Analysis of Vessel Sliding Bearing Wearing Characteristics and Contact Angle

Yan-Jun YAN\textsuperscript{1,a,*}, Xin-Yue WU\textsuperscript{2,b}

\textsuperscript{1}College of Power Engineering, Naval University of Engineering, Wuhan, 430033 China
\textsuperscript{a}328058852@qq.com, \textsuperscript{b}wuxinyue@hotmail.com
*Corresponding author

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Abstract. The paper establishes the dynamics temperature field model and dynamics pressure distribution model in the sliding bearing aiming at the dynamic status of sliding bearing. Upon combining the bearing width, bearing diameter, relative gap and pressure field distribution rules, and the relationship between sliding bearing load, rotating speed and contact angle, the model may further reduce the wear extent of sliding bearing in the whole running period and effectively optimize the sliding bearing in high-speed and heavy-load conditions.

Introduction

Radial sliding bearing is widely used in medium and large-scale vessel main shaft, large-scale gear case and other high-bearing parts due to its features in high bearing capacity [1], impact resistance, smooth and reliable working, low noise, high operating accuracy, etc. The shafting power transmission system is an important constituent part of the vessel power device. The reliable and safe operation of shafting is an important condition to guarantee the performance of vessel power. Sliding bearing is one of the key parts of large-scale vessel shafting, which plays the role of support and bearing. The sliding bearing is easy to break down in working due to its high bearing load and more wear factors. With the large-scale development of vessel in China, the output power of vessel power device becomes higher and higher, and the requirement for sliding bearing is also higher and higher. Therefore, it is very important to reasonably and optimally design the sliding bearing, effectively lubricate and cool it, reduce wear, prolong service life, improve service efficiency and do a good job in maintenance, use and management of sliding bearing.

In recent years, multi-bush cylinder sliding bearing, cylindroid sliding bearing, mismatching bush sliding bearing and water lubrication sliding bearing have been developed in the filed of sliding bearing. The research shows that different structure forms have important influence on the working performance of sliding bearing in the same working environment.

The main parameters influencing the wear property of sliding bearing are bearing width-diameter ratio, eccentricity ratio, relative gap, oil film thickness, shaft contact angle, radial load lubricating oil viscosity and bearing rotating speed. The movement mode of sliding bearing friction pair is relative sliding, so friction and wear become the important problem in the research of sliding bearing. Different lubrication conditions may generate
different friction status. The friction status of sliding bearing may be divided into dry friction, boundary friction, mixed friction and fluid friction. One cycle of sliding bearing will pass the four kinds of friction. The internal friction and wear extent of sliding bearing is determined by the distribution of pressure field and temperature field, which has high correlation with oil film thickness. The current research of sliding bearing mainly centers on the establishment of oil film and the decrease of wear, ignoring the boundary friction in starting operation status and standby status, while the wear of boundary friction to sliding bearing is far larger than the fluid friction under oil film status. Most faults of sliding bearing are caused by the mixed friction. Therefore, the paper establishes the dynamics temperature field model and dynamics pressure distribution model in the sliding bearing aiming at the dynamic status of sliding bearing. Upon combining the bearing width, bearing diameter, relative gap and pressure field distribution rules, and the relationship between sliding bearing load, rotating speed and contact angle, the model may further reduce the wear extent of sliding bearing in the whole running period and effectively optimize the sliding bearing in high-speed and heavy-load conditions.

Main Types of Radial Sliding Bearing

The common radial sliding bearing has monolithic round-pad bearing and splitting sliding bearing (it is divided into partial-pad bearing and tilting-pad bearing). The monolithic sliding bearing has simple structure, which is generally used in low-speed and low-load machine. Under high speed, it is unable to adjust the bearing gap due to the poor stability and large wear gap. Relative to monolithic bearing, the splitting sliding bearing may adjust bearing gap under high speed, and the installation method is simple.

National Research on the Theme

The design variables are bearing hole diameter, shaft neck diameter and bearing width. At present, as for different forms of sliding bearing, difference method or finite element method may be used to research the static and dynamic property of bearing. The mathematical model may be established to optimize the bearing design through changing the structure parameters of bearing. Hou Mengqi[2] establishes the radial 3D fluid lubrication numerical analysis model and gets the influence of structure parameters and operation parameters of sliding bearing on lubrication performance. In 2012, Huang Shoufeng[3] from Zhengzhou University researched the pressure distribution of bearing oil film under different eccentricity ratios and rotating speed through FLUENT simulation software, and drew the conclusion that the bearing pressure increases as the increase of rotating speed and eccentricity. The model is applied in various bearing forms for the optimal design under different working conditions and constraint conditions.

