Cold Spray Repair of the Surface Coating on Д - 30 Engine Center Transmission Cartridge Receiver

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Abstract. According to the wear and spalling of the aluminum bronze coating on the central transmission cartridge receiver surface of Д-30 engine magnesium alloy, the cold spraying process was used to carry out the process test and the casing coating repair. The results show that the cold spraying process can obtain better effect than plasma spraying in repairing aluminum and copper coatings.

1. Introduction

The Д - 30 engine is a turbofan engine with high thrust and low fuel consumption developed by Russia. It has been widely used in large bombers and transport aircraft, and its performance is very reliable [1]. During the overhaul of the engine, it was found that the aluminum bronze anti-wear coating on the outer surface of the central transmission cartridge receiver magnesium alloy fell off seriously. Therefore, cold spraying technology was used to repair the coating during maintenance.

Cold spraying technology, also known as low temperature pneumatic spraying technology, is a new spraying technology invented by Russian scientists in the 1990s, as shown in Fig. 1 [2]. In this technology, high-speed gas (air, nitrogen or argon) after preheating and pressurizing is used to accelerate the powder particles. After passing through the Laval nozzle, the powder particles reach the sound speed and then collide with the substrate in a completely solid state to produce plastic deformation and coating deposition [3]. Compared with the traditional thermal spraying, the cold spraying has little thermal influence on the substrate. No oxidation or phase transition occurs in powder particles during spraying, and the microscopic characteristics and physical and chemical properties of powder in its initial state can be completely maintained [4].

As a new coating preparation technology, cold spraying technology can be directly repaired on the surface of waste parts through spray forming [5]. Using cold spraying technology to repair the magnesium alloy central transmission cartridge receiver has the following advantages: (1) the repaired aluminum bronze part has good compatibility with the base metal [6]. (2) The spraying deposition efficiency is high [7]. (3) The spraying aluminum bronze coating has dense structure and high bonding strength [8]. (4) The portable spraying equipment can be used for field operation, and the working gas source is compressed air, which has low cost and no pollution [9].
2. Test of Cold Spray Aluminum Bronze Coating

2.1. Test material and process
The base material of the central transmission cartridge receiver is ZM5 magnesium alloy. Before the test, the oil stain on the surface is cleaned with acetone, dried and blown with sand. The aluminum bronze powder and aluminum powder used in spraying were offered by Beijing Mining and Metallurgy Institute, and the purity was above 99.9%.

The cold spraying equipment used in the laboratory was imported from the Institute of Theoretical Mechanics and Application, Novosibirsk Branch, Russian Academy of Sciences in 2007 by Beijing Institute of Aeronautical Materials. The working parameters of the coating are shown in Table 1.

Table 1. Cold spray parameters

| Working gas  | Temperature | Gas pressure | Moving Speed |
|--------------|-------------|--------------|--------------|
| Compressed air | 300-400 °C  | 2.0-2.5 MPa  | 30-50 mm/s   |

In the experiment of cold spraying aluminum bronze coating, pure aluminum coating was sprayed on the surface of ZM5 substrate as the intermediate bonding layer, and then the aluminum bronze coating was sprayed on the cold sprayed aluminum layer. After the test, SEM was used to analyze the surface and cross-section morphology of cold sprayed aluminum bronze coating, and the deposition structure of powder particles was observed.

2.2. Test results

(a) Cross section morphology of cold sprayed aluminum interlayer
(b) Cross section morphology of cold sprayed aluminum bronze coating

Fig 2. Cross section morphology of cold sprayed aluminum bronze composite coating and its intermediate layer
Fig. 2 shows the micro section morphology of cold sprayed aluminum bronze composite coating. Fig. 2 (a) clearly shows the deformation of aluminum particles during deposition. Due to the large volume of aluminum particles, the deformation is also relatively sufficient, and the mechanical occlusion phenomenon is obvious. The bonding between the coating itself is very dense, and the micro cracks are very small. The pores are almost invisible, and the joint with ZM5 matrix is very dense.

