2022

Numerical Analysis of Journal Bearing in Rotary Compressor

JEONGBAE LEE

Numerical Analysis of Journal Bearing in Rotary Compressor

Jeong-bae Lee[1]*

[1] Advanced C&M R&D Lab., SAMSUNG ELECTRONICS Co., Ltd.,
Suwon-si, Gyeonggi-do, Republic of Korea
E-mail: jb_lee@samsung.com

* Corresponding Author

Keywords: Rotary compressor, Lobe bearing, Hydrodynamic lubrication, Rolling piston

ABSTRACT

In this study, in order to investigate the characteristics of journal bearing in rotary compressor, numerical analysis of hydrodynamic lubrication and dynamics of the journal were carried out. The Reynolds equation of journal bearing for periodic compression force of rotary compressor were solved to obtain the locus of journal. The lobe bearing is adopted for comparison to the current plain journal bearing. Analysis results compare the minimum film thickness and frictional loss of both bearings. The analysis results reveal that the lobe bearing can improve the efficiency and the reliability of rotary compressor.

1. INTRODUCTION

Rotary compressors are employed for a variety of purposes due to its compact structure and excellent performance. The bearing of the compressor is an important component that has a great impact on the performance and reliability of the compressor. In particular, for the refrigerant change or for improvement compressor efficiency, the importance of bearing is increasing.

Generally, the rotary compressor has a plain journal fluid bearing that is easy to process. In this study, for the purpose of improving the performance of the rotary compressor, the case of adopting the lobe journal fluid bearing was analyzed. It was compared with the case of supported by conventional plain journal bearings.

The lobe bearings are reported to have excellent reliability and friction loss compared to plain circular bearings in some cases. Particularly, in the case of a rotary compressor, a periodically repeated bearing load is generated, so that the lobe bearing is possible to have various advantages over plain bearings. In this study, the characteristics of the compressor supported by the lobe bearing were analyzed and compared with the case of supported by conventional plain journal bearings.

Figure 1 shows the structure of a typical rotary compressor. As shown in the figure, the rotary compressor is a structure for performing a compression stroke by the eccentric rotation of the shaft. Both sides of the shaft are supported by a journal fluid bearing. In the figure, a compression chamber is formed by a roller and a vane, which makes a load to be applied to the shaft by a pressure generated in the compression chamber. As described above, a plain journal bearing is generally adopted as a journal bearing of a rotary compressor. Many studies have been made for the journal bearings of these rotary compressors.

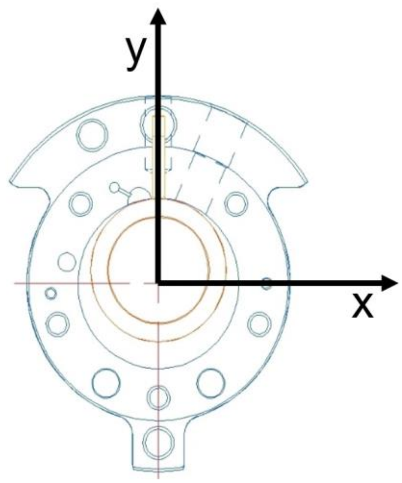

Figure 1: Schematic diagram of the rotary compressor cylinder

2. COMPUTATIONAL METHODS

Figure 2 shows the coordinate system of the bearing used in this study. As shown, bearings and journals form a bearing gap. The pressure is generated in the oil inside the bearing gaps by motion of journal. In this study, we used Multiphysics analysis tool Comsol to analyze the characteristics of bearing. The pressure generated in the bearing of the shaft was calculated using the Reynolds equation. By solving the movement equation of the shaft, and calculates the trajectory of journal.

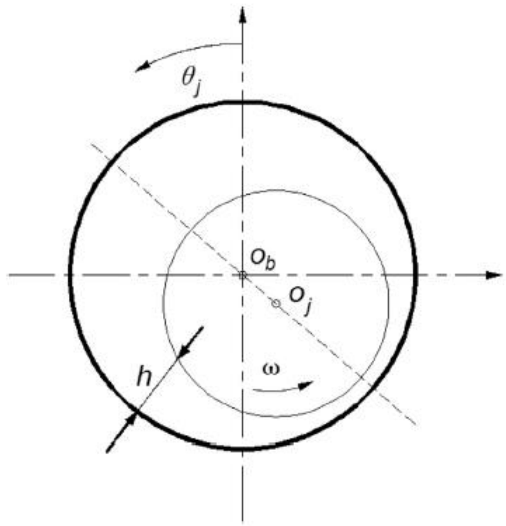

Figure 2: Journal center position in bearing

Equation 1 is the Reynolds equation used in interpretation. Consequently, provided that the definitions of the journal and bearing height, the Reynolds equation takes the form:

$$\frac{\partial(\rho h)}{\partial x} + \nabla_t \cdot (h\rho \mathbf{V}_{av}) = 0 \qquad (1)$$

where $h = h_j + h_b$ and the tangential velocity, $\mathbf{v}_{av}$ represents the mean velocity of the flow in the reference plane.
Table 1 shows the main dimensions and physical properties of the bearing used in the analysis. It shows bearing dimensions of a single cylinder type of rotary compressor.

