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ABSTRACT

Experimental analysis on the oil supply characteristics of scroll compressor for package air conditioner has been presented based on the experimental apparatus operating at variable speed. Scroll compressor has four major lubricating parts : the lower journal bearing, the main journal bearing, the orbiting scroll journal bearing and the thrust bearing between the orbiting scroll and the main frame. And oil is supplied to the lubricating parts by the rotation of the crankshaft. The flow rates were measured with the change of 3 major elements : positive displacement oil pump, main frame and crankshaft, which have great effects on the oil supply system. The measured results show that the pump efficiency increases as the swept volume of positive displacement oil pump increases, the structure of oil passage in main frame has great effects on the flow rate to the thrust bearing between main frame and orbiting scroll, moreover, the configuration of the inner oil passage in crankshaft has great effects on the pump efficiency.

INTRODUCTION

Scroll compressor consists of a motor, a shaft, fixed and orbiting scrolls, and main and lower frames that support the shaft. It is superior to rotary and reciprocating type compressors in efficiency, noise and vibration due to its structural advantages. But it is rather difficult to supply enough oil to the lubricating parts because these parts are located at the upside of compressor. So it is much more important to supply oil properly to these parts for reliability. Oil plays important roles in compressors' reliability, such as the prevention of gas leakage at the compression chamber, the lubrication of the lubricating parts and the cooling of the lubricating parts heated by friction heat. Especially the operating condition of bearings is much severer as adapting inverter technology into scroll compressor . When the operating speed of compressor is high, the PV value becomes so large that the scuffing phenomena happen from high friction heat. In other hands when the operating speed is low, the Sommerfeld number becomes so low that the metal contacts happen from low minimum film thickness. Therefore it's very important that the oil flow rate should be supplied more than required according to the variable speed. For the satisfaction of above needs to the inverter technology, the positive displacement oil pump is considered. In this study an experimental analysis has been carried out for the design of oil supply system, especially 3 major elements : positive displacement oil pump, main frame and crankshaft.

Experimental Apparatus

As shown in Fig.1, scroll compressors have four major lubricating parts: the orbiting scroll journal bearing, the main journal bearing, the main thrust bearing and the lower journal bearing. Out of the oil pumped up through the inner hole of crankshaft from the base reservoir by the centrifugal force and pumping capacity of the rolling piston typed oil pump, some flows out through the upper oil discharge hole of crankshaft by the centrifugal force between the inner and the outer radius of crankshaft and others gets to the upper end of crankshaft. The oil passing the upper oil discharge hole of crankshaft lubricates the main journal bearing. It goes up along the groove and clearance of the main journal bearing except a little oil discharge in the downward, and then flows into the oil discharge hole of the thrust surface and the orbiting space of orbiting scroll at main frame. Oil transported to the upper end of the shaft flows in two mid path - through the gap between the slide bush and the crankshaft pin and through the clearance and groove of the O/S journal bearing. And then the oil flowing through the two mid path is transported to the orbiting space of orbiting scroll at main frame. And some of the oil joining in the orbiting space of orbiting scroll at main frame returns to the base reservoir through oil return pipe and others is supplied to the thrust bearing.

And the schematic diagram of experimental apparatus used is shown Fig.2. Oil is pumped from oil supply reservoir to the experimental apparatus, and the desired oil level is set. When the electric power is on, the experimental scroll compressor runs at desired operating speed using inverter. The measuring points of flow rate in the experimental apparatus are the following. First Q1, the flow rate of return-oil from the main frame was measured and second Q2, the flow rate through the thrust surface was measured by internally equipped cone-type accumulator and the last Q3, the flow rate passing through oil hole located in the upper of crankshaft to main journal bearing.

RESULTS AND DISCUSSION

The Oil Supply characteristics of Rolling Piston Typed Oil Pump

First, investigating the percentage of the flow rate measured, most of the oil pumped up through the inner hole of crankshaft from the base reservoir is discharged to the return-oil hole of main frame. The amount of that is almost up to 95%. The other oil is discharged through the thrust surface of main frame to the thrust surface . And the flow rate passing through oil hole located in the upper of crankshaft to main journal bearing is almost zero. From those results, it can be concluded that the flow resistance to the return-oil hole of main frame is small enough to flow out, but the flow resistance through the thrust surface of main frame to the thrust surface is big because of the sealing effects between the thrust surface of main frame and orbiting scroll, and the flow rate passing through oil hole located in the upper of crankshaft to main journal bearing goes up because of centrifugal force.

