Research on the Application of Manufacturing Technology for Large-size Bearing Raceway Surface Integrity

Jikun Yu and Mingyu Wu*
Dalian Ocean University, Dalian, Liaoning

*Corresponding author e-mail: 15541185675@163.com

Abstract. Various types of standard and non-standard large-size rolling bearings, which function as a rotating force and a main bearing force in the equipment, have continuously improved their performance requirements. This paper proposes surface integrity manufacturing technology for Large-size Bearing Raceway, analyzes the domestic and international overview and development level, research content and key technologies, and the expected indicators and social benefits.

Keywords: Large-size Bearing; Surface Integrity; Manufacturing Technology

1. Introduction
With the continuous improvement of the performance requirements of large-scale mechanical equipment, various types of standard and non-standard large-size rolling bearings, which play a role of rotation and main bearing force in the equipment, have continuously improved their performance requirements. As shown in Figure 1, the super-finishing processing technology can effectively improve the processing quality of the rolling bearing ring or roller surface and improve the serviceability. However, so far, bearing companies in developed countries in Europe and the United States have only been testing the ferrule raceway super-finishing technology for large and extra-large bearings (about 1200 mm in diameter). However, the domestic bearing products of this type are basically ground and assembled directly after delivery, and no super-finishing machining is performed.

Figure 1. Raceways and Rollers for All Types of Large Rolling Bearing Rings

2. Overview, Level and Development Trend of Researches at Home and Abroad
At present, the world's first Supfina bearing super-finishing machine in the field of bearing ring super-finishing research are as shown in Figure 2(a), and it is only possible to super-finish the bearing...
ring raceway with a diameter of 1000 mm or less.\textsuperscript{[1]} And its ultra-precision machine principle still uses the oilstone oscillation polishing of the traditional oilstone indexing structure, as shown in Figure 2(b)(c)(d). This super-finishing machine is not ideal. After finishing, there are often defects such as Imprint of grinding wheel and Cumulative tumors produced by super-finishing, as shown in Figure 2(f). During use, a butterfly-like crack source can be further formed, as shown in Figure 2(g), which causes wear, as shown in Figure 2(h), which ultimately leads to bearing failure and affects bearing life.

\textbf{Figure 2.} Large-size Rolling Bearing Ring Raceway Polishing Equipment and problems

The United States completed surface integrity manufacturing as early as 1970, and in 1971 carried out military safety life design. Damage tolerance and durability design was completed in 1975. Through the establishment of surface integrity process parameter control domain, high-speed machining and other processing methods the world’s first anti-fatigue manufacturing technology to achieve surface integrity. However, the content is strictly confidential and few articles have been published.\textsuperscript{[2]}

China’s related research started late. In the 1990s, some domestic industries established surface quality research institutions, and proposed the concept of “no stress concentration” anti-fatigue manufacturing. In 2003, 12 academicians jointly proposed to the State Council to carry out research on the project “Research on the Development of Anti-fatigue Manufacturing and Long-life Critical Infrastructure Components”.\textsuperscript{[4]} However, in recent years, breakthrough results have been achieved in the single-end technology of anti-fatigue manufacturing based on surface integrity. For example, Academician Zhao Zhenye proposed the concept of “no stress concentration” anti-fatigue. The aircraft landing gear manufactured by this method does not break the fatigue test 5000 flight hours, increases the load by 30%, continues to test to 6000 flight hours, and remains intact. More than the maximum life expectancy of 5000h flight time of foreign 300M steel similar landing gear.\textsuperscript{[5, 6]} Prof. Zhang Dinghua from Northwestern Polytechnical University studied the grinding parameters, grinding fluids and machining processes to produce surface layer fatigue-resistant grinding technology that is close to “no stress concentration”, and studied the surface integrity of GH4169 high-temperature alloy. The relationship between the grinding depth and the grinding depth is optimized. The surface roughness and surface topography of titanium alloy were also studied by high-speed milling method. The process parameters were controlled to ensure that the surface roughness was within 0.6 μm of Ra, and the grinding and polishing requirements were met.\textsuperscript{[6,7]} The Chinese Bearing Association He Jiaqun has obtained the anti-fatigue manufacturing of large-scale wind power bearings. Fine grinding can produce grinding cracks and grinding metamorphic layers, and further apply the field of oilstone oscillation super-finishing bearing ring raceway, because the oil stone is oscillated to produce Cumulative
tumors produced by super-finishing, the Cumulative tumors produced by super-finishing is further enlarged to produce micro-cracks, which leads to stress concentration and affects the Long service capacity of the bearing. [8]

