# Research on an Aspherical Airbag Polishing Technology

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**Keywords:** Aspheric Surface; Magnetorheological Torque Servo; Polishing Force

**Abstract:** Aiming at the problem that the control precision of the polishing force in the current airbag polishing method is not high, a method of aspheric numerical control airbag polishing technology is designed, which is clarified from the composition, working principle and modeling. On the basis of the research, a large number of experiments have been carried out to prove that the method is feasible, and the aspherical mirror surface with the surface roughness Ra≤0.03μm is obtained, as well as the aspherical precision and ultra-precision machining are realized.

## 1. Introduction

At present, China's aerospace industry has made a great leap forward, high-speed rail technology is in a leading position in the world, the Liaoning and manned spaceflight technology is attracting worldwide attention, and bridges, roads and ports of China are also developing rapidly. The requirements for the surface quality of mechanical parts are getting higher and higher, especially for the aspheric surface. The traditional polishing process not only takes a long time, but also has low efficiency, and manual work cannot guarantee the stability of each batch of products. With the maturity of computer-aided technology in intelligence and automation, the ultra-precision polishing technology has achieved breakthrough development.

The airbag grinding and polishing technology [1], which was first proposed by the Optical Laboratory of University of London, has received more and more attention and exploration, and has been continuously improved. Studies have shown that the polishing pressure between the airbag and the aspheric surface during the polishing process determines the polishing quality of the aspheric surface [2]. The existing airbag polishing technology generally controls the polishing pressure by controlling the air pressure inside the airbag. Although the pressure can be adjusted independently, the pressure control accuracy is not high enough because of the compressibility of the air, which makes the pressure inside the airbag is difficult to achieve stepless adjustment [3].

In view of the traditional polishing cannot fully meet the quality requirements of aspheric surface of science and technology, this paper proposes a new numerical control polishing method, that is, the numerical control polishing method of aspheric airbag. Experiments have been carried out, and according to the data, the aspheric surface roughness has high precision and quality.

## 2. The working principle and structure of the airbag polishing system

### 2.1 The structure of the polishing system

The airbag polishing system designed in this paper is shown in Figure 1 below. It is divided into two parts, mainly including: lathe chuck, aspherical parts, airbag, connecting rod, tool holder, air pressure adjustment unit, air compressor, torque transmission system, Lathe tool holder, controllable current source, torque measurement feedback device connected to the computer. The above part is called the "polishing tool subsystem", which can adjust the internal pressure of the air bag and transmit the output torque of the magnetorheological fluid. It consists of adjustment system, air bag, lathe chuck, and aspherical parts.

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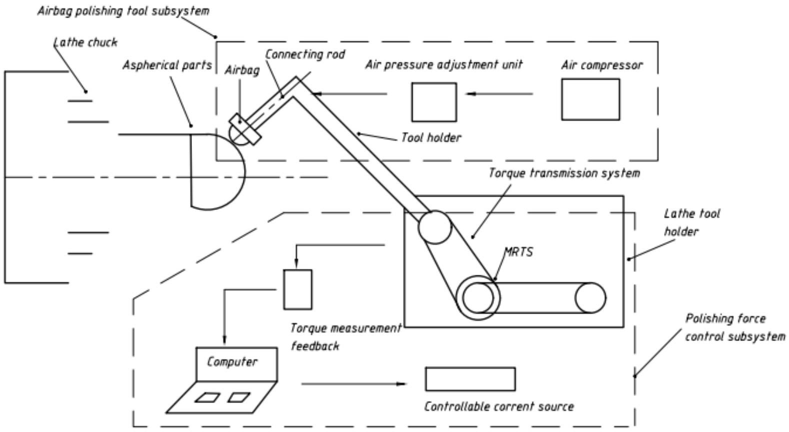


Figure 1 Composition of airbag polishing system.

### 2.2 Magnetorheological Torque Servo

The magnetorheological torque servo consists of seven parts. The structure principle is shown in Figure 2. It is a servo control device, and the servo control device is the torque generated under the action of the magnetorheological effect. It consists of 7 parts: shell, MRF-magnetorheological fluid, shearing disc, input shaft, output shaft, magnetic isolation ring, and excitation coil. When the coil is energized, the Newtonian fluid solidifies; when the working disk rotates, the magnetorheological fluid generates shear yield stress, and the casing moves, which will drive the output shaft to rotate together. Once the output shaft rotates, a torque is generated, which is applied to the excitation coil. After experiments, the server has strong controllability and fast response.

