Volume 11 Issue 3, 2025
DOI: 10.6919/ICJE.202503_11(3).0012

Calculation of Bearing Elastic Deformation Temperature Rise Simulation Research

Yuting Ma[a]

University of Shanghai for Science and Technology, Shanghai 200082, China

[a]mytgemma@163.com

Abstract

High-end equipment bearings require long life, high precision, and high stability, and their influencing factors need to be thoroughly and systematically investigated. Temperature increase will greatly promote the organizational structure changes, which will directly affect the fatigue life of bearings. This paper adopts a numerical simulation calculation method to simplify the bearing model in the alternating stress elastic deformation of the temperature change. Based on the finite element analysis method to establish the steady-state thermal analysis model of the bearing, the simulation calculation results show that compared with the load change, the temperature rise caused by the speed change is more drastic, and the effect of speed on the bearing temperature is more obvious.

Keywords

Axlebox Bearing; Elastic Deformation; Finite Element Analysis.

1. Introduction

With the development of modern industry, rotating machinery and equipment for high-speed, high precision, and high stability requirements are increasingly high. As the key components of rotating machinery and equipment, bearings directly affect the performance of the entire mechanical equipment, research and development of high-performance bearings is an important topic. Rolling bearings are widely used in various fields due to their high transmission efficiency, small friction torque, low friction power consumption, and other advantages[1]. Bearings are also known as the 'joints of industry'. Bearing temperature, as an important performance indicator of bearings, plays an important role in ensuring the normal operation of bearings. Therefore, it is crucial to study the temperature rise mechanism of bearings and analyze the temperature field distribution of bearings.

There can be several reasons why bearings warm up, the main ones being that when the bearing is in operation, frictional heat is generated due to the friction between the rolling elements and the raceways causing the bearing to warm up. Poor lubrication or lubricant aging, frictional heat will be more significant. Bearings are subjected to loads that exceed their rated carrying capacity, which can lead to excessive friction and heat when the bearings are in operation. Incorrect bearing mounting, such as too tight or too loose mounting, non-parallel or non-perpendicular, etc., will result in increased friction when the bearing is in operation, resulting in temperature rise. Bearings need sufficient lubrication to reduce friction and wear. Insufficient, contaminated, or improperly used lubricant will result in poor lubrication, which in turn will cause the bearings to heat up. Damaged or badly worn bearing parts can lead to increased friction and excessive heat generation. Mechanical vibration and imbalance can subject bearings to additional loads, increasing friction and heat generation.

Bearing temperature calculation is currently the main method used: in the solution of the bearing friction power consumption based on the use of generalized Ohm's law based on the establishment of the thermal resistance network method as well as based on the finite element analysis software finite element method[2]. Harris establishes the calculation model of friction power consumption of each part of the bearing, analyses the three kinds of heat transfer modes existing in the bearing, establishes the mathematical calculation model of heat conduction coefficient, convection coefficient and heat radiation of the bearing, and calculates the temperature rise of the bearing based on the thermal resistance network method[3]. Tarawenh simulated the temperature rise of train bearings, established a finite element model, obtained the temperatures of the components in each part of the bearings, and analyzed the relationship between the heat generation rate of the bearings and the surface temperature of the bearings[4]. Kang Seok Kim[5] used the finite element method to build a spindle system with an actual layout for temperature rise simulation based on calculations to obtain the frictional power consumption of the bearings, and designed tests to verify the validity of the finite element analysis.

There have been a large number of studies on the simulation method of rolling bearing temperature rise, but there are relatively few studies on analyzing the thermal effect of elastic deformation of bearings under alternating stress and examining the effect of roller roundness deviation on temperature rise to confirm whether the thermal effect of elastic deformation of the material is one of the main factors of bearing temperature rise. In this paper, numerical simulation is used to calculate the temperature change produced when the simplified model of the bearing is elastically deformed under alternating stress.

2. Methods

2.1 Geometric Modeling

In this paper, the axlebox bearing is taken as the research object, which is modeled using 3D software and then imported into the thermal deformation simulation calculation model. Considering the amount of calculation data and the problem of simplifying the calculation model, the bearing model is further simplified in Figure 1(b).

