fig.2 The cross section of the laser cladding track

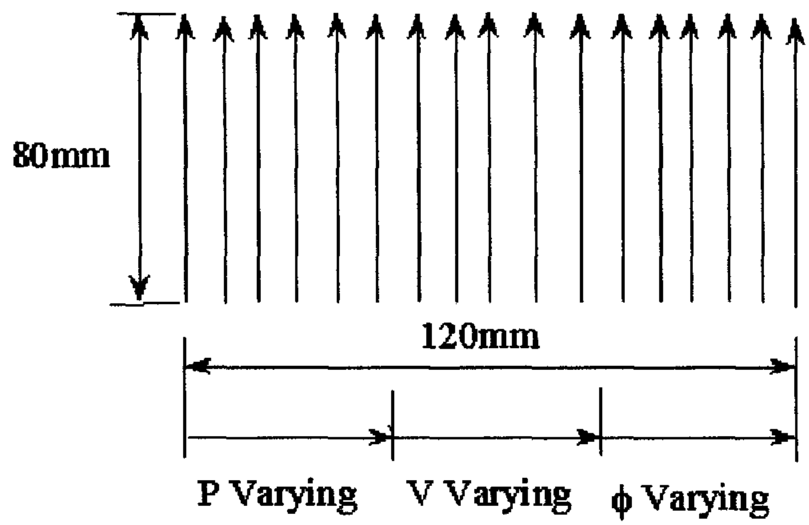


Fig. 3 The scanning track and the method of parameter variation in experiments

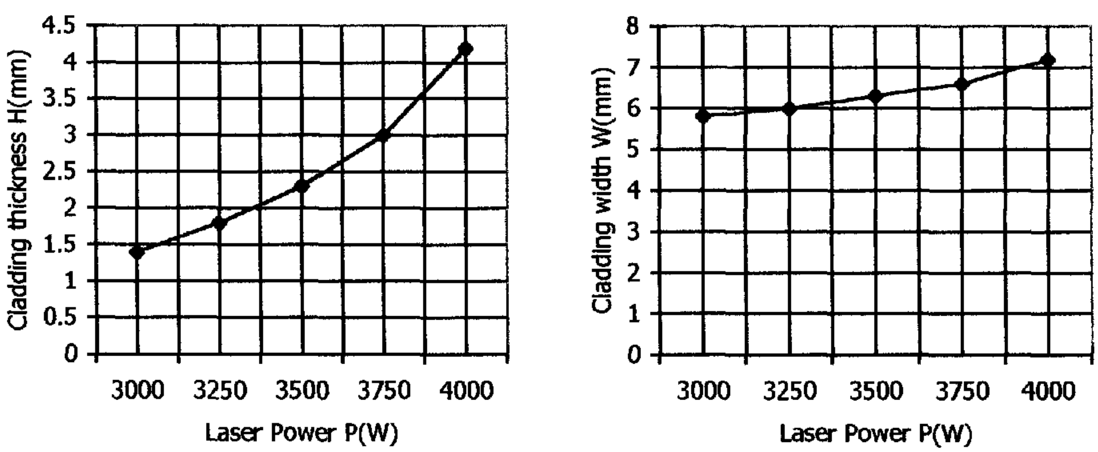


Fig. 4 The influence of laser power on laser cladding thickness and width when scan speed V is 5mm/s, laser beam diameter D is 5mm, delivering powder G is 9g/min delivering gas Q_1 is 220 l/h, restraining gas Q_2 is 3.5ml/min.

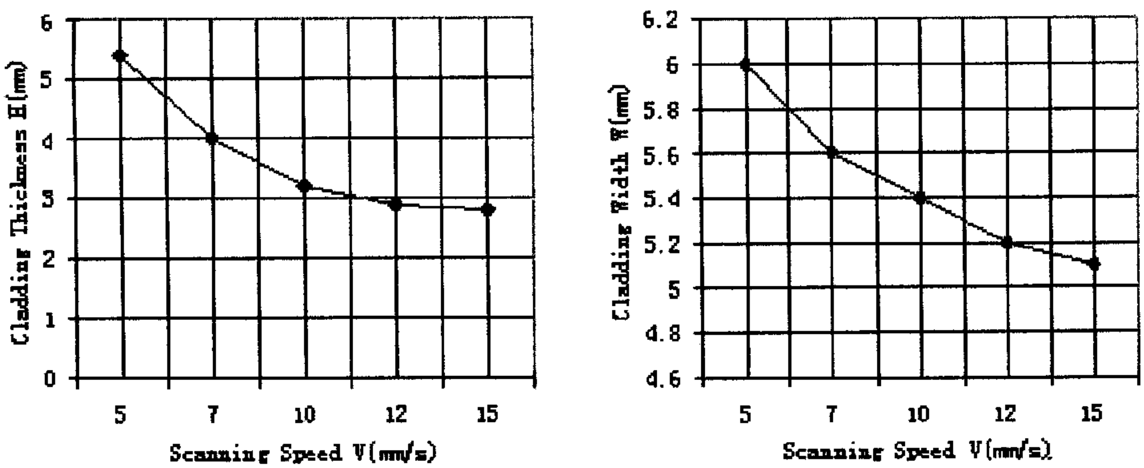


Fig. 5 The influence of scanning speed on laser cladding thickness and width when laser power P is 4000W, laser beam diameter D is 5mm, delivering powder G is g/min, delivering powder gas Q_1 is 220 l/h, restraining gas Q_2 is 3.5ml/min.

