Power Saving Technology of Scroll Compressor for Car Air Conditioner

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POWER SAVING TECHNOLOGY OF SCROLL COMPRESSOR
FOR CAR AIR CONDITIONER

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ABSTRACT

It is necessary to save the input power of the compressor for car air conditioner in order to protect from the
global warming. The input power of the compressor has been reduced by developing the high efficiency capacity
control scroll compressor and by using the outer demand capacity control. The high efficiency scroll compressor has
been achieved by developing the high strength scroll center profile. The designed compression volume ratio is
increased by using the two-stage center profile, so the re-compression loss is reduced. Suction pressure can be
controlled to an optional pressure by the new developed demand capacity control valve. By this demand capacity
control valve, discharge air temperature can be controlled directly without reheat by heater core. Therefore, the
compressor input power can be reduced very much in total.

INTRODUCTION

The reduction of the amount of release of CO₂, that is, saving energy is required to protect from the global
warming. Especially, saving energy is required for automobiles. In the respect, high efficiency car air-conditioner
must be developed because it consumes the higher power in the engine accessories. The larger power saving can be
obtained by the direct temperature control with the demand capacity control of the compressor, than by usual
temperature control by reheat with the hot water coil. The high efficiency compressor is also developed by the
decrease of loss.

In the demand capacity control of the compressor, the suction pressure is controlled suitably corresponding to
the load. The high increase in efficiency of the capacity control and the loss decrease of the scroll compressor for the
car air conditioner and the power saving by the demand capacity control as a system are presented in this report.
TO INCREASE THE EFFICIENCY OF THE CAPACITY CONTROL COMPRESSOR

Re-compression power loss decrease analysis

The test compressor which aimed to realize the high efficiency is shown in figure 1. The compression chambers are formed between the orbit scroll and fixed scroll. The compression chamber moves to the center and the volumes become smaller with the revolution of orbit scroll. A scroll compressor has two symmetric compression chambers from the structure, and these two compression chambers are connected with the high pressure chamber at the same time as shown in figure 2, and they are also connected with the discharge port at that time. It joins as usual when both scrolls engage in the start point of the involute curve of the scroll. The angle of the engagement at that time is called the $\beta$ angle. The ratio of the compression chamber volume at the $\beta$ angle and the volume when the compression chamber is formed, is called the design volume ratio. When the operation pressure ratio of the compressor is higher than the pressure ratio which depends on the design volume ratio, the compression chamber pressure becomes higher on the way of the compression operation as shown by the solid line of figure 3, and the unnecessary power is used. The gas of the central high-pressure chamber expands by connecting with the compression chamber, and it is compressed again. This is called the re-compression power loss.

Especially in the capacity control mode, the rate of the re-compression power loss is large. In order to reduce the re-compression loss, the high pressure chamber volume must be reduced the re-compression power loss in the capacity control mode. It is equivalent to enlarge the design volume ratio to decrease top clearance volumes in the scroll compressor. In order to enlarge the design volume ratio, the number of the scroll revolution must be increased; i.e. the $\beta$ angle of scroll must be decreased. But, when the $\beta$ angle is small, a lap thickness in the center of the scroll becomes small as shown in figure 3, and the stress becomes large. The high strength scroll profile, which is called two stage profile in this report, shown in figure 4 is developed. The bottom step is thicker than the upper step, and the lap stress can be reduced by 26%. The upper stage of the fixed scroll engaged with the lower stage of the orbit scroll, and the lower stage of the fixed scroll engaged with the upper stage of the orbit scroll. The $\beta$ angle can be made small without the increase of the lap stresses by this profile, and the high pressure chamber volume can be made small. As the result the design volume ratio can be enlarged, and re-compression power loss is decreased. When the design volume ratio was made to change by this profile, the isentropic efficiency can be improved by 8% with this profile as shown in figure 5.

Verification by cylinder pressure measuring

The cylinder pressure of the compressor was measured to analyze the performance of the capacity control compressor. The effect of the loss decrease was verified by measuring cylinder pressure of the test compressor. The cylinder pressure of the capacity control compressor is shown in figure 6. The result of the loss analysis is shown in figure 7. The re-compression and leakage losses can decrease by 28% with two-stage profile at 100% load.

The comparison of the efficiency between the developed scroll compressor and the swash plate compressor is...
shown in figure 8. These compressors efficiencies are shown as the ratio to that of the full load scroll compressor as 100%. The efficiency of the scroll compressor is higher than that of the swash plate compressor at wide range.

**POWER SAVING BY THE DEMAND CAPACITY CONTROL**

*Demand capacity control mechanism*

The capacity control scroll compressor is controlled by the built-in control valve to keep the suction pressure of the compressor constant by detecting the suction pressure. It always tries to keep the suction pressure and refrigerant evaporating temperature constant by this control strategy. For example, when the heat load of the air conditioner is large and it needs to enlarge cooling capacity, the temperature difference between the air temperature and the refrigerant evaporating temperature becomes large, and it can get large cooling capacity. When the heat load of the air conditioner becomes small, the suction pressure becomes lower. So the capacity control works to make the cooling capacity lower and the air conditioner discharge air temperature can be controlled at the constant temperature. But, this controlled temperature is constant, so the temperature is controlled by the hot water coil when higher temperature is demanded.