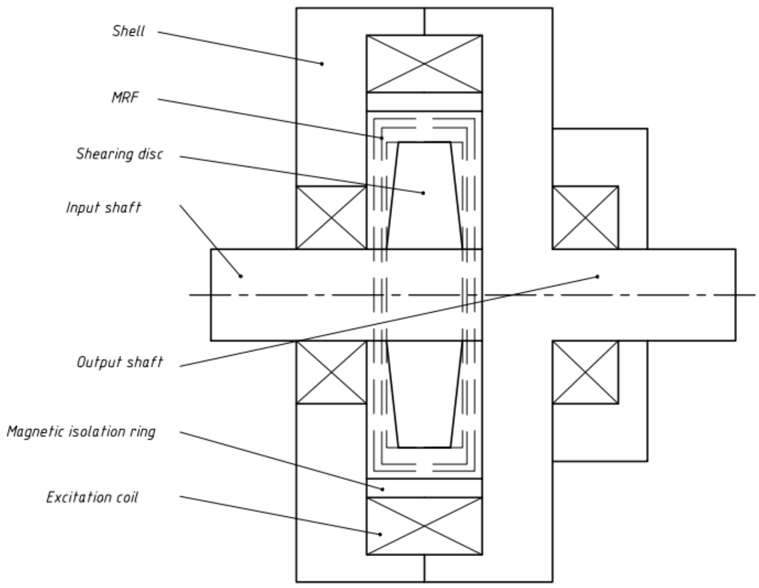


Figure 2 The composition of magnetorheological torque servo.

### 2.3 The working principle of the polishing system

The working principle and process of the polishing system are shown in Figure 3. Two parts are fixed on the lathe tool holder: the airbag polishing tool system, and the magnetorheological torque servo, which ensures the movement with the feeding of the lathe tool holder during the polishing process. The air bag receives the torque transmitted by the torque system, and then tightly compresses the surface of the part on the aspheric surface, thereby generating a throwing force. During the polishing process, the rotation speed of the aspherical parts is controlled by the main motion system of the CNC lathe. The internal pressure of the air bag is controlled in real time by the air pump and the air pressure adjustment system, and it can also be adjusted in advance before the polishing starts, so that the internal pressure of the air bag is always constant. In the actual grinding and polishing: the computer draws the feedback of the output torque from the magnetorheological torque servo, the output torque is the data from the torque detection system, and then controls the excitation current applied to the magnetorheological torque servo, Furthermore, the output torque of the magnetorheological torque servo forms a closed-loop control, and finally achieves the purpose of real-time monitoring and control of the polishing force.

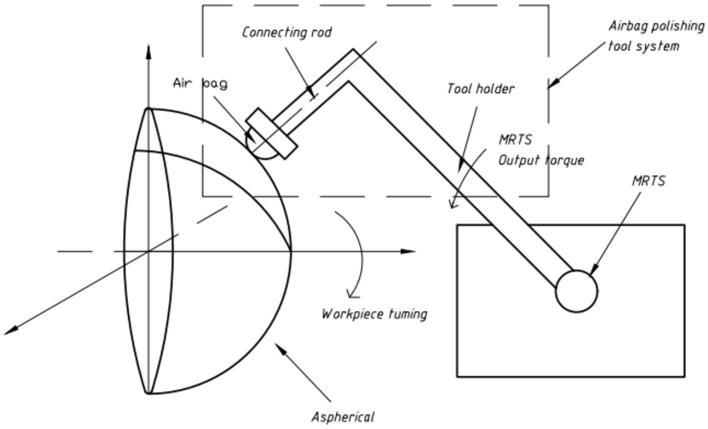


Figure 3 The polishing principle.

