Study of Multiple-Point Oil-Jet Lubrication of High-Speed Ball Bearings

Mingxing Wu, Wei Wu, Shihua Yuan and Jibin Hu

The air-oil, two-phase flow inside the multiple-point, oil-jet lubrication ball bearing was studied based on CFD (computational fluid dynamics) theory and technique, and compared with single-point, oil-jet lubrication. The results indicate that the air-oil distribution inside the bearing with multiple-point, oil-jet lubrication is more uniform than single-point injection.

Introduction

The running state of rolling bearings affects an entire system's performance. To ensure smooth operation, an effective lubrication is important. For high-speed ball bearings, oil-jet lubrication can prove quite beneficial (Ref. 1). The lubrication performance of the rolling bearing has been comprehensively investigated via the single-phase method (Ref. 2), but in fact the air oil, two-phase flow will be formed inside a bearing with oil-jet lubrication (Ref. 3). Many studies of the two-phase flow formed by bearing lubrication have been investigated, but these were all dedicated to bearing chambers of aircraft engines with single-point, oil-jet lubrication (Ref. 4).

In this work, the two-phase flow inside the high-speed ball bearing with multiple-point oil-jet lubrication was simulated using CFD software and compared with single-point, oil-jet lubrication. The results can be used to optimize the accurate lubrication design of the bearing.

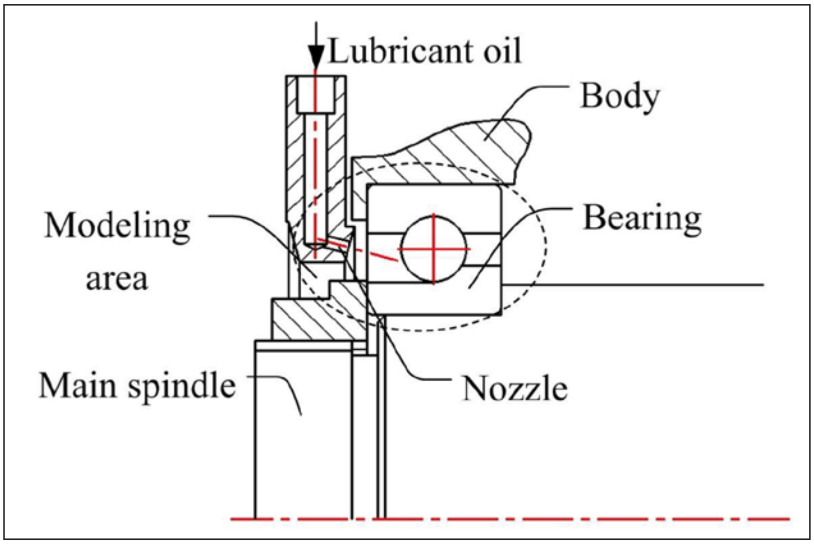

Figure 1 The schematic of oil-jet lubrication.

CFD Model

Figure 1 shows the structure chart of an oil-jet lubrication ball bearing. The three-dimensional model of flow field inside the dual-nozzle bearing was built based on the structure shown in Figure 2, and the computational mesh has 118,709 cells. The sliding mesh plane was used at the edge of the flow field inside the bearing to complete the data transfer in the entire computation domain.

The nozzle inlet was set as "mass flow inlet," and the outlet boundary was set as "pressure outlet" (atmospheric pressure). Different walls were also added to the rotation boundary conditions and no slip conditions. The standard wall

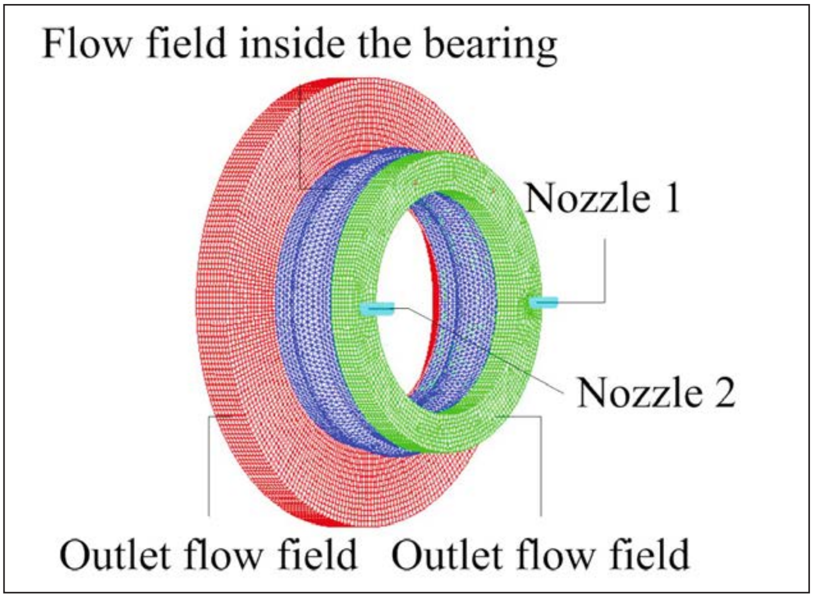

Figure 2 Calculating grid for the whole domain.

