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A HIGH RELIABILITY STUDY OF THE SCROLL COMPRESSOR

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ABSTRACT

A fundamental study of the improvements made to the scroll compressor's reliability is presented.

It has been found that the tilting of the main shaft significantly reduces the journal bearing's performance. For this reason, a new bearing system has been developed.

Compression of the liquid refrigerant causes high pressure within the compression chambers and this can lead to the scroll wrap breaking.

A method to reduce this high pressure has been investigated and a new pressure relief mechanism has been developed.

INTRODUCTION

Recently the scroll compressor has been increasingly used in the middle class (1.5-7.5Kw) packaged air conditioners. These compressors are required to be sufficiently reliable for the following operations:

1. The continuous intake of moist vapor refrigerant into the compressor.
2. Starting operation with condensed refrigerant in the compressor shell and suction path.

The solutions to these problems require us to address the following:

1. The tilting of the main shaft, which is a result of the operating load being applied to a different point of the support bearing.
2. The high pressure caused by the compression of liquid refrigerant condensing in the suction path.

THE INVESTIGATION TO IMPROVE THE BEARING SYSTEM

The characteristic of our scroll compressor's bearing system is that the orbiting scroll bearing is situated above the two bearings supporting the main shaft, and so the load on the main shaft acts outside of the two support bearings, and tends to tilt and bend the main shaft.

During the compressor operation, the intake of saturated refrigerant thins down and reduces the viscosity of the lubricating oil. Both the reduced viscosity and the tilt of the shaft greatly reduce the load capacity of the journal bearing. This causes partial contact,and subsequent unusual wear or seizure.

The mathematical analysis of the scroll journal bearing has already been presented.[1] But when we institute the dimensions of the journal bearing to secure reliablity considering the tilting shaft,the dimensions increase. And the large dimensions of it increase the friction loss to reduce the compressor performance.

For this reason, a new type of bearing mechanism to reduce the influence of the tilting shaft has been investigated.

Fig.1 shows a section of the 3Kw class scroll compressor for an air conditioner with our new type of bearing system. A slider inserted in the orbiting scroll's journal bearing enables the rotating radius variable. The main shaft is supported by the two bearings on both sides of the rotor. The upper bearing consists of the journal bearing, while the lower one consists of a ball bearing.

Fig.2 shows the details of our new bearing system. The main shaft has a crowning at the axial center of the orbiting scroll bearing plane which supports the load. The slider which comes into contact with the main shaft's crowning is able to tilt along it. The sleeve is inserted into the main bearing,and the main shaft has a circular crowning at the axial center facing the sleeve. A pin located between the sleeve and the main shaft enables the sleeve and the main shaft to rotate together and also allows tilting along the main shaft's crowning.

Calculation

The tilt of the main shaft and the bearings supported by the crowning were calculated as follows:

1.The tilt of the main shaft at the supporting point was calculated employing the Finite Element Method.

2.The tilting journal bearing's reaction force's point of action was calculated with the Reynold's equation using the Finite Difference Method and the pressure distribution was obtained.

3.The amount that the contact point on the crowning was moved by the tilt of the shaft together with the balance point of the tilt (calculated in 2.) was calculated.

Fig.3 shows the calculation results of our scroll compressor model shown in fig.1. This has been calculated from the main journal bearing's dimensions which are 35mm in diameter and 25mm in width. And when the CT/ET=68/12°C, (341.2/285.2K) with low oil viscosity(3cst:3X10E-6 m^2/s). The calculated main shaft tilting angle Φ is 1.3 10E-3rad.

The sleeve tilting angle Ψ changes by means of moving the contact point related to the crowning radius. This is almost ten times smaller than the shaft tilting angle.

Experiment Of The New Bearing System

To verify the effects of our new bearing system in actual operation,the journal bearings were observed by applying the contact resistance method.

Fig.4 shows the electric model of the experiment.

The 3Kw class scroll compressor was used and the voltage between the journal bearing and the main shaft was observed.

Fig.5 shows the results of the orbiting scroll journal bearing experiment. The bearing's dimensions are 28mm in diameter and 25mm in width. The voltage between the journal bearing and the main shaft was almost at the maximum voltage setting while the operation was observed. This means that the main shaft and the orbiting journal bearing were insulated by an oil film in an almost hydrodynamic lubrication state.