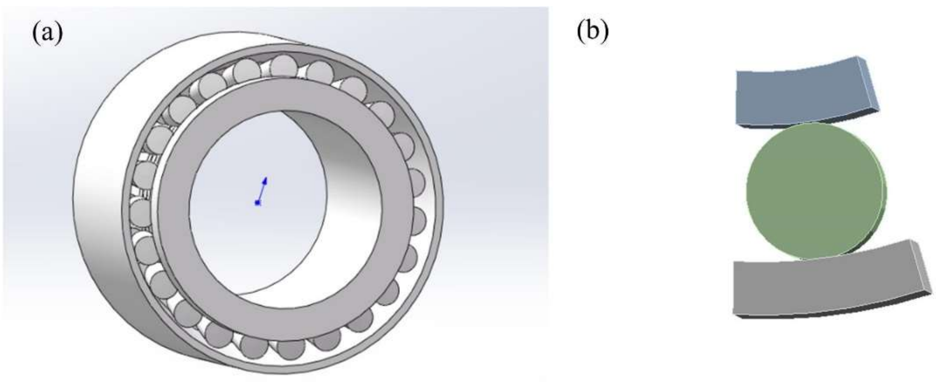

Figure 1. Simplified 3D modeling of bearings

2.2 Material Property Settings

In this paper, the material of bearing inner and outer rings is GCr15 bearing steel, and the thermal-physical parameters of the bearing steel are calculated by using the material software, as shown in Figure 2. And imported into the material database of numerical simulation software. GCr15 bearing steel is a widely used, low alloy content, excellent performance of high-carbon chromium bearing steel, bearings in the working process must withstand extreme loads and friction, so GCr15 has a high and uniform hardness and wear resistance[6].

 Volume 11 Issue 3, 2025
DOI: 10.6919/ICJE.202503_11(3).0012

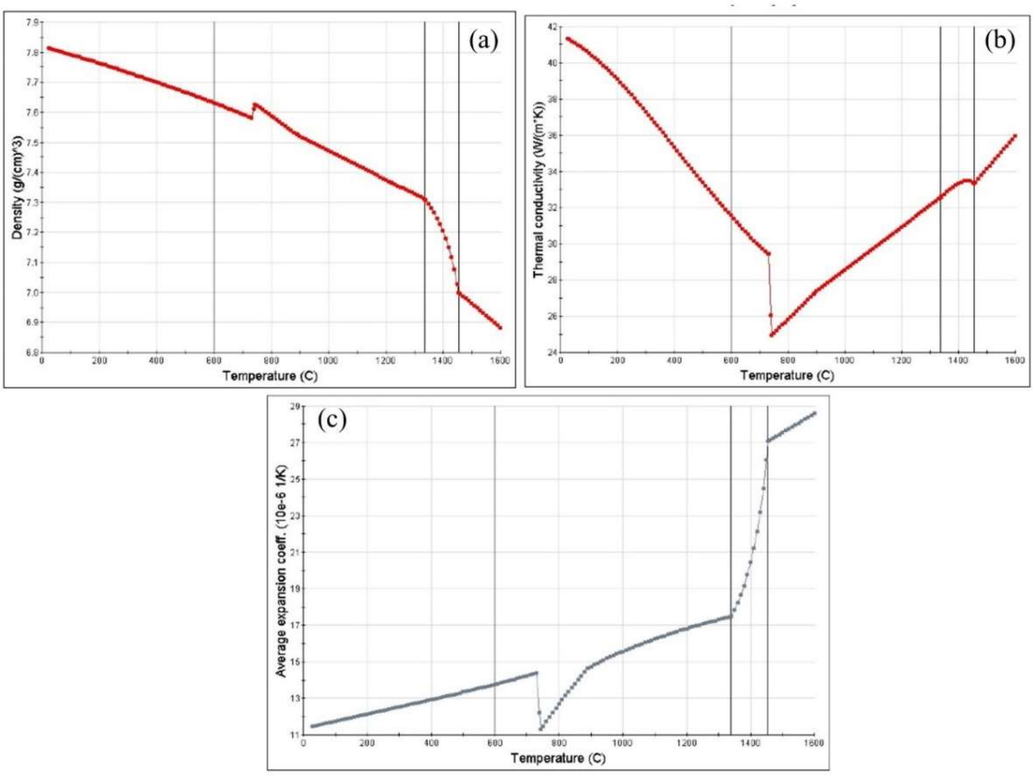

Figure 2. GCr15 Partial Thermophysical Properties (a) Density (b) Thermal Conductivity (c) Coefficient of Thermal Expansion