Second, comparing with the results of centrifugal oil pump, centrifugal oil pump has the limit speed, at which speed the flow rate is measured into zero. In contrast to that, rolling piston typed oil pump discharges oil steadily ,even small quantity at low speed. From this result, centrifugal oil pump requires some operating speed for developing pressure gap, the source of centrifugal force, but in the case of rolling piston typed oil pump, oil is pumped as much as the swept volume of pump even at low speed and steadily flows out.

And third, investigating the effect of the change of oil level on the flow rate measured, centrifugal oil pump is affected by approximately 10% of total flow rate, but rolling piston typed oil pump has almost same flow rate. It can be explained by the pressure gap resulting from the potential energy of oil level in the case of centrifugal oil pump.

Measurements of the total oil flow rate discharged through system were made for several values of the swept volume . Fig.3 shows the variation in total flow rate with increasing the swept volume. The total flow rate is defined in units Q/Q_{ref}, representing the total flow as a ratio of the flow at any swept volume and operating speed to a defined reference condition flow. The defined reference flow Q_{ref} was chosen to be at 0.258cc/rev as the swept volume, 60Hz operating speed.

Fig4. shows the variation in pump efficiency of rolling piston typed oil pump with increasing the swept volume. The pump efficiency is defined in units η/η_{ref}, representing the pump efficiency as a ratio of the pump efficiency η_{ref} . The defined reference pump efficiency η_{ref} was chosen to be at 0.258cc/rev as the swept volume, 60Hz operating speed. As the swept volume increases, the pump efficiency also increases.

The Oil Supply Characteristics to the Oil Passage Structure of Main Frame

Measurements of the flow rate to the thrust bearing were made for several structures of the oil passage of main frame . Fig.5 shows the flow rate to the thrust bearing with 3 models of the oil passage structure of main frame. The flow rate is defined in units Q/Q_{ref}, representing the flow as a ratio of the flow Q_{ref} The defined reference flow Q_{ref} was chosen to be at 0.185cc/rev as the swept volume, 60Hz operating speed using main frame of "A" model.
The total amount of flow rate measured is almost same with the change of the oil passage structure of main frame, but the flow rate to the thrust bearing between main frame and orbiting scroll is affected in a large scale. The flow rate to the thrust bearing with A model is measured at lowest speed, and the flow rate to the thrust bearing with C model is measured in a largest quantity at high speed. These results show that not only the oil hole between main journal bearing and thrust surface but also the oil groove located on the thrust surface have great effects on the flow rate to the thrust bearing.

The Oil Supply Characteristics to the Inner Oil Passage of Crankshaft

Measurements of the total oil flow rate discharged through system were made for several configurations of the inner oil passage in crankshaft . Fig.6 shows the total oil flow rate with 3 models of the inner oil passage in crankshaft. Model "A" has the characteristics of inclined oil passage, Model "B" of straight oil passage and model "C" of offset oil passage. The flow rate is defined in units Q/Q_{ref}, representing the flow as a ratio of the flow Q_{ref} The defined reference flow Q_{ref} was chosen to be at 0.368cc/rev as the swept volume, 60Hz operating speed using crankshaft of "A" model.

Fig7. shows the variation in pump efficiency of rolling piston typed oil pump with 3 models of the inner oil passage in crankshaft. The pump efficiency is defined in units η/η_{ref}, representing the pump efficiency as a ratio of the pump efficiency η_{ref} . The defined reference pump efficiency η_{ref} was chosen to be at 0.368cc/rev as the swept volume, 60Hz operating speed using crankshaft of "A" model.

Fig.7 shows how great the configuration of the inner oil passage in crankshaft has effects on the pump efficiency of rolling piston typed oil pump. From the results it can be concluded that inclined oil passage has the largest pump efficiency among them.