INVESTIGATING THE REDUCTION OF HIGH PRESSURE

In the event of recommencing the operation of the compressor after a long period of time,condensed refrigerant in the suction path of the compressor is drawn into the compression chambers,filling it with liquid refrigerant,decreasing the volume during the operation and causing high pressure and the risk of breaking the scroll wrap in the compression chambers. To avoid such a risk, it is necessary to develop a system which is able to relieve the pressure when it exceeds a critical level.

A system has been developed which is able to effectively limit the excessive pressure without effecting the standard performance.

Fig.6 shows this system. A pair of scroll compression chambers surrounded by the frame wall and one suction port is set into the surrounding space. The suction port is opened near to the fixed scroll wrap end, so that the liquid refrigerant flows straight into the compression chamber which is formed by the fixed scroll wrap end. In the other compression chamber, liquid refrigerant is drawn into the space surrounded by the frame wall. To enable such intake of refrigerant,more liquid refrigerant is drawn into the compression chamber located near the frame suction port compared to the other compression chamber. This subsequently creates a pressure difference between the chambers. The pressure of the compression chamber situated near to the frame suction port is higher than the other compression chamber.

Fig.7 is a diagram which explains this pressure relief mechanism. A pressure imbalance between the compression chambers as described above,makes a rotating momentum on the orbiting scroll. This rotating momentum is able to set the direction against the operating rotation by choosing which side of the compression chambers to set near to the frame suction port.

The oldham ring is located between the orbiting scroll and the frame to support this rotating momentum. When the rotating momentum goes against the direction of the operating rotation,we can obtain the orbiting scroll rotation against the direction of operation by means of making a clearance between the oldham groove in the side wall. The orbiting scroll will rotate ϕ (rad) according to the oldham groove clearance when the rotating momentum acts on it. This rotation causes a different phase between the orbiting scroll wrap and the fixed scroll wrap, and then the orbiting scroll moves radialy to compensate this difference by means of a slider.By this action, clearances are made between the orbiting wrap and the fixed wrap of the compression chambers near the frame suction port and it relieves the pressure. The clearance δ (mm)is described as follows at the involute scroll wrap:

$\delta = 2a\phi$--(1) (a:involute base radius (mm))

The orbiting scroll rotating momentum is calculated with the geometrical dimensions of it and the pressures of the compression chambers described as in Fig.6. When the momentum is in the opposite direction to the operating rotation,the orbiting scroll rotates in the relieving direction.

Experiment Of The Pressure Relief Mechanism

The pressure in the compression chambers of the scroll compressor with a 60Hz electric source was observed.

Fig.8 shows the observed pressures when starting with the compressor shell fully filled with liquid refrigerant. The compressor formed a suction path like Fig.6,but without the relief mechanism of the oldham grooves. The upper part of fig.8 shows the pressure in the compression chamber located near to the frame suction port and the lower part of fig.8 shows the pressure in the opposite compression chamber. The upper figure of the pressure increased greatly and it indicated that the max peak was 135 kg/cm^2 (13.2MPa). But the lower figure of the pressure indicated that the max peak was 75 kg/cm^2 (7.4MPa) and there was a difference between them.

Fig.9 shows the observed pressures with the developed relief mechanism. The oldham relief angle ϕ =5deg(0.087rad) was set. The upper and lower parts of this figure correspond with Fig.8. The upper part shows that the steadily increasing pressure suddenly reduced after reaching a max pressure of 75 kg/cm^2 (7.4MPa). The pressure in the other compression chamber peak was 75 kg/cm^2 (7.4MPa).

This result shows that the relief mechanism worked according to its purpose and significantly reduced the pressure in the compression chamber.

CONCLUSIONS

The new mechanisms which have been developed are able to increase the compressor's reliability without reducing the high performance of the scroll compressor.

1.A new bearing system has been developed,which is able to reduce the effects of the tilting of the main shaft. This was largely achieved by calculation but verified by experimentation.

2.A pressure relief mechanism has been developed, which operates by rotating the orbiting scroll against the operating direction. It was observed that when using this relief mechanism, the maximum pressure was reduced by 45%.