2.3 Meshing

Mesh delineation is a key step in finite element analysis. The size and quality of the mesh delineation have a direct impact on the time required for the calculation and the accuracy of the results. The number of meshes directly affects the size of the calculation and the accuracy of the results, so the number of meshes should be reasonably controlled. Grid density According to the requirements of the analysis content, different grid densities are used in different parts of the model, which can reduce the size of the calculation without affecting the analysis results. Grid division of the model, this paper mainly analyzes the temperature field distribution of the bearing roller, therefore, in order to reduce the amount of calculations while ensuring the accuracy of the bearing temperature field calculation results, the density of the grid division of the bearing roller increased, the number of grids increased, the rest of the mesh division of the density of the mesh reduced, the number of grids reduced, the grid division of the total number of 2128 cells and 10,555 nodes, the specific mesh division as shown in Figure 3 shows.

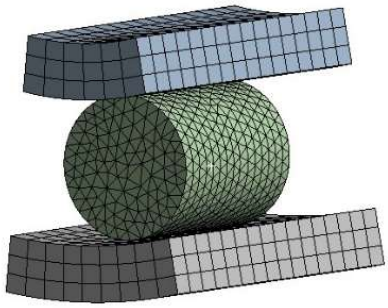

Figure 3. Schematic of bearing mesh analysis

ISSN: 2414-1895 DOI: 10.6919/ICJE.202503_11(3).0012

2.4 Boundary Condition Setting

Contact analysis needs to set the contact of each part of the model, and the contact types are Bonded, No Separation, Frictionless, Rough and Frictional. According to the actual working condition of the bearing, the contact type is selected as frictional contact, and the surface of the roller is selected as the contact surface and the surface of the raceway is selected as the target surface. According to the selection principle of normal stiffness, after selecting several groups of stiffness for trial calculation and comparing the results, the normal stiffness is taken as 1. The coefficient of friction is adopted as 0.001 for cylindrical roller bearings.

The roller contact loads were set to 5000N, and 7500N; the rotational speeds were 500,1000r/min respectively where the ambient temperature was set to 25°C, the outside air flow rate was 10 m/s, and the surface heat transfer coefficient was 46W/(m2 °C). The heat generation was loaded in the form of heat flow rate to the inner and outer surfaces in contact with the rolling body and raceway, and thermal convection was loaded on the inner and outer rings as well as on the outer surfaces of the rolling body.

3. Results and Discussion

After the pre-processing is completed, the bearing is directly solved by transient thermal analysis, and after the solution is completed, the calculation results, bearing temperature field, deformation, and equivalent stress distribution cloud diagram can be viewed in the results module. Figure 4 shows the load and speed changes for the bearing temperature rise and stress relationship, from the perspective of bearing temperature rise, it is obvious that changes in speed on the bearing elastic deformation temperature rise have a greater impact, and the faster the speed of the temperature rise in the process of temperature fluctuations. The change of rotational speed has less influence on the stress-strain concentration of the bearing, while the influence of load is slightly larger.

