Research on Surface Integrity Manufacturing of Bearing Ring Raceway Based on Plasma Polishing Principle

Jikun Yu*
College of Applied Technology, Dalian Ocean University, Dalian 116000, Liaoning, China

*Corresponding author e-mail: yujikun@dlou.edu.cn

Abstract. Plasma polishing technology is a new ultra smooth surface processing method with low cost, no pollution and no waste. It has been widely used in semiconductor industry and optical component manufacturing, but the research on the processing and manufacturing of key mechanical parts is still in the exploratory stage. In this paper, by using RC-ECMA150KVA plasma polishing equipment, plasma polishing technology is used to solve the surface integrity manufacturing problem of large-size rolling bearing ring raceway, which not only improves the processing quality of ring surface, but also realizes the function of surface corrosion and surface modification, and greatly improves the high service performance of rolling bearing.

Keywords: Plasma, Rolling Bearing, Surface Integrity, Manufacturing

1. Introduction
As the key component of China's mechanical equipment manufacturing industry, rolling bearing plays an important role in the development of industrialization, especially in the field of aeroengine, high-end machine tools and high-speed railway transportation. Rolling bearing has become the main bottleneck of high-end equipment manufacturing industry, and its failure form is mainly contact fatigue. Therefore, it is necessary to introduce new methods and processes to manufacture the surface integrity of key mechanical parts such as rolling bearing rings, so as to improve the service performance of bearings. In this paper, the raceway of rolling bearing ring was polished by plasma polishing method. The micro morphology of raceway surface was observed, and the surface rust removal and surface modification were further studied.

2. Development Status of Bearing Ring Surface Finishing Technology at Home and Abroad
At present, the traditional surface treatment of rolling bearing ring raceway in China is mainly superfinishing after grinding, because although the roughness and surface morphology only change in micron and submicron level after processing, it is easier to form lubricating oil film, which greatly improves the rated life of rolling bearing [1].However, it is mainly the Superfinishing of small and medium-sized bearing ring raceways with nominal outer diameter less than 200 mm. At present, the superfinishing technology for rolling bearing ring raceways with various sizes has been relatively mature all over the world, and most of them adopt high-frequency vibration Superfinishing of oilstone,
If supfina company of Germany is used, the surface roughness of the bearing ring raceway with oilstone superfinishing can reach below 0.2 μm, and the surface is uniform and the texture is gullied, which makes it easier to form lubricating oil film and control the micro morphology of superfinishing workpiece surface [2-3]. However, due to the differences in size, weight and raceway width between large and medium-sized bearings with nominal outer diameter over 200 mm and small bearings, the equipment and technology using oilstone super precision raceway of large bearing rings are mainly used in developed countries in Europe and America, and the equipment is expensive, so it is not widely used.

3. Plasma Polishing Method for Raceway of Bearing Ring

Plasma polishing technology is a new ultra smooth surface processing method with low cost, no pollution and no waste. It can obtain the treatment effect that traditional processing methods can not achieve. It has been widely used in semiconductor industry and optical component manufacturing, and has become a key technology in the field of microelectronics, optoelectronics and micro optical component manufacturing, but the research on key mechanical components is still in the exploratory stage [4].

3.1. Principle of Plasma Polishing

Under high temperature and high pressure, electrons will escape from the nucleus, and the nucleus will form a positively charged ion. When these ions reach a certain number, they can become plasma state. The energy of plasma state is very large. When these plasma rub with the object to be polished, the object will immediately achieve the effect of surface brightness, and any surface of the workpiece can be polished.

Plasma polishing machine is developed according to this principle, and its schematic diagram is shown in Figure 1. The polishing material is put into the electrolyte containing ammonium ion (NH4 +), and then through the output of DC voltage, the electrolytic solution around the positive electrode to be polished will evaporate instantaneously due to the high potential difference to produce bubble bags. This continuous bubble bag will produce a coating gas film on the surface of the polished material, and the evaporated particles in the middle of the gas film will dissociate due to the high voltage to produce discharge plasma, and the protrusion on the surface of the object to be polished is flattened by the discharge plasma to produce a mirror like plane, so as to complete the polishing purpose [5]. In this polishing process, only the molecular layer of the workpiece surface reacts with the plasma, the atomic spacing in the molecule is generally 0.1-0.3 nm, and the treatment depth is 0.3-1.5 nm. Therefore, the RC-ECMA150KVA plasma polishing equipment as shown in Figure 2 is used for surface finishing of metal parts, and the surface roughness can be easily controlled in the range of 0.1-1 μm, or even the surface quality will be higher.

Figure 1. Schematic diagram of plasma polishing
3.2. Advantages of Plasma Polishing
The surface finishing of large-size rolling bearing rings is usually carried out by the method of oilstone swing oscillation. After friction, extrusion and engraving, the stress distribution of the bearing ring surface is tensile stress state, which is easy to produce cracks in the service process [6]. Compared with this finishing method, the main advantages of plasma polishing are as follows:

1. According to the size of the workpiece, the workpiece can be polished near the mirror in tens of seconds to a few minutes, and the subsequent processing is simple and convenient;
2. It can effectively remove the edge burr of stamping parts or other manufacturing parts in the polishing process;
3. In the polishing process, a layer of passivation film is produced on the surface of the workpiece to keep it durable and bright, and enhance the corrosion resistance of the polished surface, so as to play the control function of the functional surface;
4. Polishing uniformity is superior, the whole workpiece surface and even all dead corner parts can achieve the same mirror effect;
5. The polishing process is controlled by electrical parameters, the whole process can be controlled by PLC automation, simple operation and convenient maintenance;
6. High production efficiency and low production cost;
7. Especially for the parts with heavy corrosion, it has the function of rust removal and cleaning [7].