CONCLUSIONS

1. The oil supply characteristics of scroll compressor can be understood by measuring the flow rate with the change of 3 major elements such as positive displacement oil pump, main frame and crankshaft, which have great effects on the oil supply system.
2. Up to 95% of all the flow rate pumped up through the inner hole of crankshaft from the base reservoir is discharged to the return-oil hole of main frame and the other flow rate is discharged through the thrust surface of main frame to the thrust surface , the last flow rate passing through oil hole located in the upper of crankshaft to main journal bearing is almost zero.
3 In the case of rolling piston typed oil pump, the pump efficiency also increases, as the swept volume increases.
4. The oil hole between main journal bearing and thrust surface and the oil groove located on the thrust surface have great effects on the flow rate to the thrust bearing.
5. The configuration of the inner oil passage in crankshaft has great effects on the pump efficiency of rolling piston typed oil pump and the gap is as much as 50% of maximum efficiency.

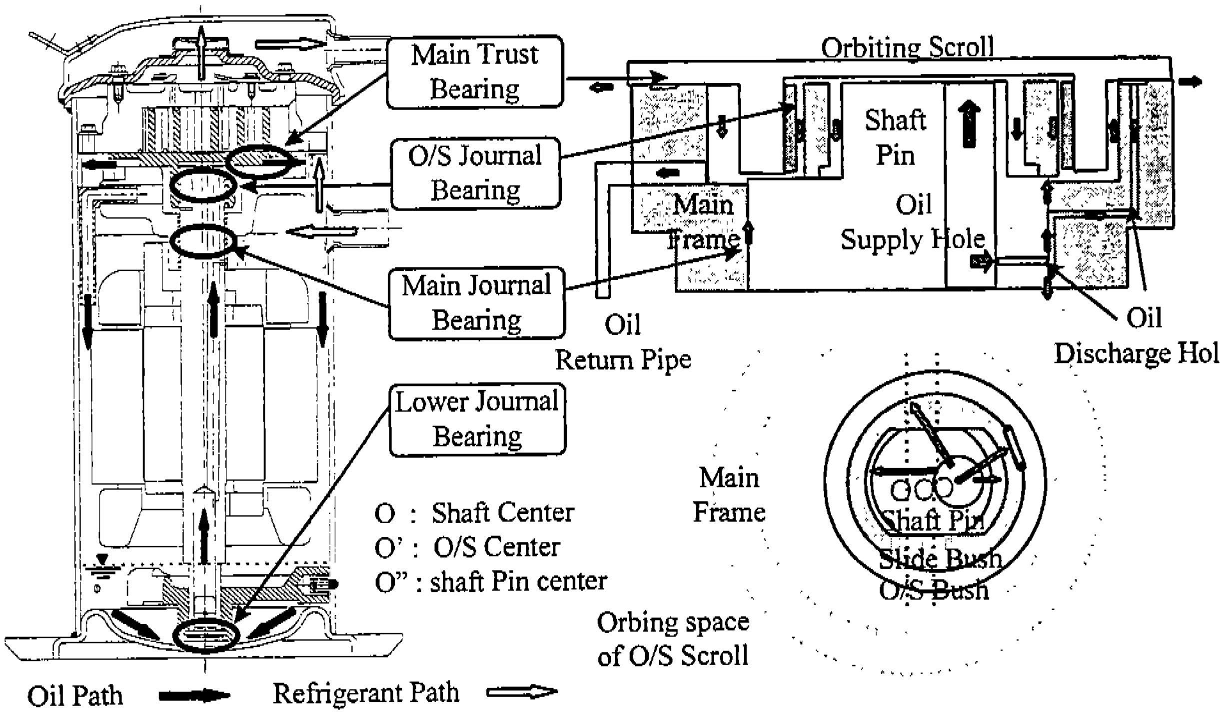

Fig. 1 Compressor Cross Section

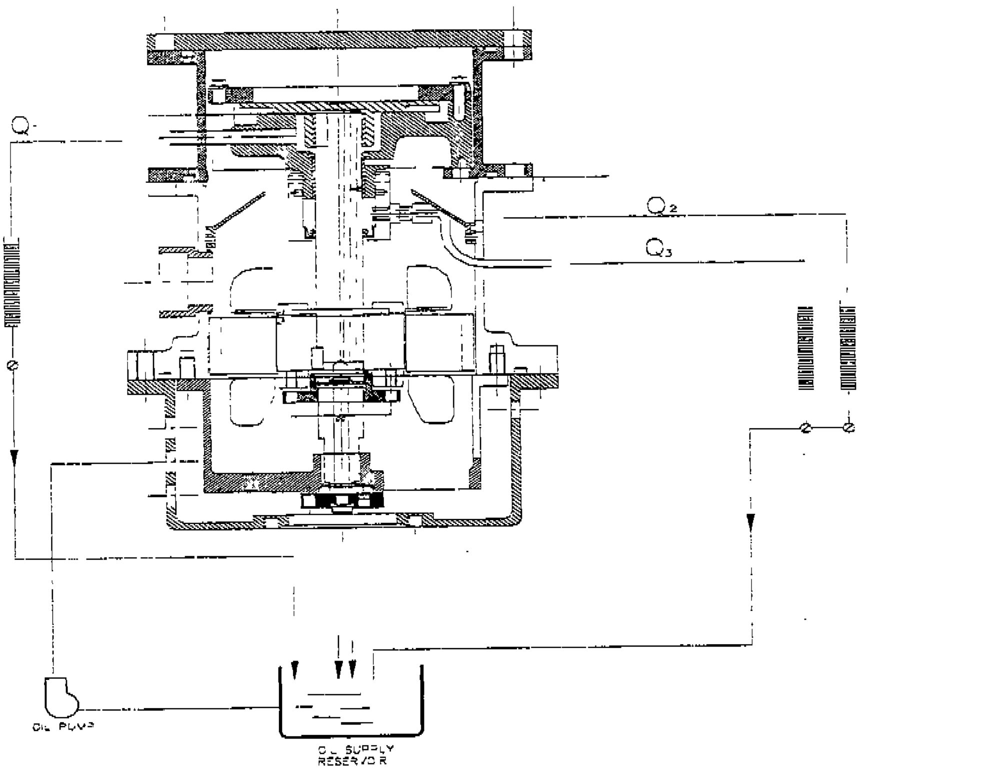

Fig. 2 Schematic Diagram of Experimental Apparatus

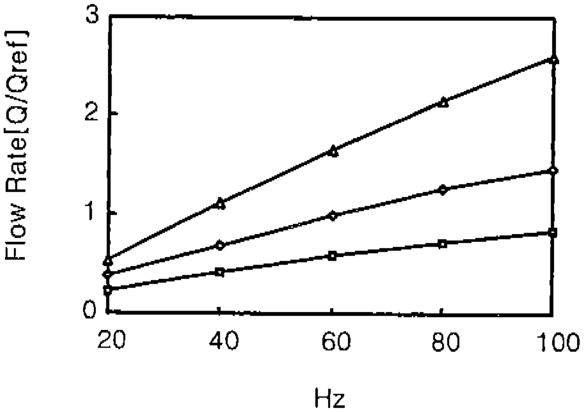

Fig.3 Total Oil Flow Rate vs Swept Volume

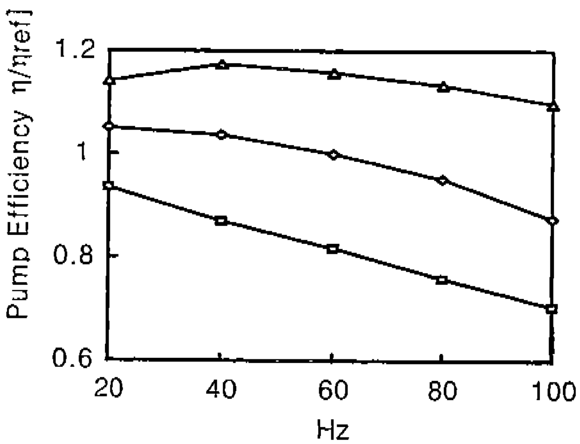

Fig.4 Pump Efficiency vs Swept Volume

Model	Symbol	Swept Volume [cc/rev]
A	—□—	0.185
B	—◇—	0.258
C	—△—	0.368

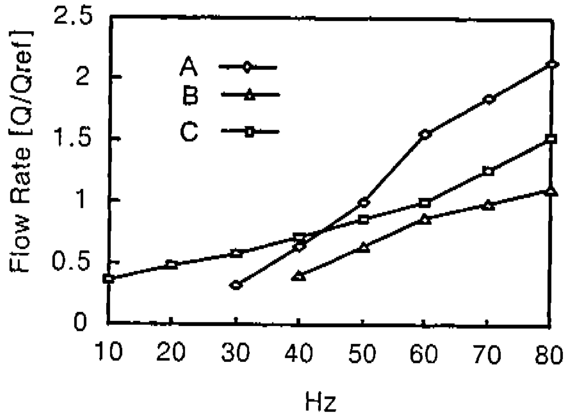

Fig.5 Flow Rate to Thrust Bearing vs
Oil Passage Structure of Main Frame

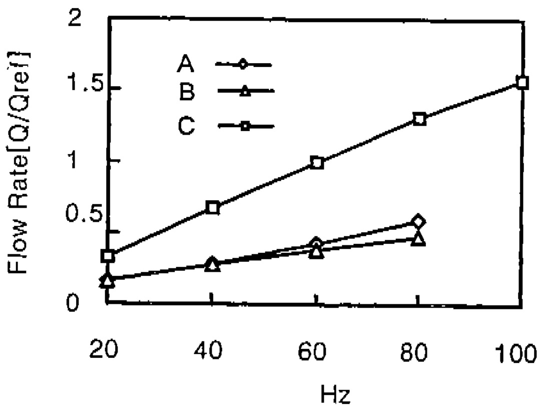

Fig.6 Total Oil Flow Rate vs Configuration
of the Inner Oil Passage in Crankshaft

