1996

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International Compressor Engineering Conference. Paper 1126.  
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DEVELOPMENT OF HIGH EFFICIENCY SCROLL COMPRESSOR FOR PACKAGE AIR CONDITIONERS

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ABSTRACT

The purpose of this study is to introduce high efficiency scroll compressor, developed by LG Electronics recently. The main parts of the scroll compressor are optimized by component analyses and experiments. For optimizing the axial clearance, the stress and the thermal deformation analysis are performed. The orbiting scroll movement is analyzed to evaluate the stability of the orbiting scroll. Each efficiency calculated by the loss analysis with performance analysis program is confirmed from experiment.

INTRODUCTION

It is required of high efficiency, of low vibration, and of low noise level for the air conditioners. Since the scroll compressor-equipped air conditioner can fulfill these requirements, almost all of the compressor makers have made an effort to develop high performance scroll compressor.

The LG Electronics has developed the high efficiency scroll compressor for package air-conditioner to satisfy above requirements. The brief structure of LG scroll compressor is shown in Figure 1. This scroll compressor adopts low pressure shell to filter the unfavorable contaminants by indirect suction[1] and to cool the motor by suction gas. Furthermore, it has features of no accumulator requirements.

In order to decrease the leakage during the process of compression, the tip seal was chosen for axial sealing and driving bush for radial sealing. The shapes of the tip seal and the groove were developed by component tests. The radial sealing mechanism has been developed through performance analysis program in order to have proper radial sealing force.

The thrust bearing is used for the supporting structure for orbiting scroll and two journal
bearings on either side of the motor for shaft.

The check valve is installed in order to prevent the reverse rotation induced by the pressure difference between discharge and compression pockets when the power of compressor is off.

This compressor reduces noise level by adding extra strength to the top shell which is the main noise source according to the experiment.

The high efficiency and reliability are verified by both experiment and component analyses.

**COMPONENT ANALYSES AND EXPERIMENTS**

**Performance simulation program**

The LG. has developed performance simulation program to analyze the scroll compressor. The characteristics of this simulation program are as follows:

1) Using real gas equation (Martin-Hou Equation)
2) Leakage modeling
3) Considering gas heating effects
4) Calculations of the gas forces, sealing forces
5) O/S dynamics modeling
6) Calculating performance

The performance analysis program was inspected by experiment. In order to measure the pressure in all compression pockets, three piezoelectric pressure transducers is mounted on the back side of fixed scroll[2]. Figure 2 shows the P-V diagrams generated by the experiment and the program. The efficiencies from the experiment and the program give good agreements as shown in Figure 3.

**Optimizing the axial clearance**

The stress and the thermal deformation analysis are performed for optimal design and reliability of the scroll profile in different operating condition including over-loading condition. After making the whole finite element model of the scroll wrap, the deformation and the stress are analyzed. The wear of the central part of scroll wrap could be caused by the deformation induced from thermal stress. Therefore, the axial clearance is designed to avoid the wear. Figure 4 shows the result of thermal stress analysis.

**Evaluating the stability of orbiting scroll**

Since the orbiting scroll movement affects friction loss and gas leakage in the compression
pockets, the consideration of this movement is the key of the scroll compressor design and the reliability. The stability of orbiting scroll is determined by the overturning moment equilibrium of the orbiting scroll. Figure 5. shows the analysis model and the standard is as follows;

\[
r_t = \sqrt{x^2 + y^2} = \sqrt{r_\theta^2 + r_r^2}
\]

\[
\frac{r_t}{R_{tho}} < 1
\]

where, \( r_t \): the distance from the center of O/S to the reaction point

\( R_{tho} \): Thrust bearing radius

Figure 6. shows the analysis result in ASHRAE-T condition. This means the orbiting scroll is stable.

**LOSS ANALYSIS**

The efficiency of compressor is generally divided into motor, volumetric, adiabatic, and mechanical efficiency. The losses affecting all of the efficiencies are analyzed according to the results from the performance experiments and analyses as described above. In this paper, the volumetric and adiabatic efficiencies are dealt with in the thermodynamics and fluid dynamics' point of view.

The volumetric efficiency is one of the indexes related to capacity. One of the major factors affecting the volumetric efficiency is the suction gas heating. The temperature of suction gas was measured in ASHRAE-T condition. In the measurement, it was found that there were about 10 ~ 13°C rise of temperature by heating. For the detailed analysis of suction gas heating, we used the part of performance simulation program to investigate influences on temperature rising. Figure 7 shows the analysis model of suction gas heating. The descriptive equation is as follows;

\[
\dot{Q}_{sgh} = \dot{Q}_{motor} + \dot{Q}_{rd} + \dot{Q}_{mech} + \dot{Q}_{leak}
\]

The results of \( \dot{Q}_{sgh} \) of above calculation is in a rise of temperature by 10.3°C. As the main factor of suction gas heating(\( \dot{Q}_{sgh} \)) is the heat flux from the motor(\( \dot{Q}_{motor} \)), reducing \( \dot{Q}_{motor} \) is the most effective to achieve high efficiency in aspect of volumetric efficiency. The second major effect on suction gas heating is the heat flux from the discharge gas(\( \dot{Q}_{rd} \)). From the
result of the calculation, $\dot{Q}_{td}$ is the 27.2% out of $\dot{Q}_{sgh}$.

Figure 2 describes the P-V diagram. The adiabatic efficiency can be obtained from this P-V diagram. Inner line is the P-V diagram by theory and the exterior lines are the ones by experiment and simulation. The difference between theoretical and real PV diagrams is the adiabatic loss. The adiabatic loss is analyzed into pressure drop in suction process, gas leakage in compression process, and overcompression in discharge process.

The major one of adiabatic losses is the gas leakage in the compression process which is closely related to the axial clearance between the fixed scroll and the orbiting scroll. The smaller axial clearance, the lower gas leakage, however, there are some problems of reliability by the wear on the central part of the wrap as the axial clearance is smaller than the optimal value. The secondary loss comes from the overcompression in the process of discharge. Therefore, reducing the overcompression is the key factor to achieve high adiabatic efficiency.

The mechanical efficiency is calculated in each friction part.

Figure 8 shows the needed power and power loss obtained from the experiment.

CONCLUSIONS

This scroll compressor developed by LG have features as follows;

1. High efficiency compressor with tip seal sealing mechanism
2. The minimized gas leakage in compression pocket by optimized axial clearance.
3. Driving bush design having proper sealing force through the performance analysis simulation
4. The optimized mechanism by component analyses and experiments.

REFERENCES

Fig. 1 Compressor structure

Fig. 2 P-V diagram

Fig. 3 The comparison of efficiencies

Fig. 4 The thermal deformation of orbiting scroll

Fig. 5 Analysis model of orbiting scroll dynamics
Suction

Gas

Flow In

Eccentricity of thrust reaction

1

0 60 120 180 240 300

Crank angle [deg.]

Fig. 6 Eccentricity of thrust reaction (ASHRAE-T condition)

Motor Loss (15%)

Mechanical Loss (7.7%)

Adiabatic Loss (5%)

Theoretical Power (72.3%)

Fig 7. Analysis of suction gas heating

Fig 8. Needed Power and Power Loss