From the research status and level of research at home and abroad, it is not difficult to see that there is a big gap between China and developed countries in bearing manufacturing based on surface integrity. In early 2012, China launched the “China Heat Treatment and Surface Modification Technology Roadmap” preparations, and then held several seminars and clearly stated that stress concentration can sensitively lead to reduced life and failure of high-strength critical base parts. This shows that future research priorities and technology development trends are obvious. [4]

The quality of the surface layer of the bearing ring raceway directly affects its service performance, especially during the material removal process. Surface defects such as micro-cracks, high tensile stress state and tissue damage caused by improper processing methods seriously damage the surface integrity of the workpiece and reduce bearing fatigue strength or fatigue life. When the surface of the bearing ring is ultra-precision processed, although the roughness and surface topography only change in the micron and submicron range, it can greatly improve the rated life of the rolling bearing and increase its life by more than 30%. The reason is known from the fracture mechanics. The larger the surface roughness value, the deeper the surface groove mark, the smaller the radius of the bottom, the more severe the stress concentration, and the worse the fatigue resistance. [9] Therefore, it is a development trend to improve the surface roughness quality and fatigue life of the bearing ring raceway. However, it should be pointed out that from the viewpoint of the formation mechanism of the lubricating oil film, the lower the roughness value, the better the better, and it also has the optimum interval value, which requires further study.

In addition to the effect of surface topography and roughness on the serviceability of rolling bearings, residual stress acts as an unstable stress state. When the applied load interacts with the residual internal stress, the internal stress will be redistributed, and the shape and dimensional accuracy of the workpiece will change. When the load is unloaded, the internal stress will be redistributed once again, so that its distribution will affect the fatigue performance of the rolling bearing. It has a big impact. Caruso S et al. pointed out that during the use of parts, residual tensile stress will promote the formation and expansion of fatigue cracks and reduce the service life of the workpiece. Therefore, the ideal stress distribution is residual compressive stress. [3] Therefore, reducing stress concentration and changing high tensile stress to compressive stress technology is another development trend.

3. Research Contents and Key Technologies

3.1 Main Contents of the Research
(1) Pressure field and velocity field homogenization control principle of complex surface polishing of grinding granular flow.

According to the fluid dynamics and rheological analysis, the distribution law of the processing parameters such as pressure, velocity and flow rate of the workpiece surface during the abrasive flow polishing process. On this basis, the material quantitative removal model is established by means of grinding principle and tribological material wear theory. The conditions of uniform flow field are got by analyzing the distribution of parameters such as surface topography, residual pressure and roughness after polishing of grinding granular flow.

(2) Mechanism of action of viscoelastic abrasive media on bearing ring surface and low roughness surface creation method

Prepare abrasive flow media of different viscosity, abrasive type. Through the test, the polishing mechanism of the viscoelastic abrasive media to the large-size bearing ring raceway is analyzed, and the method of creating a low-roughness surface of the bearing ring with different viscoelastic abrasive grains is verified.
3.2 Key Technologies

(1) How to achieve precise control of viscoelastic fluids to ensure the established force and motion transmission of abrasive particles in random abrasive grains

Through the analysis of the flow characteristics of the abrasive flow, the distribution rules of the processing parameters such as pressure, velocity and flow of the random abrasive group are obtained. Combined with the fixture, the formed flow field is formed on the abrasive flow, and the abrasive trajectory in the controlled abrasive grain group is ensured to achieve the specified force and velocity transmission.

(2) How to construct anti-fatigue surface modification layer under viscoelastic abrasive flow polishing

By establishing the anti-fatigue manufacturing parameter control domain of viscoelastic abrasive flow polishing, the quantitative removal mechanism of the material and its performance change are studied, and then the functional surface with high surface integrity is obtained; Through the optimization of the abrasive flow profile fixture and test parameters, combined with the detection of the surface micro-morphology of the fluid abrasive polishing, the stress concentration is reduced. Change the high tensile stress to compressive stress, and then control the microscopic properties of the material surface to construct a high fatigue resistant surface metamorphic layer.

4. Various Technical Indicators to be Met

Based on the theory of surface integrity, this study focuses on the precise and efficient polishing of the inner and outer ring raceways of large-size bearing rings with high service performance required by high-end bearings in China’s equipment manufacturing industry. The research aims to:

(1) The control principle of homogenizing the polishing flow field of the abrasive flow is proposed, and the pressure sudden change at the inlet and outlet is reduced. In addition, it seeks to solve the problem of uneven polishing such as “over-polishing”, “under-throwing” and “rounding” at the entrance and exit of the traditional viscoelastic abrasive flow, and improving the surface integrity index of bearing ring raceways used in industrial equipment manufacturing for high quality and long service life.