Table 2: Bearing parameters

Parameter	Value	Description
Rj	7.15mm	Journal Radius
H	15mm	Journal width
ω	1800rpm ~5400rpm	Angular velocity
μ	2.5cP	Lubricant viscosity

The rotary compressor is a structure in which the load according to compression is applied to the eccentric portion of the shaft, and the load is supported by bearing on both sides of the eccentric portion. The rotary compressor generates a periodic load, and the compressed load is supported by the journal bearing on both sides of the compression chamber. Figure 3 shows a load that acts on a journal bearing by a compressed load. The left figure is a figure illustrating the X-directional load, and the right is a figure showing a load in the Y direction. To simplify the calculation, only a compressive load periodically acts on journal is considered for equation of motion of journal. The forces by unbalance of shaft and deflection of shaft were not reflected in the calculation of journal motion.

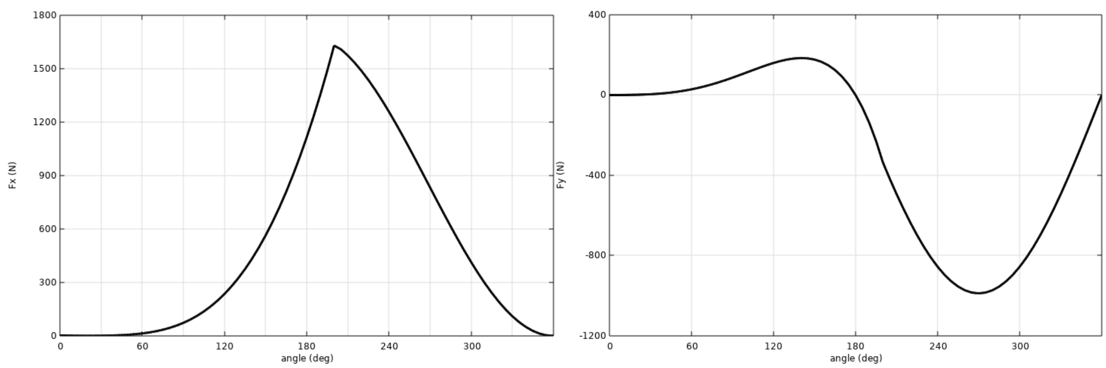

Figure 3: Bearing load of rotary compressor

Figure 4 shows an example of a pressure generated inside the upper and lower bearings. In this study, it was calculated how the bearing gaps changed according to the motion of the journal by the compressed load without considering the deformation of the shaft. The reliability of the bearing was examined by calculating the trajectory of the journal center and comparing the minimum fluid film thickness. In addition, the loss of bearing was calculated based on the frictional force acting between bearing and journal. The bearing losses are compared for the case supported by lobe bearing and by the current plain journal bearing.

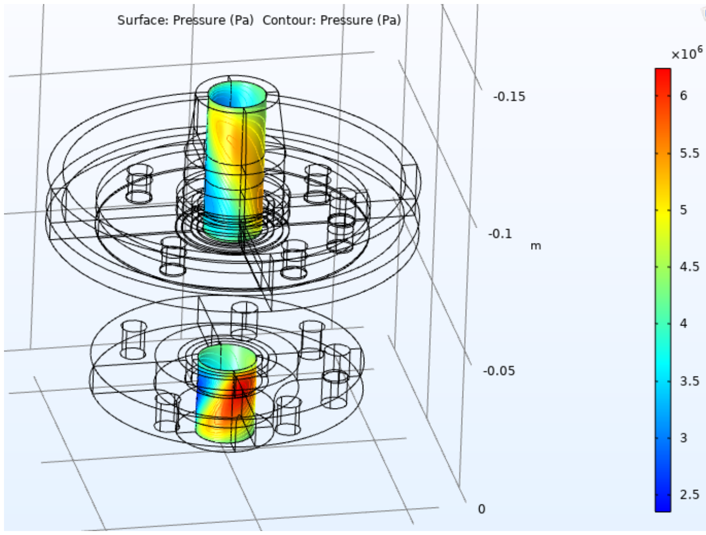

Figure 4: Pressure distribution in rotary compressor journal bearing

Figure 5 shows the layout position of lobe bearing in the rotary compressor. As shown in the figure, the center of the lobe bearing was located at the center of the cylinder, and the long axis direction of the lobe bearing was changed with respect to the vane direction and the bearing characteristics were analyzed.