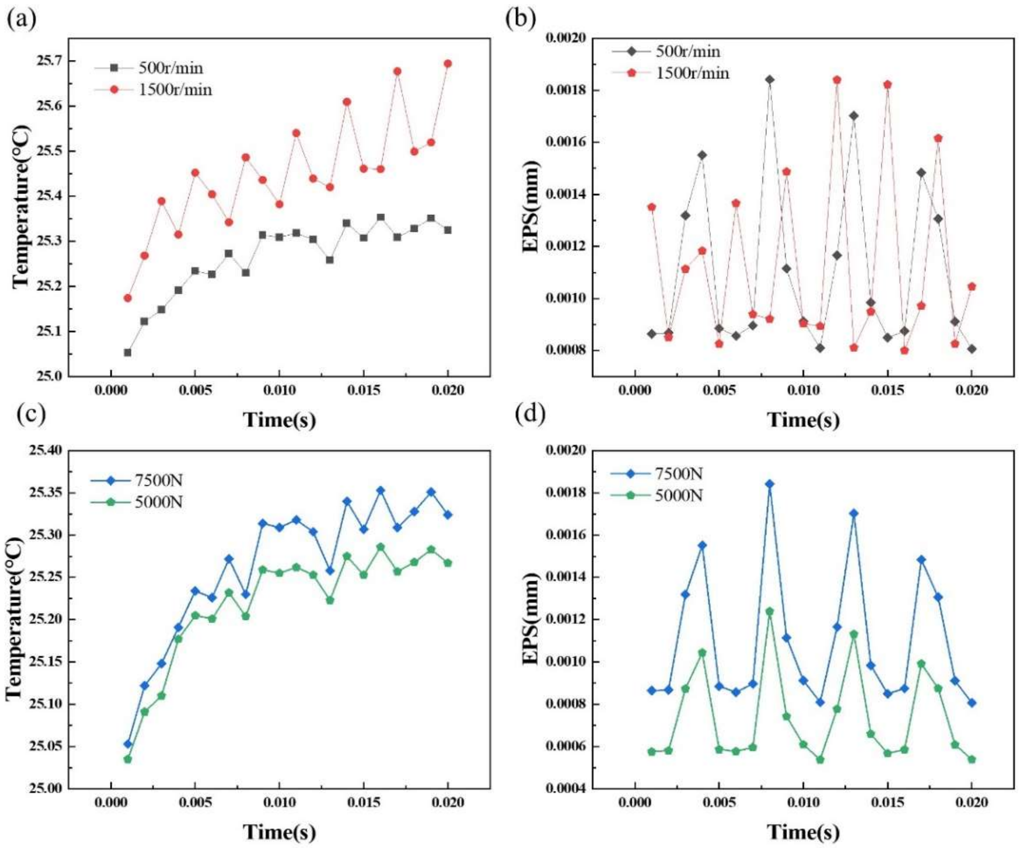

Figure 4. Relationship between time-temperature, time-strain during elastic deformation

ISSN: 2414-1895 DOI: 10.6919/ICJE.202503_11(3).0012

As can be seen from Figure 5, the highest temperature region of the bearing during operation occurs at the contact between the roller and the inner raceway of the inner ring of the bearing, and the second high-temperature region is the contact between the roller and the inner raceway of the outer ring of the bearing, which is due to the heat generated by the roller through spinning, rotation and contact with the inner and outer ring raceways, and the heat dissipation of the inner ring is poorer than that of the outer ring; and the outer ring has the lowest temperature on the outer surface. This is because there is no heat source on the outer surface of the outer ring and good heat dissipation conditions.

The temperature change defined by the Joule-Thomson effect for solids is always slight due to the fact that the deformation process of the metallic material in the elastic zone leads to insignificant volume changes (less than 1 %). The temperature change of the bearing in the calculation results is not very obvious, but of course, the places where the stress concentration is generated are also the places where the temperature rise is more obvious, and in the subsequent study of the temperature rise of the bearing, the elimination of the stress concentration can be considered to achieve the alleviation of the temperature rise.

