Experimental study on characteristics of Ti-6Al-4V after plasma spraying

Dai Chunhui, Lao Xingsheng, Liu Yong, Wang Wei

No.19, Yangqiaohu Avenue, Wuhan, Hubei, China

ch.dai@163.com

Abstract. The surface modification of Ti-6Al-4V substrate was carried out by plasma spraying method (WC-17%Co). The surface morphology and composition of the coating were analyzed. Then, under the air environment, the surface of the plasma sprayed WC was carried out. Friction test of three pairs of friction materials filled with 15% glass fiber + 5% graphite, PTFE filled with 25% glass fiber, and PTFE filled with 60% tin bronze. The treated material improves the friction characteristics of the substrate. However, due to the large thickness and hardness of plasma spraying, it is difficult to use sandpaper to reduce the surface roughness, which will affect the dimensional accuracy of the parts.

1. Introduction
Wear is the main reason for shortening the life of mechanical equipment, and the spraying technology can modify its surface[1]. Plasma spraying is a method in which a plasma fox is used as a heat source to heat and accelerate the deposition of powder particles on the surface of a substrate, wherein the particle velocity of the supersonic plasma spraying can reach 600 m/s[2]. Plasma spraying has the advantages of short processing time and high coating quality, and is widely used in various types of equipment[3] to improve the performance of the material[4]. Researchers have carried out more researches on this, such as using TiAl pre-alloy powder plasma spraying to prepare alloy coatings[5,6], using Ti and Al elemental powder plasma spraying to prepare Ti-Al intermetallic compound coatings[7], using Ti and Al ball milling powders to spray coating, and study the reaction and spray products during spraying[8].

The microstructure of the surface modified layer was observed and analyzed by scanning electron microscopy (JEOL JSM-6480). Figure 1 shows the surface topography of the modified sample. It can be seen from Fig. 1 that the surface modified layer prepared by plasma spraying is relatively rough, and the sprayed particles are agglomerated together in a spherical shape, and there are voids between the particles; this is because the sprayed particles form pores in the process of overlapping each other, and the pores are The subsequently sprayed molten particles are covered and embedded to ensure a high bonding strength between the coatings; in addition, there is a partial melting zone on the surface of the coating; from the energy spectrum, the surface layer is mainly composed of W, C, Co and O elements. Composition, W, C and Co are the main components of the coating, and O element is formed by slight oxidative decarburization of WC particles during coating preparation.

After the sample was cut, the sample was mounted, polished, cleaned, etc., the thickness of the coated layer was measured by a metallographic microscope (OM) to a thickness of 80 μm.
2. Friction characteristics experimental scheme

2.1. Friction specimen
The friction sample parameters are listed in Table 1, the friction specimen base material is TC4 titanium alloy, and the plasma sprayed tungsten carbide sample can only be ground to 2.0 μm under the existing conditions due to the excessive hardness.

Table 1. Friction sample parameters

| material   | Sample size | Surface roughness |
|------------|-------------|-------------------|
| Substrate  | Φ30mm*10mm  | ≤0.9μm            |
| WC-17%Co   | Φ30mm*10mm  | 2.0μm             |

2.2. Friction sample
There are three types of friction materials, as shown in Table 2. The end portion having a diameter of 2 mm and a height of 3 mm is a contact end with the disk sample.

Table 2. Friction material

| name    | material                                         |
|---------|--------------------------------------------------|
| Material A | Filled with 15% glass fiber and 5% graphite polytetrafluoroethylene |
| Material B | Filled with 25% glass fiber PTFE                |
| Material C | 60% tin bronze PTFE                             |

2.3. Experimental condition
The experiment adopts the pin-disk contact method, the titanium alloy and its surface treatment sample are disc patterns, and the reinforced polytetrafluoroethylene pair is a pin. The wear resistance of the friction pair was evaluated by the HT-1000 friction and wear tester. In the experiment, the pin-disk contact method was adopted, the disk was fixed, and the pin was rotated, as shown in Fig. 2.
Experimental sample
Friction sample

Figure 2. Schematic diagram of friction experiment device.

Wear test trajectory (spin on the disk slide track) Radius: 4mm; disk speed: 336 r / min; contact load: 2000g (20N); wear stroke time: 30min.

3. Results and analysis

3.1. Substrate surface

(1) friction Coefficient
Table 3 shows the friction coefficient of the surface of the substrate and the different reinforcing polytetrafluoroethylene composites. Figure 3 shows the variation of the friction coefficient during the friction process. It can be seen that the friction coefficients of the three reinforced PTFE composites on the surface of the substrate are relatively close, ranging from 0.12 to 0.14.

Table 3. Substrate and different PTFE.

| material | Roughness/ m | Change of Sales length/mm | Average friction coefficient |
|----------|--------------|---------------------------|-----------------------------|
| A        | 0.162        | 0.997                     | 0.129                       |
| B        | 0.159        | 1.335                     | 0.140                       |
| C        | 0.158        | 1.135                     | 0.127                       |

(2) Amount of wear

Figure 4 and figure 5 show the wear of the substrate and the different reinforced PTFE materials. It can be seen that the surface of the substrate is worn more seriously and the scratches are more obvious. The damage to the three materials is relatively slight.
After testing, the maximum roughness of the surface of the A material is about 1.1 μm, the maximum roughness of the B material is slightly larger, about 2.2 μm, and the maximum roughness of the C material is the largest, reaching 1.6 μm.

3.2. Plasma sprayed WC surface

(1) Friction Coefficient

Table 4 shows the friction coefficient of the surface plasma sprayed WC sample and the three friction materials. Figure 6 shows the change of the friction coefficient during the friction process. It can be seen that the friction coefficient of the plasma sprayed WC surface and the three friction materials is between 0.124 and 0.135.

| material | Roughness/m | Change of Sales length/mm | Average friction coefficient |
|----------|-------------|--------------------------|----------------------------|
| A        | 2.663       | 1.365                    | 0.125                      |
| B        | 2.434       | 1.591                    | 0.135                      |
| C        | 2.481       | 1.337                    | 0.124                      |
Figure 6. Plasma spraying WC and friction coefficient of different materials.

(2) Amount of wear
Figures 7 and 8 show the wear of the plasma sprayed WC specimen surface and the three mating materials. After testing, the maximum roughness of the A material is about 20.0 μm, the maximum roughness of the B material is relatively large, about 19.5 μm, and the maximum roughness of the C material is about 14.5 μm.

Figure 7. Surface wear of plasma sprayed WC samples.

Figure 8. Enhanced PTFE surface wear.

4. Conclusions
In this paper, the surface modification of Ti-6Al-4V substrate was carried out by plasma spraying method (WC-17%Co). The surface morphology and composition of the coating were analyzed. The thickness of the coating was tested to be 80μm.
Then, under the air environment, the friction test of the plasma sprayed WC surface and the three pairs of friction materials was carried out. It was found that the friction coefficient was reduced by 0.004, 0.005 and 0.003 compared with the matrix after the surface modification treatment, and the hardness is greatly increased, and the friction characteristics are improved. On the other hand, plasma spraying also poses certain problems. For example, the thickness of the plasma spray is large, the thickness of the coating affects the dimensional accuracy of the part; after the surface treatment, the hardness increases, resulting in post-processing problems.

5. References
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