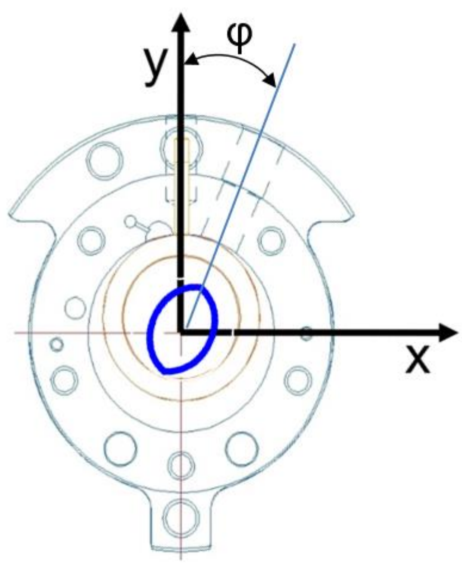

Figure 5: Lobe bearing in rotary compressor

In this study, the characteristics of 2 lobe bearings and plain bearings were compared. In this study, the lobe bearing's average bearing gap is same as the gap of the plain bearing. Figure 6 shows the circumferential gap of the 2 lobe bearings used in the analysis. The reliability characteristics of the lobe bearing and the plain bearings were compared by the minimum film thickness. And the frictional loss of both bearing were calculated to compare the bearing loss.

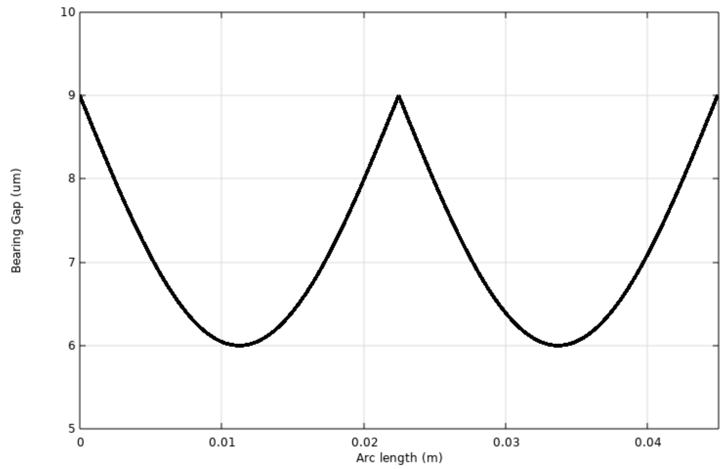

Figure 6: Gap of 2 lobe bearing

3. RESULTS AND DISCUSSION

3.1 Results of Plain Journal Bearing

Figure 7 shows the trajectory of journal center for current plain journal bearing. Initially, the center of the journal was placed at the center of the bearing and the motion of journal was calculated with the periodic bearing load. After a certain period of time as shown in the figure, the trajectory of the journal center shows repetitive trajectory. The minimum film thickness is about 0.5 ㎛ at the position near 100˚ with respect to the vane slot.

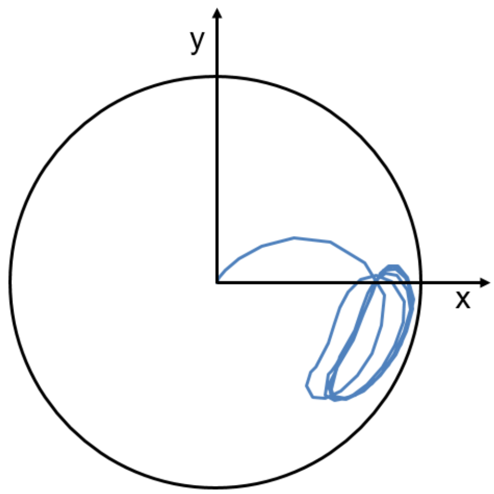

Figure 7: Trajectory of journal center of plain journal bearing

3.2 Results of 2-Lobe Bearing

Figure 8 shows the trajectories of journal center for a rotary compressor supported by a lobe bearing. The lobe bearing was analyzed for cases where the angle between lobe bearing and vane direction makes 30 ˚ to 150 ˚. The rotation speed of the journal was changed to 1800 rpm, 3600 rpm, and 5400 rpm for the same compressed load. The figure 8a is shows the case where the lobe bearing direction forms 0 degree and 30˚ with respect to the vane. The minimum film thickness is smaller than the plain bearing, which is less reliability. As the rotational speed increase, the minimum film thickness is slightly increased.

