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Analysis of Oil Supply Characteristics for Reciprocating Compressor

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왕복동 압축기 오일 급유 특성 분석

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Abstract

A problem of oil supply for a reciprocating compressor is very significant for an evaluation of reliability. Since a rotational motion of a crank shaft for the reciprocating compressor with small capacity is used for a power source of oil supply, a centrifugal force of the rotational shaft provides a stroke of oil inside the shaft like a centrifugal pump. The pumped oil rises following an inner wall and provided to a bearing passed through an oil supply hole at the side of the shaft for lubrication of the bearing. In this study, the amount of oil supply has been investigated by a numerical analysis for various conditions such as a shape of a groove, rpm of the compressor, and a shape of a flow channel. Also, a method of increasing oil supply for a low rpm has been studied so that the function can be improved for a variable condition.

1. Introdution

Lubrication is important for good reliability and high performance in hermetic refrigeration compressor. While delivery of lubrication into various sliding surface is usually carried out by separate oil pumps attached to a large open-type compressor, employment of such oil pumps is not a common practice for small hermetic refrigeration compressor used for household refrigerators or room air conditioners because of poor cost effectiveness and compactness. Thus, rotating motion of crank shaft is utilized for most of small hermetic refrigeration compressors as a power source for oil pumping. However, it is hard to make a fine control of the amount of oil supply for the small hermetic refrigeration compressors, particularly when compressor speed is variable. For such variable speed compressors, shortage or overflow of the oil supply can take place depending on the compressor speed [1]. Therefore, the objective of this study is to obtain performance data of the oil supplying system for a variable speed reciprocating compressor using CFD simulation method. To validate the simulation results, the reciprocating compressor was tested experimentally with a variation of compressor speed.

2. Experiment

Since the rotating motion of the crank shaft is used for the oil pumping of the reciprocating compressor, the centrifugal force of the shaft provides the climbing power of the oil inside the shaft. The climbing oil follows the inner wall and transfers to the journal bearing via the oil supply hole for lubrication of the bearing. There is a spiral groove at the outer surface of the crank shaft which is inserted at the journal bearing for the path of the oil by the difference of the pressure. The passed oil through the oil groove of the crank shaft and the journal bearing is partially used for the lubrication of the crank pin and rest of them is exhausted at the center of the crank pin.

An over flow method has been selected for the experiment in this study. The pumped oil by the centrifugal force of the shaft at the end of the spiral groove has been collected in a beaker to be measured. The experiment has been performed for three types of the shaft as shown in Table 1.

Table.1 Amounts of pumped oil for various types of shaft (CC/min)

Type \ rpm	2200	2880	3480	3800
Type A : Tetragonal groove, Straight cylinder of pick up	22.5	67.8	91.0	104.3
Type B : Triangular groove, Straight cylinder of pick up	15.1	38.2	63.2	75.7
Type C : Triangular groove, Bending tube pick up	12.6	26.5	42.3	60.0

3. Numerical Simulation

In order to simplify the analysis of the oil supply system, the following assumptions have been applied for the present model [1] : (1) the oil is in incompressible laminar flow, (2) there is no phase change in the oil, and (3) the properties of a working fluid inside of a control volume are constant [2,3]. The governing equations of the oil supplying system have been derived from the continuity and momentum equations as follows:

$$\frac{\partial \rho}{\partial t} + \nabla(\rho \overline{v_r}) = 0 \quad (1)$$

$$\frac{\partial}{\partial t}(\rho \overline{v_r}) + \nabla(\rho \overline{v_r}\,\overline{v_r}) + \rho(2\vec{\Omega} \times \overline{v_r} + \vec{\Omega} \times \vec{\Omega} \times \vec{r}) = -\nabla P + \nabla \tau + \rho \vec{g} + \vec{F} \quad (2)$$

The method of the single rotating reference frame has been used to

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consider the rotation of the crank shaft for the numerical simulation. The numerical analysis has been carried out under the assumption that the oil is filled up in the steady-state flow path. The inlet pressure of the oil supply system has been calculated by the use of the atmospheric condition and the centrifugal force. The values of the pressure have been interpolated by a PRESTO method, the continuity and momentum equations have been solved by a SIMPLE method, and a FLUENT, a commercial CFD simulation program has been performed at the compressor speeds of 2200, 2880, 3480, and 3800 rpm with the oil temperature of 60℃.