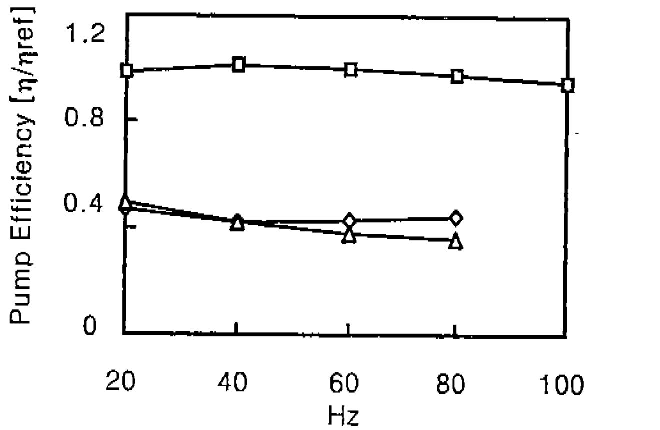

Fig.7 Pump Efficiency vs Configuration
of the Inner Oil Passage in Crankshaft

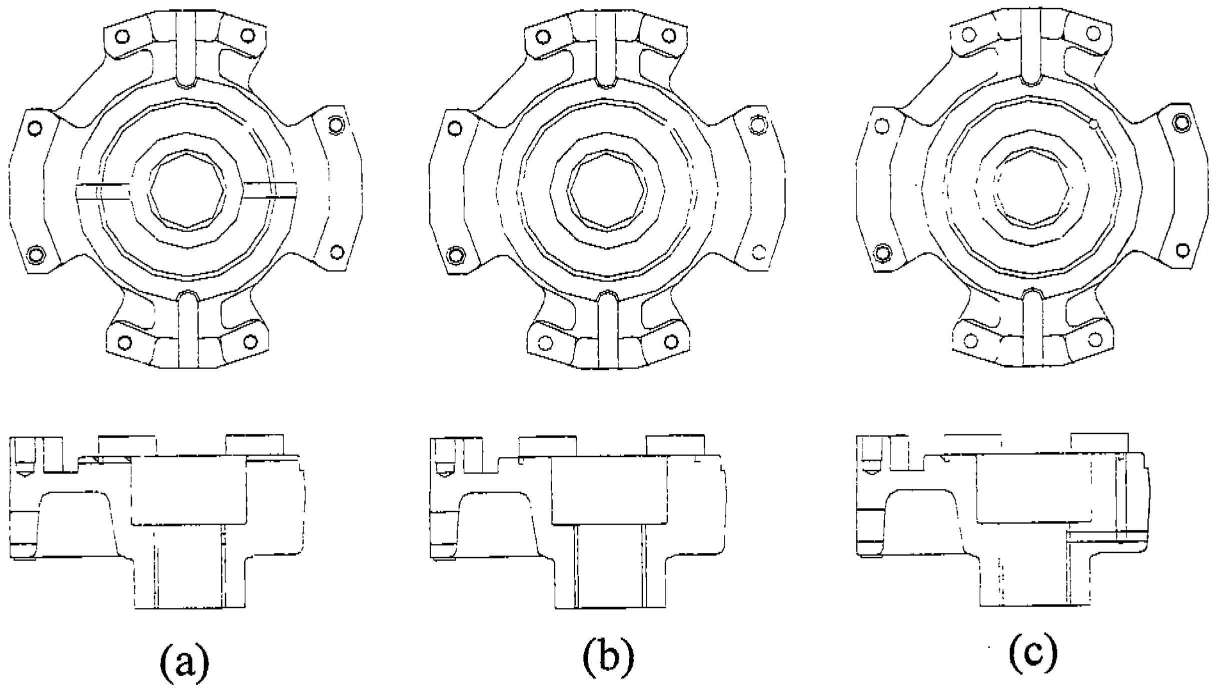