Figure 8b is results of performing the interpretation for when the lobe bearing is placed 60 ˚ and 90 ˚ with respect to the vane direction. In the case of 60 degrees as shown in the figure, it shows the minimum film thickness similar to the conventional plain bearing. When a lobe bearing is placed 90 ˚ with respect to vane direction, the minimum film thickness is increased more than 4 times that of plain journal bearing. Figure 8c is results of performing the interpretation for the lobe bearing is placed 120 ˚ and 150 ˚ with respect to the vane direction. As shown in figures in both cases, the minimum film thickness is increased by the plain journal bearing, which shows improved reliability.

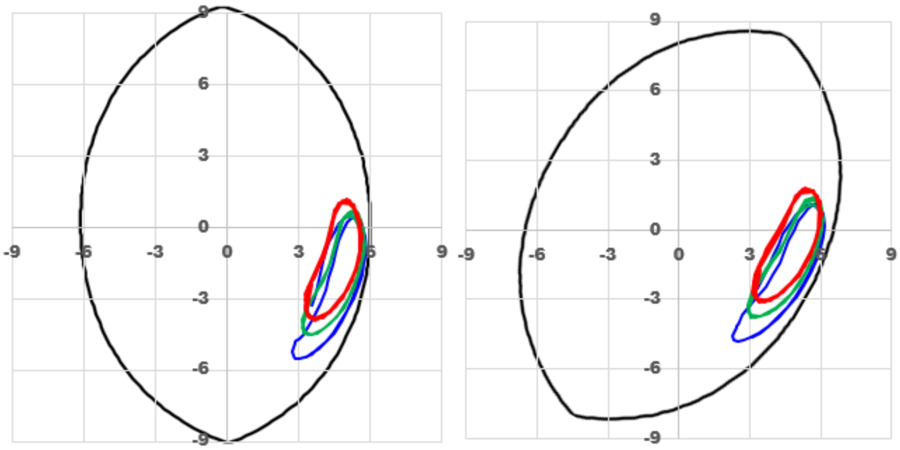

Figure 8a: Trajectories of Lobe bearing(Φ=0 ˚,30˚)

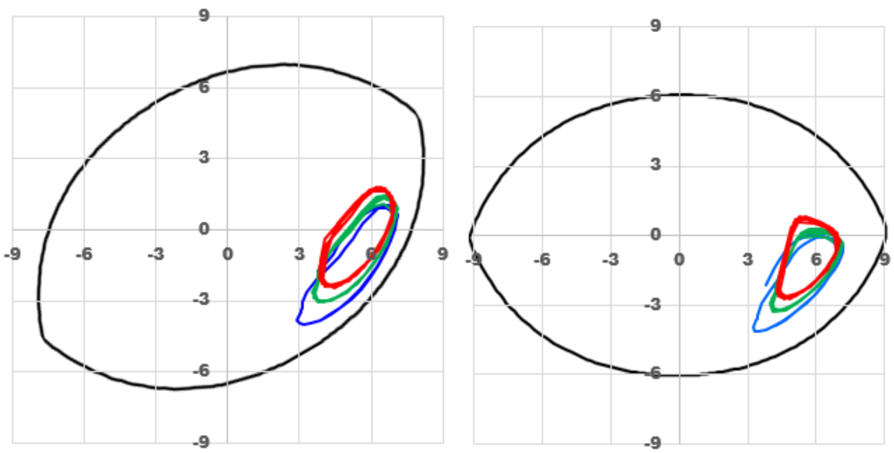

Figure 8b: Trajectories of Lobe bearing(Φ=60 ˚,90˚)