It can be seen from Fig. 2 (b) that the aluminum bronze coating sprayed on the top of the cold sprayed aluminum coating is relatively uniform and dense. Different from the cold spraying aluminum coating, obvious melting phenomenon can be seen at the joint of particle deformation, which indicates that the mechanical occlusion and metallurgical bonding of particles exist together in the aluminum bronze coating. Scanning electron microscope analysis shows that the average porosity of the two composite coatings is about 1%. According to the literature, the porosity of ordinary flame spraying is 10% ~ 20% [10]. The porosity of arc spraying is generally about 10% and that of plasma spraying is 2% ~ 5% [11-12]. Compared with the traditional thermal spraying method, the porosity of the coating was significantly improved by cold spraying. On the other hand, the interior of the two composite coatings bears compressive stress, which is conducive to the preparation of thick coatings [13].

As the anti-wear coating of the central transmission cartridge receiver, the aluminum bronze coating has higher requirements on the compactness and bonding properties of the coating. It can be seen from Fig. 2 (a) and (b) that the cold spray aluminum coating forms a mechanical bite at the convex and concave parts of the matrix blown sand surface. There is an obvious interface between the aluminum bronze coating and the cold sprayed aluminum, and there is no transition layer. The defects and holes can hardly be seen under the electron microscope, which shows that the bonding performance of the aluminum bronze coating with the substrate through the intermediate layer is very good. On the other hand, there is no delamination in the whole coating system under the electron microscope except for a small amount of pores and micro cracks, which indicates that the cold spraying coating has high cohesive strength. Therefore, the cold spraying process as the coating repair process of the central transmission cartridge receiver is in line with the requirements.

3. Repair Process of Aluminum or Copper Composite Coating on Magnesium Alloy Casing Surface
According to the coating falling off on the central transmission cartridge receiver surface of the Д - 30 engine, the repair process includes three steps: removing the original coating, repairing by cold spraying and coating processing.

3.1. Removing the original coating
The transmission cartridge receiver is installed on the lathe fixture. The inner surface of the cartridge receiver is limited by a large circle, which highlights the epitaxial surface of the transmission cartridge receiver and is fixed in advance along the outer circle of the epitaxial surface. Then, the runout of the small circle on the central cartridge receiver inner surface should be corrected to within 0.02mm, and then the transmission cartridge receiver should be fixed. The turning tool is used to remove the residual coating on the surface of the cartridge receiver. It should be processed to the specified size according to the overhaul manual [14]. After the runout of the turning surface relative to the inner surface of the central gearbox is not greater than 0.03mm, the parts can be removed.

3.2. Repairing by cold spraying
Before spraying repair, the turning surface of the central transmission cartridge receiver should be cleaned with acetone, and sprayed with corundum sand [15]. The rest parts should be protected by sand blowing tape. Oil, dust and dirt are not allowed to fall on the sandblasting surface. The transmission cartridge receiver is installed on the spraying rotating fixture, and the pure aluminum powder for spraying is added into the cold spraying system. The pure aluminum coating with thickness of 0.15 ~ 0.2mm is prepared on the turning surface. The spray gun is emptied and loaded with aluminum bronze
powder. The aluminum bronze coating with thickness of 0.8 ~ 1mm is prepared on the cold spraying aluminum surface.

3.3. Coating processing
The transmission cartridge receiver should be removed and installed on the lathe fixture again. After the runout of the small circle on the central cartridge receiver inner surface is corrected to within 0.01mm, the parts are fixed [16]. The spraying surface should be turned, and the runout of the big circle and small circle on the cartridge receiver inner surface relative to the spraying surface should be kept below 0.03mm. After machining, the size of the repaired surface should be checked according to the manual of the engine.

4. Conclusion
The results show that the ZM5 central transmission cartridge receiver of the Д - 30 engine can be repaired by cold spraying, and the dimension recovery meets the requirements of the engine. The time and maintenance cost can be saved by using this method.

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