Effect of Laser Cladding Process Parameters on Microstructure of Titanium-aluminum Composite Coating

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Abstract. The 3D printing powder Ti-48Al-2Cr-2Nb was selected, a mixed powder of 1% hBN and 1% TiC was added, and 21-4N steel was used as the substrate, and the above coating was prepared by laser cladding technology. Scanning electron microscope (SEM) and micro hardness tester were used to study the effect of laser power and scanning speed on the microstructure and properties of the cladding layer. The results show that the coating on the substrate is not formed when the laser power is 1000W, and the coating is burnt yellow when the power is 1300W; when the power is 1200W, the coating on the substrate is well formed and the coating quality is not defective when the scanning speed is 400mm/min.

1. Introduction
Since the 1980s, laser cladding technology has begun to appear in people's field of vision and has attracted more and more attention [1-3]. As a new technology, laser cladding technology shows great advantages in improving the surface strength and hardness of materials. The powder feeding methods of laser cladding are mainly divided into synchronous powder feeding type and preset type. The main raw materials it is mainly based on powder [4]. In recent years, it has been widely used in aerospace, automobile manufacturing and other fields [5]. Titanium-aluminum intermetallic compounds mainly have anti-corrosion, anti-oxidation and flame-retardant capabilities, so that they have a broad market prospect, and the manufacturing cost is even lower than the cost of steel materials [6]. However, the current research is still mainly on the performance of materials, and there is no in-depth discussion on the performance of laser cladding. Therefore, the study of laser cladding process parameters is conducive to in-depth understanding of the performance of titanium and aluminum materials.

2. The preparation of titanium aluminum coating
Laser cladding method was used to prepare Ti-48Al-2Cr-2Nb, hBN, TiC powder to prepare Ti-48Al-2Cr-2Nb coating technology. Taking 21-4N steel as the base, the size of the base is 40mm × 20mm × 6mm. In the completely mixed particles, Ti-48Al-2Cr-2Nb coating was synthesized on the laser machine with 1% hBN+1% TiC powder. The technological parameters of laser cladding are shown in Table 1.
### Table 1. Laser cladding parameters.

| Sample | Shield gas flow | Spot diameter | Powder feeding rate | Laser power | Scan speed | Remarks  |
|--------|-----------------|---------------|---------------------|-------------|------------|----------|
| 1      | 12L/min         | 1mm           | 7L/min              | 1000W       | 400mm/min  | Unformed |
| 2      | 12L/min         | 1mm           | 7L/min              | 1000W       | 500mm/min  | Unformed |
| 3      | 12L/min         | 1mm           | 7L/min              | 1000W       | 600mm/min  | Unformed |
| 4      | 12L/min         | 1mm           | 7L/min              | 1200W       | 400mm/min  | Unformed |
| 5      | 12L/min         | 1mm           | 7L/min              | 1200W       | 500mm/min  | Unformed |
| 6      | 12L/min         | 1mm           | 7L/min              | 1200W       | 600mm/min  | Unformed |
| 7      | 12L/min         | 1mm           | 7L/min              | 1300W       | 400mm/min  | Charred  |
| 8      | 12L/min         | 1mm           | 7L/min              | 1300W       | 500mm/min  | Charred  |
| 9      | 12L/min         | 1mm           | 7L/min              | 1300W       | 600mm/min  | Charred  |

Before laser cladding, the substrate of 21-4N steel is sanded with 400, 600, 800, and 1000 mesh sandpaper, and then ultrasonically cleaned for 10 minutes to remove contaminants such as dust and rust. Ti-48Al-2Cr-2Nb, hBN, TiC mixed powder is ball milled in a ball mill for 2h, and the ball mill speed is 210rpm (of which Ti-48Al-2Cr-2Nb powder uses 3D printing powder provided by Beijing Zhonghang Meite Powder Control Technology Co., Ltd., hBN, TiC powder is spherical powder with a purity of 99.9%). The preparation method adopts the synchronous powder feeding method, after the preparation is completed, the sample line is cut into 10mm×10mm×10mm samples for experimental research.