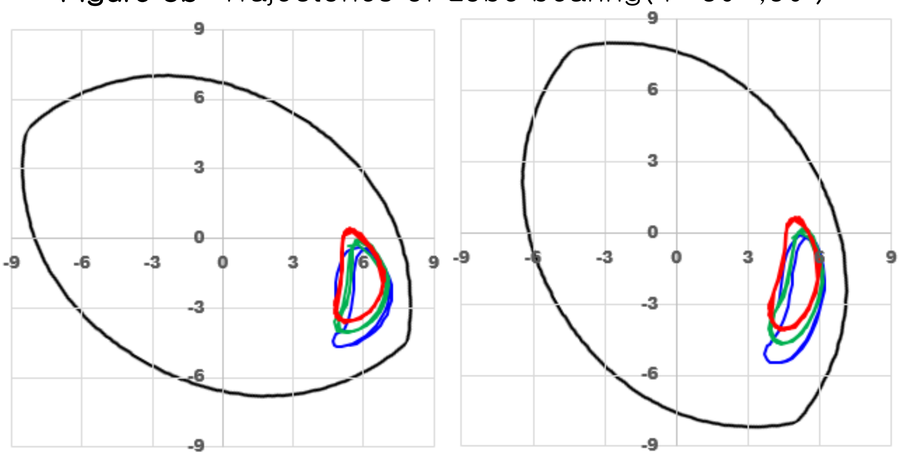

Figure 8c: Trajectories of Lobe bearing(Φ=120 ˚,150˚)

Figure 9 shows the bearing losses of the lobe bearing and the plain journal bearing. As shown in the figure, the lobe bearing is shown to reduce the bearing loss significantly compared to the plain journal bearing.

From the analysis result, it is shown that when supporting a rotary compressor with a lobe bearing, the arrangement angle of the lobe bearing is very important. If appropriately supports with lobe bearing, it is possible to enhance the reliability of the bearing, and further reduces the friction loss of the bearing and improve the performance of the compressor.

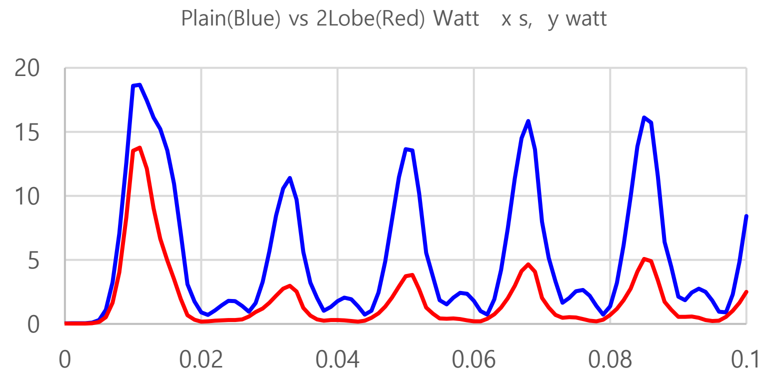

Figure 9: Bearing Loss with time

4. CONCLUSIONS

In this study, the characteristics of the journal bearing of the rotary compressor were examined. The characteristics when the rotary compressor bearing are composed with lobe bearing was compared with currently plain journal bearing. From the study, the following conclusions were obtained.

- To calculate the characteristics of the bearing, the trajectories of journal center were obtained with consider compression force of compressor.
- When supporting a rotary compressor with a lobe bearing, the arrangement angle of the lobe bearing is very important. If appropriately supports with lobe bearing, it is possible to enhance the reliability of the bearing and improve the performance of the compressor.

NOMENCLATURE

C	clearance	(μm)
h	gap height	(μm)
H	bearing height	(mm)
P	pressure	(Pa)
t	time	(s)

u	velocity vector	(m/s)
ρ	density of the fluid	(kg/m^3)
ω	journal angular velocity	(rpm)

Subscript

j	journal
b	bearing

REFERENCES

Bin Huang Le-qin Wang Jia Guo , 2014,"Performance comparison of circular, two-lobe and elliptical journal bearings based on TEHD analysis", *Industrial Lubrication and Tribology*, Vol. 66 Iss 2 pp. 184 – 193

Haifeng Zhang, Jianhua Wu, Fei Xie, Ang Chen, Yanzhong Li, 2014,"Dynamic behaviors of the crankshafts in single cylinder and twin-cylinder rotary compressors", *international journal of refrigeration*, pp. 3 6 – 4 5

Katsumi, K., Shotaro, M., Akira, K., 1996, Tribological Evaluation of Rotary Compressor with HFC Refrigerants, *Proceedings of International Compressor Engineering Conference at Purdue*, p. 413-418.

Takashi, F., Makoto, H., 1996, HFC/POE Lubricity Evaluation on the Rotary Compressor in System Operation, *Proceedings of International Compressor Engineering Conference at Purdue*, p. 121-126.

Mitsuhiro, F., Tadashi, Y., Takashi, S., 1996, Observation of Oil Film Condition in A Cylinder of Rotary Compressor, *Proceedings of International Compressor Engineering Conference at Purdue*, p. 401-406.

Katsuya, M., Hitoshi, H., Makoto, H., 1998, Lubrication Analysis of Rotary Compressors for HFC Refrigerants, *Proceedings of International Compressor Engineering Conference at Purdue*, p. 301-306.