Fig. 8 Models of Main Frame used in the Experiment

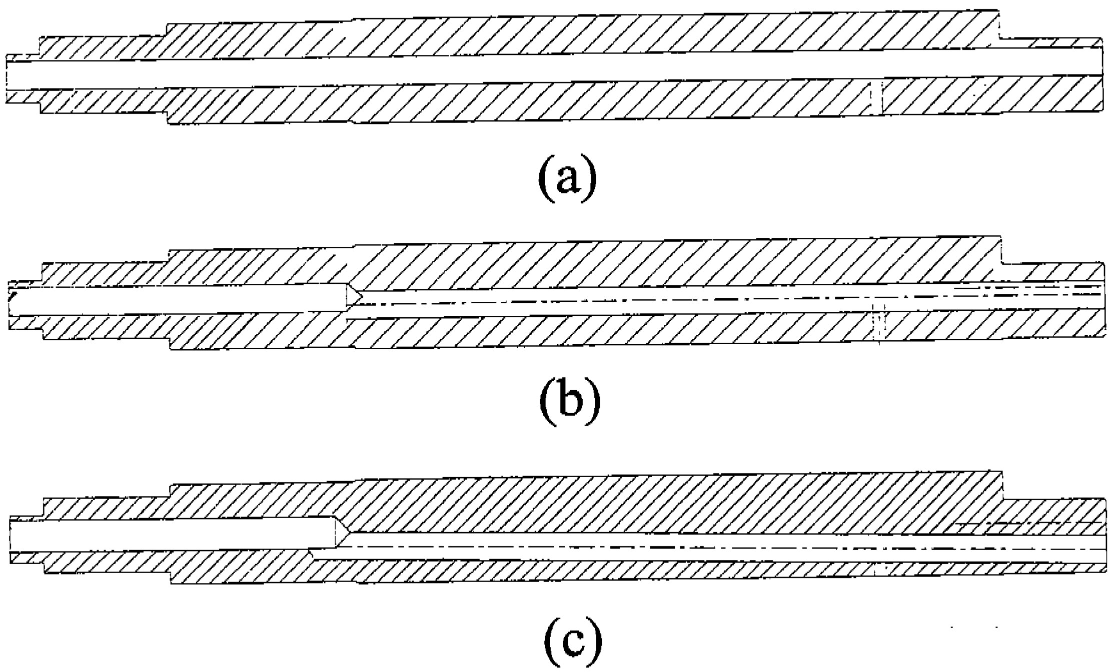

Fig. 9 Models of Crankshaft used in the Experiment