(2) Establish a process data set for the precise polishing of viscoelastic fluid abrasive flow on the inner and outer ring raceway surfaces of large-size bearing rings with long service life. On the basis of the test, the process parameters are optimized to improve the quality of the surface layer of the large-size bearing ring raceway, mainly including reducing the roughness and improving the surface fatigue resistance, such as the bearing ring raceway surface stress, plastic deformation and other physical properties. This can satisfy the theory and method of manufacturing and manufacturing of specific surface texture and surface layer metallurgical quality requirements for long service life.

Through the research of this project, the high-efficiency and precise polishing method of the medium-sized (nominal outer diameter of 90mm or more and 430mm or less) bearing ring raceway is solved, so as to achieve:

1) The surface roughness Ra of the large bearing ring raceway is between 0.1 and 0.15 μm, respectively;
2) Large bearing’s manufacturing precision reaches P2 level;
3) Achieve bearing surface integrity control and increase bearing life by 30%;

5. Analysis of Scientific Significance and Economic and Social Benefits

Along with “Made in China 2025”, there are nearly eight areas in the top ten key development areas that involve high-performance bearing parts, such as precision narrow-section thin-walled bearings in the field of robotics, large aircraft engine spindle bearings in the field of aerospace equipment, large slewing bearings for yaw and pitching of wind power in the field of power equipment, in the field of marine engineering equipment Low-noise and vibration nuclear submarine bearings, railway bearings in the field of advanced rail transportation equipment, lightweight and anti-friction bearings in the
field of new energy vehicles. It can be seen that high-performance bearing parts have become the key to the implementation of “Made in China 2025”.

The application research on the manufacturing technology of large-size bearing raceway surface integrity around this research has important scientific significance for the implementation of “Made in China 2025”. The key technology of precise and efficient polishing of the bearing ring raceway surface with high service performance and surface integrity proposed by this research has deep scientific connotation. It is extremely important to carry out research on the final processing steps of bearing rings to reduce the surface roughness, surface topography, and stress distribution of sub-surfaces, and to avoid the generation and expansion of crack sources under alternating contact stress. The reconstruction of the surface micro-morphology obtained by precise and efficient polishing and the creation mechanism of the functional surface is the core content of the bearing parts with high service performance. Therefore, based on the surface integrity, it is important to understand the formation mechanism of residual stress and optimize the distribution and size of residual stress.

Relying on the strong bearing industry foundation of Wafangdian City and the school-running foundation of the bearing professional direction since 2004 and based on the preliminary results of the “Research on High-efficiency, High-efficiency and Precision Super-finishing Equipment for Large-Scale Rolling Bearing Ring Rolling Grinding Flow”, further research on the high service performance based on the surface integrity of the ferrule raceway is carried out. The target market is positioned in the high-end market for large and extra-large bearing manufacturing. Combined with the actual situation of the college’s professional transformation and development, based on serving the economic development of Liaoning Bearing and implementing the group-based education proposed by the Ministry of Education, it has enormous economic and social benefits, which are mainly reflected in the following two aspects.

5.1 Based on the bearing industry cluster, promoting enterprise technological innovation will have good economic benefits.
Bearing manufacturers in the region have a huge demand for super-finishing processing of rolling bearing rings. Wafangdian is the “China Bearing Capital”, with more than 500 bearing companies, ranking the first in China. However, for a long time, most small and medium-sized bearing manufacturers have weak scientific research awareness and low investment in research and development, which has led to a relatively backward level of bearing manufacturing and a vicious circle. With the continuous advancement of “Made in China 2025”, enterprises must transform and develop. They must pay attention to the application of new technologies, new processes and new methods, and take the road of manufacturing high-end bearing products to enhance their core competitiveness. This provides a broad market space for the research and application of large-size bearing ring raceway polishing based on surface integrity and high service performance. Therefore, carrying out research on this project will inevitably produce good economic benefits.

5.2 Combining the bearing profession, carrying out group-based education and serving the regional economic development will inevitably produce good social benefits.
The Ministry of Education clearly pointed out in the comments on the in-depth promotion of vocational education group-based education: encourage local universities to focus on regional development planning and industrial structure. Under the leadership of the government, a regional education group for bearing industry clusters, including schools, bearing industry associations, industries and enterprises, has been established. The group's interest chain is used as a link to carry out group-based education, integrating production, teaching and research and development. Function in one, to promote school-enterprise win-win development. Under the background of the Ministry of Education and the Provincial Department of Education to promote group-based education, the application of large-scale bearing raceway surface integrity manufacturing technology was carried out in a grounded manner. Thereby promoting the deep integration of the industrial chain, the Job position and the teaching chain, boosting the transformation of scientific research results, improving the quality
of running schools, and the social benefits are obvious.

Acknowledgements
Fund Project: 2016 Liaoning Science Research General Project (Project No.: L201613); 2017 Liaoning Science Research General Project (Project No.: QL201723); 2019 Liaoning Science and Technology Fund Project (Project No. BS-201933)

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