We have developed the demand capacity control valve, which control the suction pressure by the outer electric signal to achieve the non-reheat control. This capacity control valve is composed of two parts, which are shown in section in figure 9. First is the pressure control valve part, which creates control pressure by detecting suction pressure and discharge pressure. It is the same function as the usual control valve. The second is the demand control part, which has the function to change demand value of suction pressure. The stepping motor moves the shaft to change the spring load, which control the demand value. A demanded suction pressure can be changed when the number of the pulses of the stepping motor is changed. The demanded suction pressure range of this control valve has wide from 0.15MPa to 0.5MPa. The stepping motor needs the electric power only to change the demanded suction pressure. So it is good for energy saving.

*The effect verification of the demand capacity control*

The capacity control flow chart is shown in figure 10. The demanded suction pressure is determined a pressure set up signal is input to the stepping motor as a pulse. The control pressure to the bypass piston is output from the demanded suction pressure and the compressor suction pressure. The position of the bypass piston is set from the spring force and the pressure difference between the suction pressure and the control pressure. The amount of bypass gas is controlled by the position of this bypass piston. The compressor suction pressure is decided by the compressor capacity as a balance point of the system, and the discharge air temperature is decided by the suction pressure. The compressor suction pressure changes by the above. The discharge temperature is adjusted automatically by the capacity control valve even if the compressor rotation speed changes. The suction pressure is changed only decided value of the demand control valve. The measured discharge air temperature is shown in figure
11. The air conditioner discharge temperature can be almost kept constant regardless of the compressor rotation speed, and the air conditioner discharge temperature can be changed by changing the demanded suction pressure of the capacity control valve.

As for the usual car air conditioner, the discharge air temperature is controlled by using a hot water coil inside the air conditioner. Therefore, the compressor power for this heat load is wasted. Non reheat control is efficient for power saving. The compressor input power is shown in figure 12. Using figure 11and figure 12, the comparison of the input power between the demand capacity control and the conventional control is shown as follows. In the case of demand control, the compressor input power is 1.2kw at compressor rotation speed of 2500 rpm and discharge air temperature of 14 degrees. On the other hand, in the case of the conventional control, which set the suction pressure of 0.12MPa, the compressor input is 2.2kw at the same conditions. The discharge air temperature with not reheat is 8 degrees. So, the compressor input can be reduced about 40%. A large power saving could be achieved.

**CONCLUSIONS**

The input power of the compressor has been reduced by developing the high efficiency capacity control scroll compressor and by using the outer demand capacity control.

1) The high efficiency scroll compressor has been achieved by developing the high strength scroll center profile. The designed compression volume ratio is increased by using the two-stage center profile, so the re-compression loss is reduced.

2) Suction pressure can be controlled to an optional pressure by the new developed demand capacity control valve. By this demand capacity control valve, discharge air temperature can be controlled directly without reheat by heater core. Therefore, the compressor input power can be reduced by 40% to the conventional control.

**REFERENCES**

(1) T,Hirano et al., Scroll Profiles for Scroll Fluid Machines, Mitsubishi Heavy Industries, Ltd. Technical Review Vol.27 NO.1 (Feb. 1990) P.35~41
Demand Capacity Control Valve
Orbit Scroll
Bypass Piston
Fixed Scroll

Figure 1 Scroll Capacity Control Compressor Section

Figure 2 Scroll Compression Process

Figure 3 Scroll Center Profile and Cylinder Pressure

\[ \beta = 160^\circ \]

\[ \beta = 200^\circ \]
Figure 4  Two-Stage Profile

Figure 5  Two-Stage Profile's Effect

Figure 6  Cylinder Pressure

Figure 7  Loss Analysis

Figure 8  Compressor Efficiency
Stepping Motor
Demand Control Part
Pressure Setting Spring
Pressure Control Valve Part
Automatic Pressure Control Valve

Figure 9 Demand Capacity Control Valve

Figure 10 Capacity Control Flowchart

Suction Pressure Control Value (MPa)

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<th>0.34</th>
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Compressor Speed (min⁻¹)

Discharge Air Temperature (°C)

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<th>5</th>
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<td>Speed (min⁻¹)</td>
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<td>2500</td>
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</table>

Compressor Input Power (kW)

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<th>2</th>
<th>1</th>
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<tbody>
<tr>
<td>Speed (min⁻¹)</td>
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<td>2000</td>
<td>2500</td>
<td>3000</td>
</tr>
</tbody>
</table>

Figure 11 Discharge Air Temperature controlled by Demand Capacity Control

Figure 12 Compressor Input