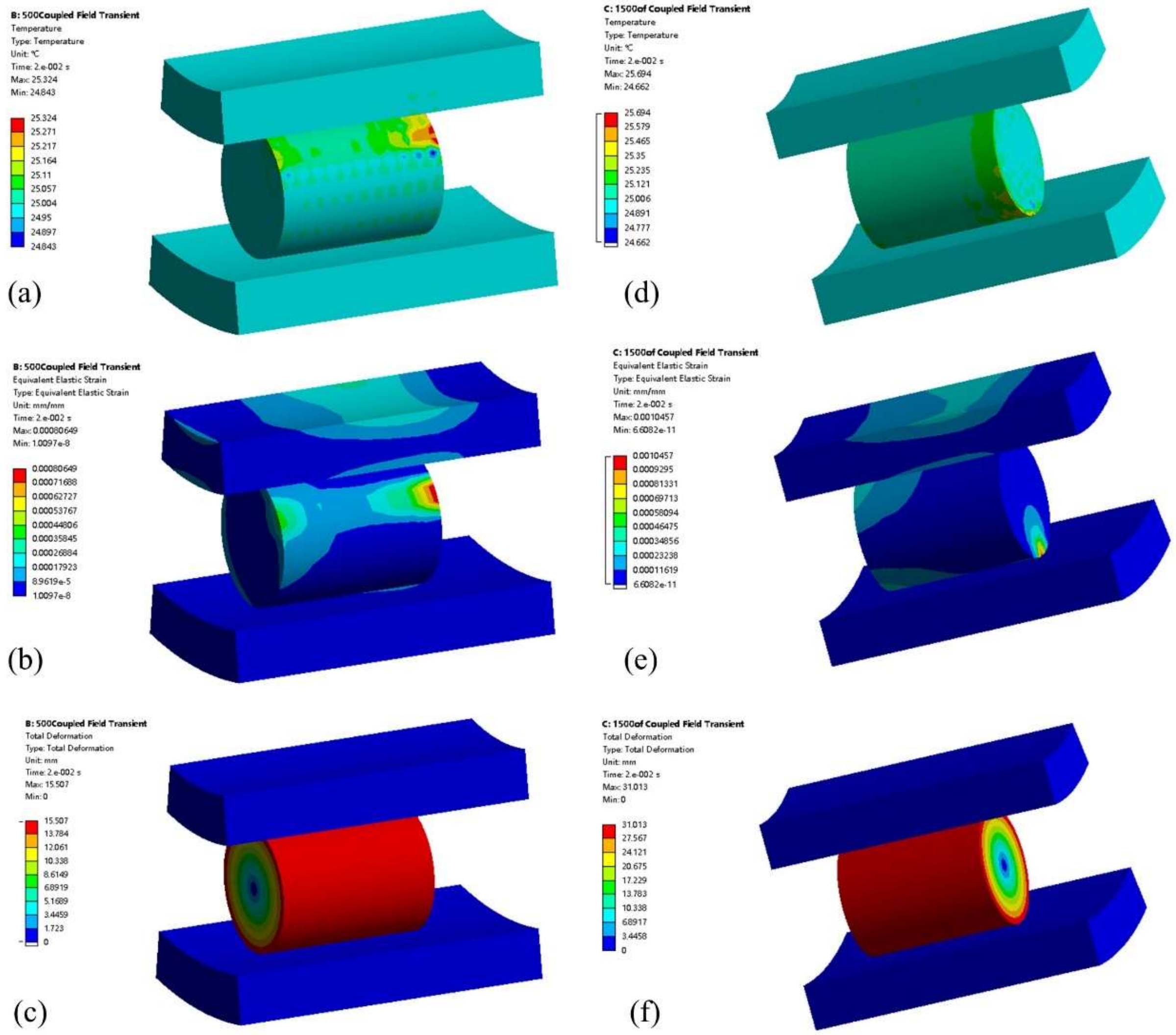

Figure 5. Cloud diagram of bearing calculation results (a) (b) (c) is the temperature field, stress field, deformation under the conditions of a load of 7500N, speed of 500r/min; (d) (e) (f) is the temperature field, stress field, deformation under the conditions of a load of 7500N, speed of 500r/min

ISSN: 2414-1895 DOI: 10.6919/ICJE.202503_11(3).0012

4. Conclusion

The temperature rise and temperature field distribution of bearings have a great influence on the service operation safety, load-carrying capacity and operation speed. Temperature rise is an important indicator to monitor the failure of the axle box bearings and analyze the influence of service conditions on the temperature rise of the axle box bearings, including operating speed, axle box bearings bear loads, etc., so as to improve the service conditions of the axle box bearings and to reduce the incidence of failure of the axle box bearings, which is an urgent problem to be solved to ensure the safety. Load and speed will directly affect the shaft temperature, the increase in load and speed will cause the rise of shaft temperature. Compared with the load change, the temperature rise caused by the speed change is more drastic, and the influence of speed on the bearing temperature is more obvious.

References

[1] H.K.D.H. Bhadeshia, Steels for bearings, Progress in Materials Science 57(2) (2012) 268-435.

[2] Zhu Peng Fei, Liu Juan, FEA and Verification of Temperature Field in Gear Form Grinding, Machine Tools and Hydraulics 45(5) (2017) 155-159.

[3] T.A. Harris, M.H. Mindel, Rolling element bearing dynamics, Wear 23(3) (1973) 311-337.

[4] C.M. Tarawneh, A.A. Fuentes, J.A. Kypuros, L.A. Navarro, A.G. Vaipan, B.M. Wilson, Thermal Modeling of a Railroad Tapered-Roller Bearing Using Finite Element Analysis, Journal of Thermal Science and Engineering Applications 4(3) (2012).

[5] K.-S. Kim, D.-W. Lee, S.-M. Lee, S.-J. Lee, J.-H. Hwang, A numerical approach to determine the frictional torque and temperature of an angular contact ball bearing in a spindle system, International Journal of Precision Engineering and Manufacturing 16(1) (2015) 135-142.

[6] Y. Su, L.J. Miao, X.F. Yu, T.M. Liu, L. Liu, J.L. Liu, Effect of isothermal quenching on microstructure and hardness of GCr15 steel, Journal of Materials Research and Technology 15 (2021) 2820-2827.