The national research on large-scale sliding bearing mainly centers on fluid friction, while the research on dry friction, mixed friction and bearing thermal deformation starts late. The foreign research started early in the field. In the opinion of C.M.M.Ettles[4] (1980-1991), if only the elastic deformation of bushing surface is considered, the thrust bearing design has no size effect, the thermal deformation of bushing surface increases with the increase of bearing size, the maximum unit of bearing capacity reduces in the approximate exponential relation
with the increase of tile size. The large-scale bearing is often in thermal ratcheting process, causing ball bearing failure. The technical measures of reducing temperature of bushing surface may improve the bearing capacity of large-scale bearing, such as radius of supporting plate, collaborative support system and cooling bearing bush. In 2006, H.C.Grag[5] summarized the research progress of dynamic and static pressure sliding bearing. In their opinion, they shall research the influence of axis deflection, bearing deformation, surface roughness, non-newtonian feature of lubricant and thermal effect on bearing performance. In 2009, B.Maneshian[6] researched the radial sliding bearing in turbulence flow condition, analyzed the influence of Reynolds number, bearing clearance and eccentricity on bearing, and compared the calculated results with the theoretical and experimental data in other papers. In 2011, M. Fillon[7] analyzed the influence of flexible bearing sleeve on bearing performance and considered the deformation of bearing sleeve, and got the relationship between bearing capacity and bearing thermal deformation.

Operating Of Sliding Bearing of Large-Scale Vessel in Run-in Period

In recent years, how to reduce the wear of large-scale vessel sliding bearing has drawn the attention of scholars. When the new large-scale vessel operates underwater, the engine and sliding bearing have a run-in period. In the run-in period, the temperature will rise sharply and shock intensely because the sliding bearing oil wedge does not reach the bearing area and the oil film is damaged, making the shaft and bush in self-friction status for a period of time. When the machine equipment is intact, the bearing will reach a balance value and work stably. In case of accident, such as overlarge bearing, overload running, it will cause excessive run-in, increase bearing temperature, cause bush deformation, lubricating oil deterioration and viscosity decrease and form dry friction, and cause strong wear and large-area “gnawing solder”. When serious, it will cause the bush enclose the shaft neck and damage the engine.

Theoretical Research of Large-Scale Sliding Bearing

Reynolds equation is the basic equation of lubrication theory analysis, which reflects the relationship between lubricating film pressure, thickness, viscosity, density and relative speed as the basis of fluid power lubricating analysis. Reynolds equation considers the circular and axial changes of viscosity and density of lubricating oil. Because the oil film thickness is in micrometer level, the average viscosity and density in oil film thickness direction is used to reduce the calculated quantity. Reynolds equation is obtained in different simplification conditions. To solve these problems, Professor Zhang Zhiming and Tu Wen from Shanghai University tabled non-linear oil-film force database method. Its calculation accuracy is similar to the finite element method, while the speed is many decades times of the finite element method, which solves the contradiction between speed and precision. At present, there is not an unified standard for the non-linear oil-film force database of sliding bearing. It is very important to calculate the static and dynamic characteristic parameters with non-linear oil-film force database and the data in the database. Kato T has presented the concept of sliding bearing in the literature. Kato T put forward stored the calculated bearing characteristic parameters with the bearing type, l/d and Sommerfied as the
parameters. Due to complex type of bearings, the data will be very huge, and it is impossible to contain the unconventional bearing types.

**Analysis of Thermal Lubricating Performance**

At present, in the design and theoretical analysis of sliding bearing, a series of clear factors shall be considered, in order to be close to the fluid pressure distribution, speed distribution, oil-film thickness distribution and temperature distribution of thrust sliding bearing in the actual conditions, and guide the design of large-scale sliding bearing. Because the test cost of heavy-load sliding bearing is high and the test expenses are expensive, the research of flexible fluid power lubrication of thrust sliding bearing has important engineering significance.

Because the viscosity and density of lubricating oil is sensitive to the temperature changes, the research and design of sliding bearing shall take the temperature into account. A mathematical model shall be set up to analyze the thermal lubrication of sliding bearing. Liu Ying and Guo Xiquan in Tsinghua University analyzed the calculation method of high-speed and heavy-load radial sliding bearing, and drew the conclusion that the high-speed and heavy-load radial sliding bearing shall use thermo-elastic property method, and the static property result is close to the test value, and the calculation convergence may be got when calculating the large eccentricity. In 2013, Shao Qi[8] from Harbin Engineering University researched the influence of unbalance load on sliding bearing capacity through the research and development of experiment table of unbalance dynamic pressure sliding bearing, and the oil film pressure. The surface of sliding bearing is coarse. When the bearing temperature is over-high in severe operating conditions, the coarse peak contact will happen and it is in mixed friction status, and the severe wear will occur. Some experts[9] discovered upon a series of research the change of sliding bearing and structure parameters may effectively reduce wear.

**Summary**

To sum up, since 1980s, there are continuous research one the lubricating performance of radial lubricating bearing. From the initial hypothesis of infinite wide and infinite narrow to now, various factors in actual operation have been considered. While the mathematical model becomes more and more perfect, the calculation results also increasingly be close to the practical conditions. The research on the lubricating performance of radial lubricating bearing further promotes the application of sliding bearing in the industry. Upon research and analysis of thermal lubricating performance of sliding bearing, the data are close to the actual conditions of bearing. Therefore, the determination of wear of sliding bearing has very important significance on the research of influence of structure parameters on wear.

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