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function was adopted for the near-wall region. The adopted iterative algorithm was SIMPLEC.

Simulation Results and Analysis

Model validation. Figure 3 shows the experimental apparatus for oil-jet lubrication; the speeds can reach up to 15,000 r/min. Three thermal resistances were uniformly placed on the outer ring of the bearing — T_1, T_2 and T_3 — along its rotational direction.

Figure 4 shows the distribution of average oil volume fraction on the rollers' surface along the circumferential azimuth. The azimuth at Nozzle 1 is 0 degrees and increases along the rotation direction of the bearing. It can be found that the air-oil distribution inside the bearing is not uniform and decreases along the rotation direction. The air-oil distribution is more uniform with dual-nozzle, which also makes the temperature distribution along the circumferential direction of the bearing more uniform. However, the temperature difference is less (Table 1); the temperature at the position with more oil volume fraction is lower. The bearing temperature distribution is affected by the non-uniform air-oil distribution, which validates the correction of the simulation model indirectly.

Non-uniform, air-oil distribution. Figure 5 shows the simulated air-oil distribution of different nozzles. The speed of the inner ring is 10,000 r/min and the oil flow rate is 3.0 L/min. It can be found that the air-oil distribution inside the bearing is not uniform. At the same oil flow rate, the more the number of nozzles, the more uniform is the oil-air distribution.

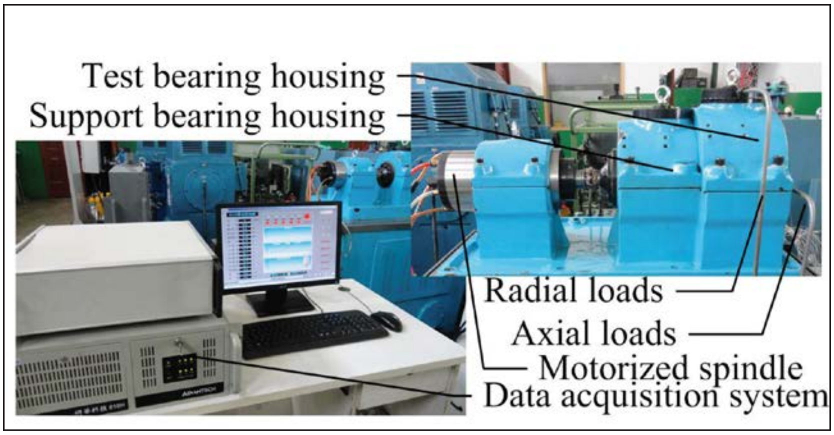

Figure 3 The test rig of bearing lubrication.