REFERENCE

1.Narumiya,et al.,Journal Bearing Performance In a Scroll Compressor,Proceedings of the 1992 International Compressor Engineering Conference at Purdue(1992),883.
2.Morishita,et al.,Scroll Compressor Analytical Model, Proceedings of the 1984 International Compressor Engineering Conference at Purdue(1984),487.
3.Sano,et al.;Scroll Type Compressor Having Curved Surface Portions Between The Shaft And Bearing Means, U.S.Patent 5,222,881, 1993.

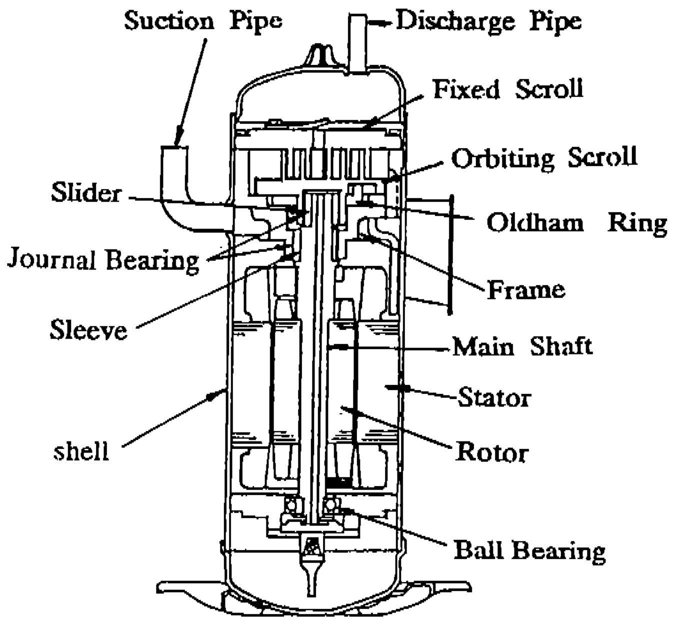

Fig.1 Section View of Our Scroll Compressor

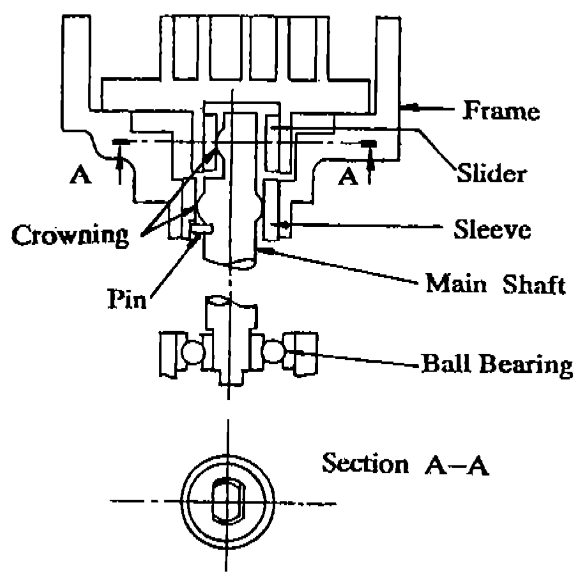