## 3. Polishing force modeling

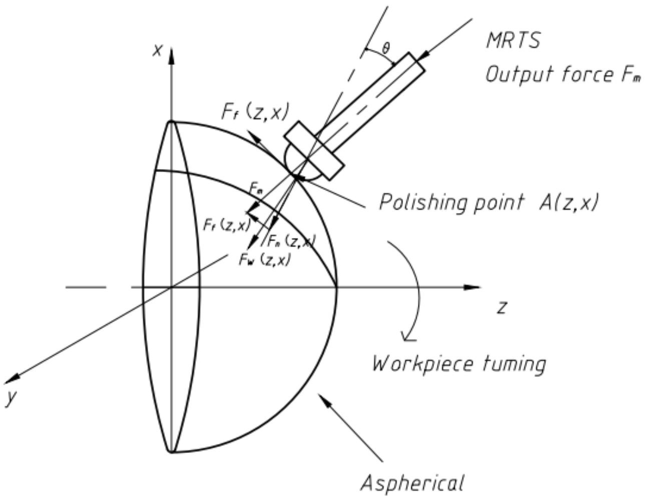


Figure 4 Polishing point force analysis.

Fig. 4 is the "Feeding principle of airbag polishing head", which is explained as follows.

(1) Polishing point:$A(z,x)$,
(2) At the polishing point, $F_m(z,x)$ produces two component forces:
$F_n(z,x)$ is a component force along the normal direction of the aspheric surface;
$F_j(z,x)$ is the force in the direction of airbag feed.
$F_m(z,x)$、$F_n(z,x)$、$F_j(z,x)$ can be determined by formulas (1)-(3):

$$F_m(z,x)= T_m(z,x)/L_1 \quad (1)$$

$$F_n(z,x)= F_m(z,x) \times \cos\theta(z,x) \quad (2)$$

$$F_j(z,x)= F_m(z,x) \times \sin\theta(z,x) \quad (3)$$

In the formula, $\theta$ is the included angle: the secondary included angle is between the normal direction of the aspheric surface and the airbag connecting rod, and L1 represents the length of the tool shank.

Normal force $F_n(z,x)$: generated by the aspheric surface of the airbag;

$F_w(z,x)$ : tangential friction force;

Component force $F_m(z,x)$ : refers to the force acting in the feeding direction of the airbag;

$F_j(z,x)$ : The frictional force $F_f(z,x)$ in this direction.

$$F(z,x) = F_n(z,x) \quad (4)$$

It can be obtained by substituting formula (1) and formula (3) into formula (4):

$$F(z,x) = F_n(z,x) = \frac{T_m(z,x) \times \cos\theta(z,x)}{L_1} \quad (5)$$

When the magnetorheological torque servo outputs torque, and when the torque is constant, the polishing force $F(z,x)$ is:

$$F(z,x) = \frac{T \times \cos\theta(z,x)}{L_1} \quad (6)$$

At this time, $\theta=0$, under this condition, the polishing force $F(z,x)$ is:

$$F(z,x)=T/L_1 \quad (7)$$

## 4. Experimental verification

In order to verify the operability and effect of the principle, the verification is done in this paper, and the surfaces of aluminum aspherical parts are respectively taken for comparative experiments. The surface roughness after finishing machining is shown in Fig. 5(a). In the experiment, the new polishing method in this paper is used, and four different areas are selected for testing. The 4 points are all before polishing. The effect of the surface roughness of the polished part is shown in 7(b).

The comparison table is shown in Table 1.

It can be seen from the comparison value and comparison effect picture of the provided surface roughness: when the method proposed in this paper is used for polishing, the value of surface roughness Ra is reduced from 1.8μm (test data before polishing) by 0.03μm (test data after polishing). Therefore, the surface quality of the aspheric surface is greatly improved.

Table 1 Comparison of roughness before and after polishing.

| Roughness *Ra*/μm | Measurement area | | | |
|---|---|---|---|---|
| | ① | ② | ③ | ④ |
| Before | 1.8 | 1.40 | 1.40 | 1.5 |
| Affter | 0.03 | 0.023 | 0.023 | 0.025 |


(a) Aspheric surface after finishing (b) Aspheric surface after polishing

Figure 5 Comparison of the effect before and after polishing.

## 5. Conclusion

(1) A new polishing method is proposed: aspheric CNC airbag polishing, and the polishing force

is independently controlled by a magnetorheological torque servo.

(2) The polishing and throwing force model related to the output torque of the magnetorheological torque servo is established, which can realize the precise control of the polishing and throwing force by controlling the excitation current.

(3) The direction of improvement in the future: there is pressure inside the airbag. In the process of force modeling, the influence of this pressure on the output torque of the magnetorheological torque servo is ignored.

## References


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