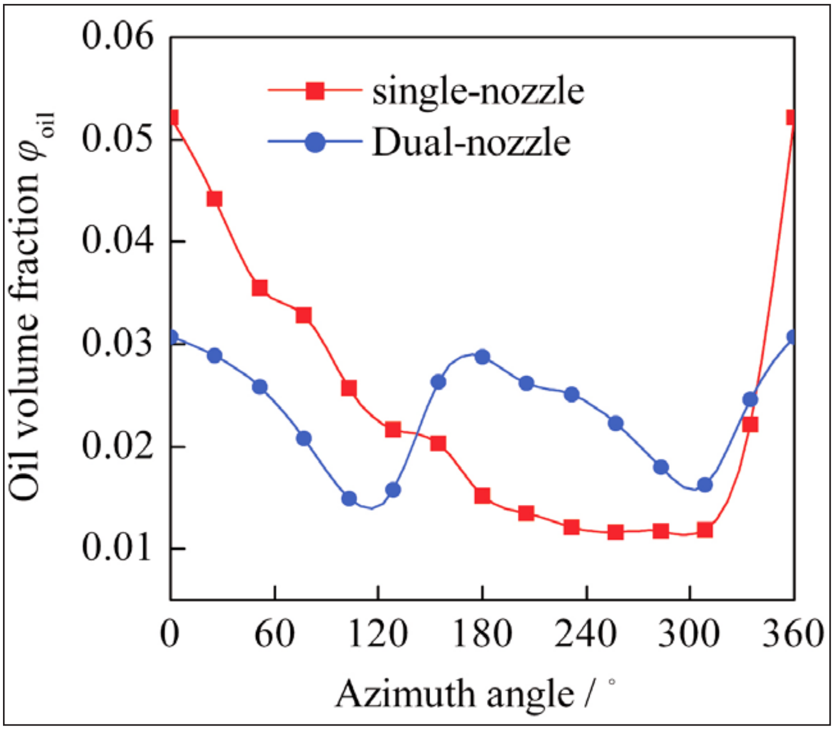

Figure 4 The oil volume fraction distribution.

Single-Nozzle, Dual-Nozzle, Tri-Nozzle

The influence of nozzle number. Figure 6 shows the variation of the average oil volume fraction inside the bearing with the nozzle number. It can be found that the average oil volume fraction increases with the increased number of nozzles. The increasing trend of average oil volume fraction slows when the number of nozzles increases to a certain value, which indicates that the impact of the number of nozzles on the oil volume fraction is limited.

Conclusions

- The two-phase flow model was used to study the flow character inside the high-speed ball bearing with multiple-point, oil-jet lubrication.
- The model was verified as correct by the test.
- The air-oil distribution inside the bearing is not uniform, and decreases along the rotation direction.
- At the same oil flow, the more nozzles, the more uniform the oil-air distribution.

Table 1 The temperature distribution of outer ring at different flow rate

Flow rate (L/min)	Temperature of outer ring (°C)					
	Single-nozzle			Dual-nozzle		
	T_1	T_2	T_3	T_1	T_2	T_3
4	51.5	54.2	57.1	77.5	77.1	79.5
6	52.4	55.8	56.9	75.1	74.5	76.2
8	53.5	56.5	58	77.1	75.5	78.2

- The oil volume fraction increases with the increase of nozzles.
- The increasing trend of oil volume fraction slows when the number of nozzles increases to a certain value, thus indicating that the impact of nozzle number on the oil volume fraction is limited. **PTE**

References

1. Pinel, S. I., H.R. Signer and E.V. Zaretsky. "Comparison Between Oil-Mist and Oil-Jet Lubrication of High-Speed, Small-Bore Angular-Contact Ball Bearings," *Tribology Transactions*," 44, 2001, pp. 327-338.
2. Harris, T. A., R.M. Barnsby and M.N. Kotzalas. "A Method to Calculate Frictional Effects in Oil-Lubricated Ball Bearings," *Tribolology Transactions*, 44, 2001, pp. 704-708.
3. Hadden, G.B., R.J. Kleckner, M.A. Ragen, et al. "Steady-State and Transient Thermal Analysis of a Shaft Bearing System Including Ball, Cylindrical and Tapered Roller Bearings," NASA CR-165365, 1981.
4. Wu, H. and G. Chen. "Numerical Research On Two-Phase Gas/Oil Bubble Flow In Bearing Chamber," *Journal of Mechanical Engineering*, 44, 2008, pp, 70-75.

Jibin Hu received the PhD degree in mechanical engineering from Beijing Institute of Technology (BIT). He is a full professor with the School of Mechanical Engineering at the BIT. Since 1995, he has been with the National Key Laboratory of Vehicular Transmission, BIT. He is the deputy dean of the School of Mechanical Engineering, BIT after 2006. His current research interests include vehicle dynamics, transmission in automobiles and tribology in gear transmission.

Mingxing Wu received the master's degree of mechanical engineering at the Beijing Institute of Technology, Beijing. She is employed at the Beijing Benz Automotive Co. LTD in the application engineering department with a focus on bearing lubrication.

Wei Wu studied mechanical engineering at the Beijing Institute of Technology (BIT), where he earned his doctorate. Since 2010, he has been with the National Key Laboratory of Vehicular Transmission, BIT. He is an associate professor of the School of Mechanical Engineering at the BIT with a focus on heat transfer and fluid dynamics.

Shihua Yuan received the PhD degree in mechanical engineering from Beijing Institute of Technology (BIT). He is a full professor with the School of Mechanical Engineering at the BIT. Since 1985, he has been with the National Key Laboratory of Vehicular Transmission, BIT. He is the chairman of the Automotive Engineering Department in the School of Mechanical Engineering, BIT after 2000. His current research interests include dynamics and control in unmanned vehicle.