3.3. Experimental Study on Plasma Polishing of Raceway of Bearing Ring
In this test, the inner and outer rings of tapered roller bearing with type code 22223 are used, and the surface roughness after grinding is 0.8RA. In order to analyze the effect of plasma polishing on the surface corrosion of bearing rings, the bearing rings are placed in the air for a period of time before the test, so that some corrosion occurs on the bearing surface, as shown in Figure 3 and Figure 4.
Put the inner ring and outer ring of the bearing into the plasma polishing equipment [8]. Due to the heavy corrosion on the surface and considering the factors of microstructure modification caused by plasma bombardment on the raceway surface of the bearing ring, the polishing time is set to 30 minutes. The specific equipment and relevant processing parameters are shown in Table 1.

**Table 1. Plasma Processing Equipment and Processing Parameters**

| Serial number | Project                        | Unit     |
|---------------|--------------------------------|----------|
| 1             | Workpiece material             | GCr15    |
| 2             | Machining accuracy             | Ra0.2    | μm       |
| 3             | Polishing speed                | 1-4      | μm/μm/min|
| 4             | Polishing time                 | 30       | min      |
| 5             | Plasma power                   | 150      | Wt       |
| 6             | Maximum dimension of workpiece | 600(L)*400(W)*500(H) | mm       |

After the test, the workpiece is taken out from the equipment, and the machined surface as shown in Figure 5 (a) and Figure 5 (b) can be observed by naked eye.

**Figure 3. Bearing ring**

**Figure 4. Rust on bearing ring surface**

**Figure 5. Surface of bearing ring after rust removal by plasma**

From the above experiments, it can be seen that after 30 minutes of plasma polishing, the surface rust can be basically removed, and the mirror effect can be achieved, but the grinding texture of the surface still exists, but the polishing texture gradually becomes disordered and the original cross texture becomes shallower [9-11].
4. Conclusion and Prospect

Through the experimental study of plasma polishing large-scale rolling bearing raceway, it can be seen that plasma polishing has a very good effect on the surface micro morphology and rust removal of large-scale bearing raceway. It can not only make the surface roughness of the parts reach sub micron level, further improve the surface quality and achieve the effect of mirror machining, but also remove the deep rust on the surface of the bearing ring raceway and modify the surface, and the surface stress is close to the compressive stress state. Therefore, the high service life and high service performance of the rolling bearing are greatly improved. However, due to the limitation of testing equipment, it is necessary to further study the sub surface distribution of plasma polished rolling bearing ring raceway, including the surface micro morphology, surface residual stress distribution, especially the change of microstructure, it is of great significance to realize the "controllability" of rolling bearing surface by plasma polishing.

Acknowledgments

Fund projects:2020 Scientific Research Funding Project of Liaoning Provincial Department of Education (QL202017); General Project of Scientific Research in Liaoning Province (QL201723); Liaoning Science and Technology Foundation Project (BS-201933); The second Zhanlan Scholar Project of Dalian Ocean University (191022007).

References

[1] Ai X., Sawamiphadi R, 1999, “Solving Elastic Contact Between Rough Surfaces as an Unconstrained Strain Energy Minimization by Using CGM and FFT Techniques”, ASME J. Tribol, 121, pp 639-637.

[2] Allwood J, 2005, “Survey and Performance Assessment of Solution Methods for Elastic Rough Contact Problems”, ASME J. Tribol, 127, pp 10-23.

[3] Crețu Sp., 1996, "Initial Plastic Deformation of Cylindrical Roller Generatrix: Stress Distribution and Fatigue Life Tests", Acta Tribologica, 4, pp. 1-6

[4] Wu Yilong, mechanism of plasma polishing, Xi'an University of technology, 2011.

[5] Wang Ji, research on plasma polishing of metal surface with electrolyte, Harbin Institute of technology, 2013.

[6] Ribeiro Filho, S. L. M., Lauro, C. H., Bueno, A. H. S., & Brandao, L. C. (2016) “Influence Cutting Parameters on the Surface Quality and Corrosion Behavior of Ti–6Al–4V Alloy in Synthetic Body Environment (SBF) Using Response Surface Method”, Measurement, 88, pp. 200-210.

[7] Bo, G., Chang, L., Chenglong, H., Guanglin, Z., Yingwei, Z., Pengfei, X., & Ning, X. (2019) “Effect of Mg and RE on the Surface Properties of Hot Dipped Zn–23Al–0.3 Si Coatings”, Science of Advanced Materials, 11(4), pp. 580-587.

[8] Zeng, L., Guo, X. P., Zhang, G. A., & Chen, H. X. (2018) “Semiconductivities of Passive Films Formed on Stainless Steel Bend Under Erosion-Corrosion Conditions” Corrosion Science, 144, pp. 258-265.

[9] Xu, Y., Chen, J., Zhu, C., Zhang, P., Jiang, G., Wang, C., Zhong, S. (2018) “High-Performance of Sodium Carboxylate-Derived Materials for Electrochemical Energy Storage”, Science China Materials, 61(5), pp.707-718.

[10] Anderson M, Patwa R, Shin Y C. Laser-assisted machining of Inconel 718 with an economic analysis. International Journal of Machine Tools and Manufacture. 2006, 46(14): 1879-1891.

[11] Fengle, Effect of Surface Stress Distribution of Roll Bearing on Its Life Parts, Machinery Manufacturing and Automation.2018.1-1,pp 10-12.