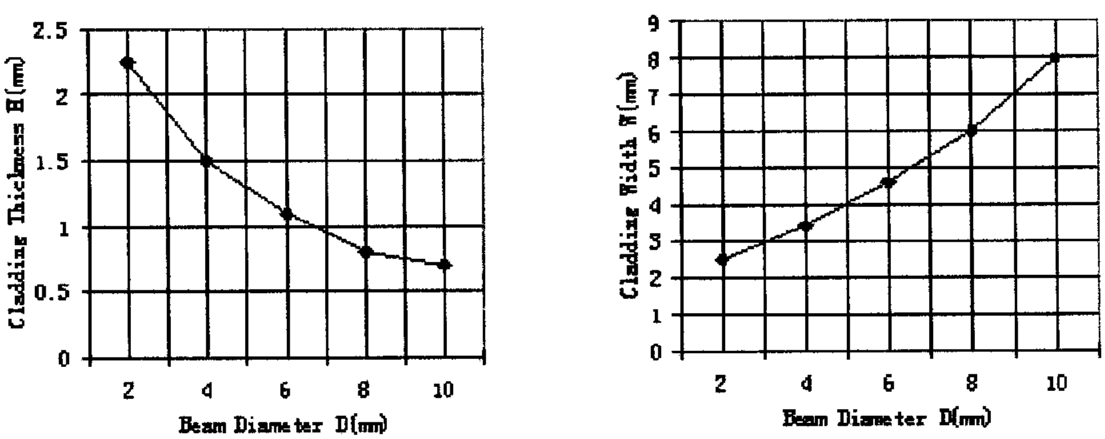


Fig. 6 The influence of laser beam diameter on laser cladding thickness and width when laser power P is 3000W, scanning speed V is 5mm/s, delivering powder G is 9g/min, delivering powder gas Q_1 is 220 l/min, restraining gas Q_1 is 3.5ml/min.

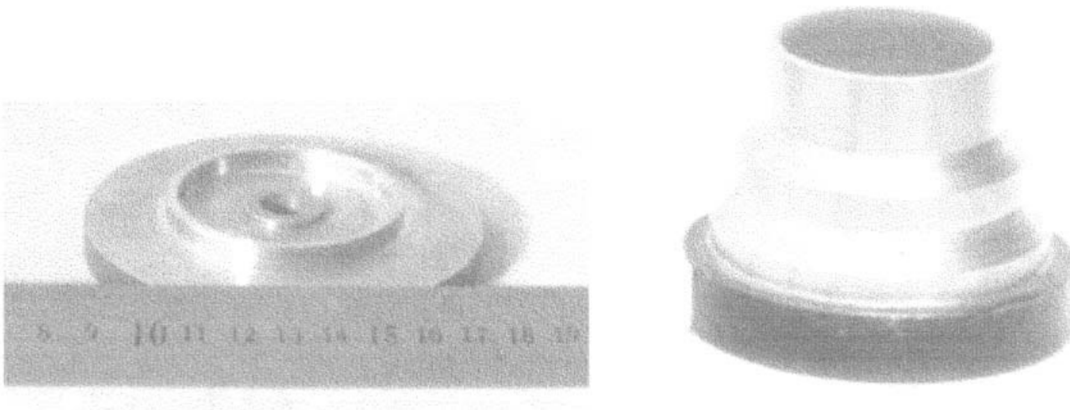
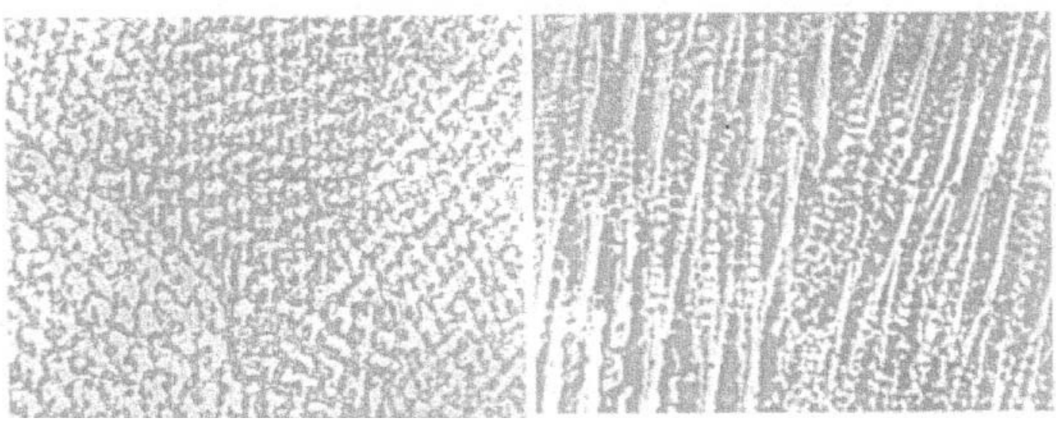


Fig. 7 Metal parts of Rene95 formed by laser cladding



(a) (×40) (b)(×400)

Fig. 8 Microstructure of Rene95 (a) casting, and (b) laser cladding