### 3. Composition and microstructure of Ti-48Al-2Cr-2Nb coating

#### 3.1. Unshaped microstructure and fracture morphology

Samples prepared with laser power of 1000W, scanning speeds of 400mm/min, 500mm/min, and 600mm/min have many cracks on the surface of the sample and light tapping will result in small metal pieces falling off from the surface layer. Find one of these small metal blocks for crack fracture analysis. Observation by SEM scanning electron microscope revealed that the crack fracture was relatively flush and there were a few bright planes. The morphology of the fracture was observed and analyzed by scanning electron microscope. Figure 1 is a scan of the cross-sectional morphology of a low-power SEM scanning electron microscope. It is observed that there are many tearing edges on the fracture. Fig. 2 and Fig. 3 are the scans of the fracture morphology of the high power SEM scanning electron microscope at a certain section. According to the comprehensive judgment of the scanning electron microscopy topography of Figure 2 and Figure 3, the fracture is relatively flat, and the fracture is judged to be brittle fracture, and the fracture of the cladding layer is brittle fracture. In the two fracture diagrams in Figure 2 and Figure 3, it is found that there are protruding points at the end points, and EDS point scanning is performed on the protruding points. The point scanning is shown in Fig. 4 and Fig. 5. According to the results of EDS point scanning, it is found that the more elements of the protruding points are still Ti and Al. In summary, the main reason for the unformed three samples with a laser power of 1000W is that the laser power is too small or the above three scanning speeds are fast, which causes a part of Ti and Al to be unmelted and the coating is not formed.
Figure 1. The fracture morphology of SEM scanning electron microscope (107 times).

Figure 2. SEM scanning electron microscope fracture morphology (350 times).

Figure 3. SEM scanning electron microscope fracture morphology (400 times).
3.2. Microstructure analysis of shaped specimens

The laser cladding process is a very fast process of heating and solidification. In laser cladding, especially in the process of multi-layer cladding, cracks are easy to occur, and cracks are an inevitable shortcoming in the laser cladding process.

Figures 6, 7, and 8 are scanning electron microscope observations of cracks formed on the surface of the coating. From the analysis of three sets of samples with a laser power of 1200W, when the laser power is constant, as the scanning speed increases, the surface cracks of the coating gradually increase and the surface is more uneven. The main reason for this phenomenon is that the laser scanning speed gradually increases, the melting speed of the molten pool and the cooling rate of the sample surface are not the same, so that the stress is different at each position, thereby forming cracks. Three sets of samples with a laser power of 1300W were observed to have a burnt yellow surface after preparation. The main reason for this phenomenon is that the laser cladding powder is burned more seriously due to the excessive laser power.
3.3. Hardness of Ti-48Al-2Cr-2Nb coating

Measure from the top of the cladding layer, take a point measurement every 100μm down, measure the microhardness three times at each point, and take the average value. Finally, draw the curve based on the above microhardness data, as shown in Figure 9.
4. Conclusion
Titanium-aluminum coating made of mixed powder of Ti-48Al-2Cr-2Nb and 1%hBN and 1%TiC was prepared by laser cladding synchronous powder feeding method. The effect of different laser cladding parameters on the microstructure of the coating was studied. The research results can draw the following conclusions.

(1) When the laser power is 1000W and 1300W, the coating is not formed. The main reason for the unformed coating with a laser power of 1000W is that the laser power is too small or the scanning speed is too fast. When the laser power is 1300W, the main reason why the coating is not formed is that the laser power is too large, which causes the surface to be scorched.

(2) When the laser power is 1200W, the coating is well formed. When the scanning speed gradually increased, it was found that the cracks on the surface of the coating gradually increased. When the laser power is 1200W and the scanning speed is 400mm/min, the coating quality is best without defects.

(3) The microhardness of the substrate is 350HV. The three sets of samples with good coating molding quality and laser power of 1200W have the highest microhardness at a scanning speed of 400mm/min, 923HV, which is about twice the microhardness of 21-4N. When the scanning speed is 600mm/min, the microhardness is the smallest, 625HV, which is about 1.5 times of the microhardness of 21-4N. It can be seen from Figure 7 that there is a clear downward trend in microhardness. The main reason for this phenomenon is to measure a transition from the coating cladding zone to the heat-affected zone, and then the microhardness slowly decreases until the matrix Micro hardness.

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