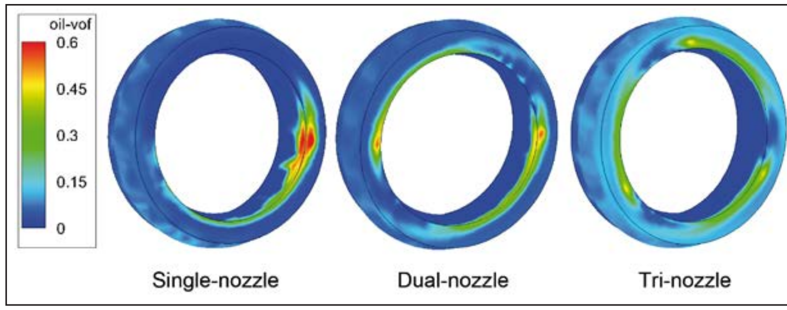

Figure 5 (a) The non-uniform air-oil distribution inside the bearing.

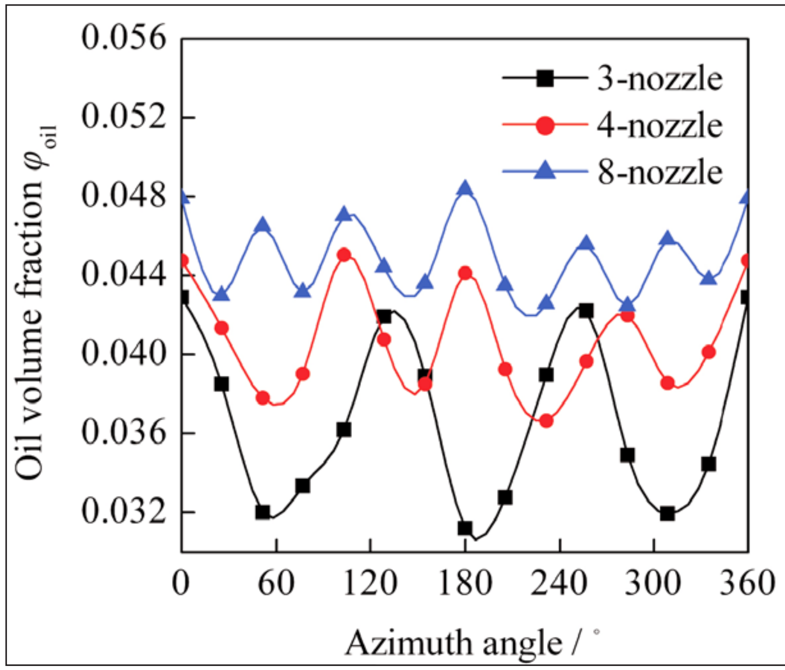

Figure 5 (b) The oil volume fraction distribution inside the bearing.

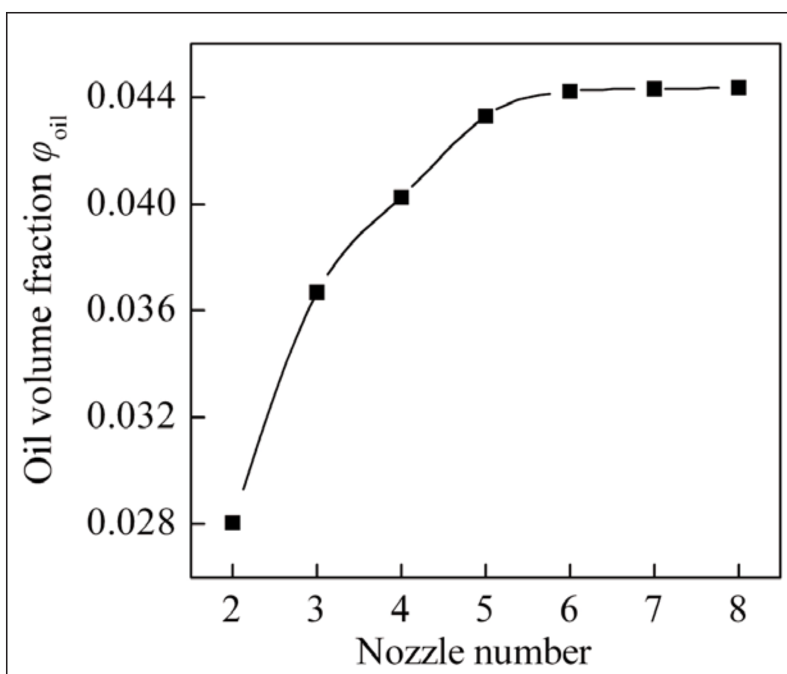

Figure 6 The variation of oil volume fraction with nozzle number.