Fig.2 The Details of Our New Bearing System

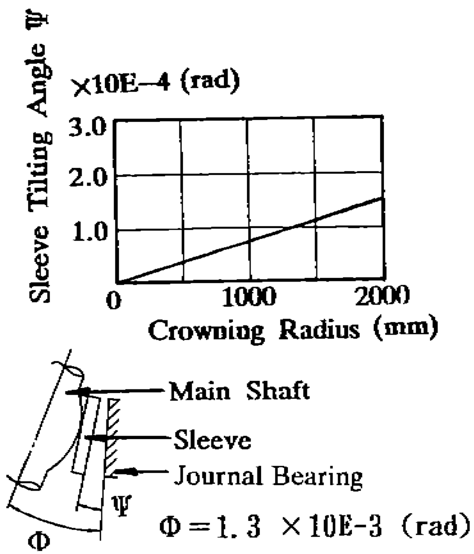

Fig.3 The Calculation Result

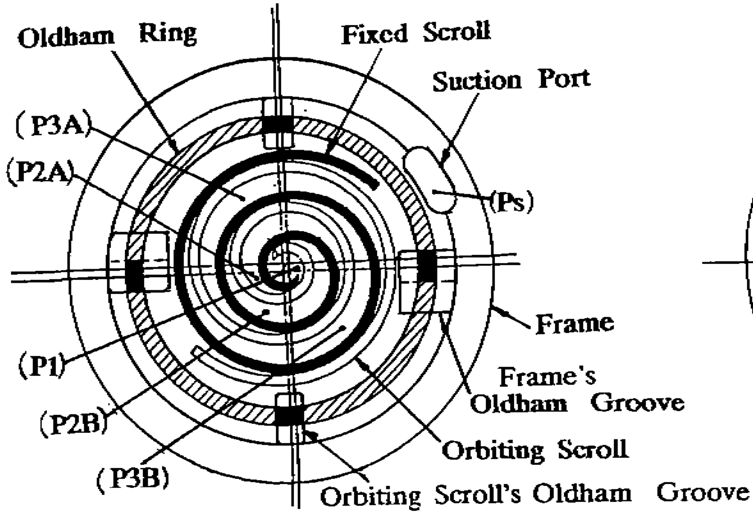

Fig.6 Pressure Relief System

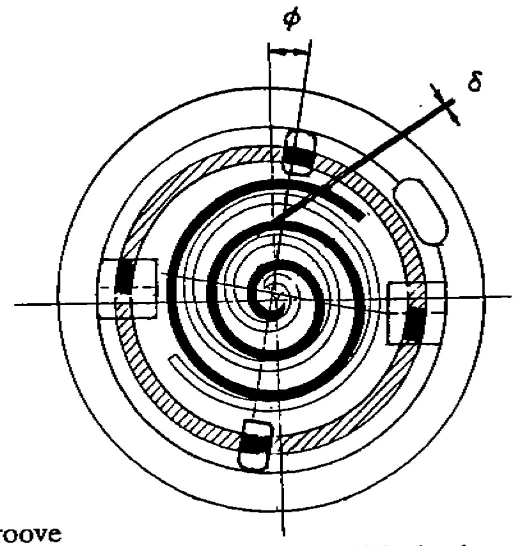

Fig.7 Pressure Relief Mechanism

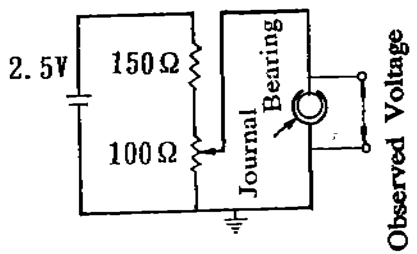

Fig.4 Electric Model

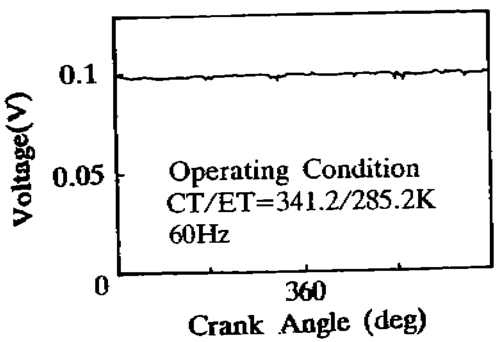

Fig.5 Voltage between the Shaft and the Journal Bearing

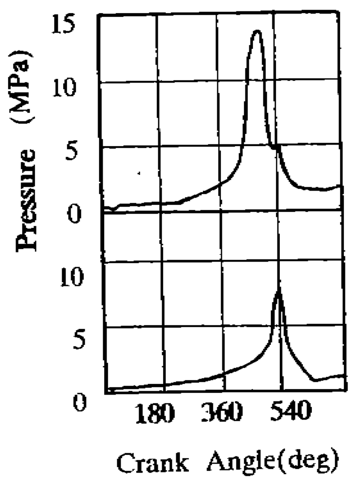

Fig.8 Pressure without Relief

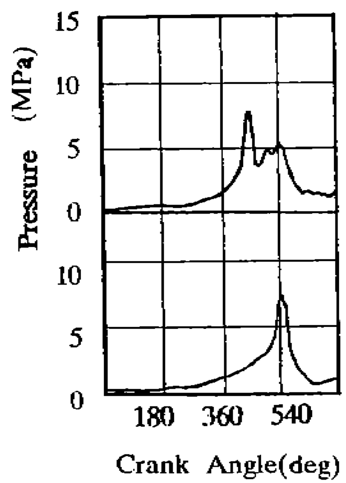

Fig.9 Pressure with our Relief Mechanism