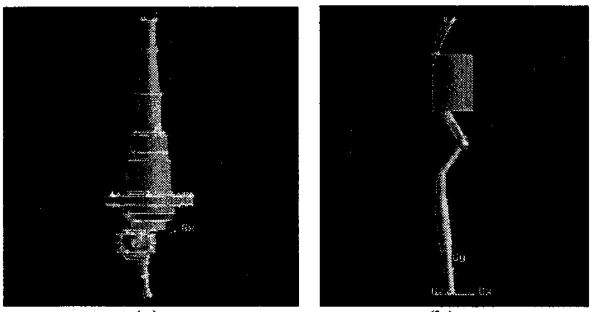
4. Results and Discussion

The type A which has already been tested experimentally has been selected for the numerical study after modeling its flow path as shown in Fig. 1. The accuracy of the numerical simulation for the type A has been confirmed by comparing with the experimental results as shown Table 2. The design factor that affects the oil pumping amount has been determined by the confirmed numerical model to investigate the change of the pumping amount by the shape of the internal flow path. Although many factors have been attempted in this study, a length of the groove lead and an area of the groove section have been observed to be most significant for the oil pumping. Thus, those two factors have been changed by a GAMBIT program as shown in Figs. 2 and 3 to analyze those effects.

The change of the oil amount by the length of the groove lead has been shown in Fig. 4 (a). If the length decreases, the pumping amount increases because the increased incident angle enlarges the climbing force. Also, if the area of the groove section increases by the distance from the central axis, the pumping amount increases significantly because volume of the oil flow path increases at the same rpm (Figs. 4 (a) and (b)). On the other side, the pumping amount decreases for the reduced area of the groove section since the pumping power by the centrifugal force is disturbed by the narrow inlet area.

Table.2 Comparison of results between experimental and numerical studies for type A (CC/min)

Case \ rpm	2200	2880	3480	3800
Experimental	22.5	67.8	91.0	104.3
Numerical	20.3	48.6	92.4	116.4

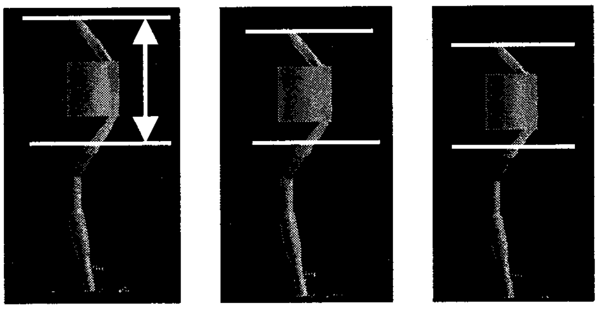


(a) (b)

Fig. 1 Modeling of (a) oil supply system and (b) oil flow path inside the system

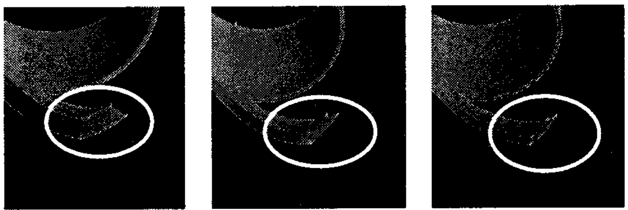
5. Conclusion

The performance of the oil supplying system for the variable speed reciprocating compressor has been investigated using the commercial CFD program. The numerical simulation has been performed with various speeds of the compressor and determined design factors. The oil flow rate has increased linearly as the compressor speed increases. The oil pumping amount has increased about 4.9% by the decreased length of the groove lead and 36.4% of the increased area of the groove section. The developed analytical model has also been used as a tool to design an optimum oil supplying system for the variable speed compressor.



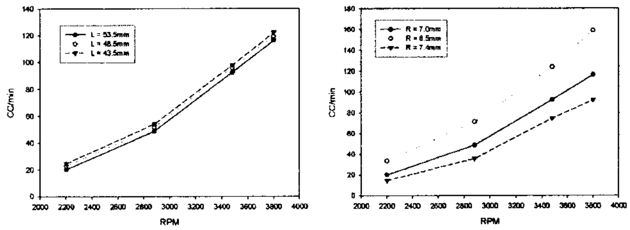
(a) (b) (c)

Fig. 2 Length of groove lead for (a) 53.5mm, (b) 48.5mm and (c) 43.5mm



(a) (b) (c)

Fig. 3 Distance from central axis for (a) 6.5mm, (b) 7.0mm and (c) 7.4mm



(a) (b)

Fig. 4 Oil pumping amount by (a) length of groove lead and (b) distance from central axis

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