Development of CO$_2$ Scroll Compressor for Automotive Air-conditioning Systems

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Introduction

• Problems of R134a Refrigerant  
• Properties of CO$_2$ Refrigerant  
• Advantage of Scroll Compressor  
• Loss Analysis of CO$_2$ Scroll Compressor  
  (Changing Displacement Only)  
• Technologies for High Efficiency  
• Loss Analysis of Prototype CO$_2$ Scroll Compressor  
• Efficiency of Prototype CO$_2$ Scroll Compressor  
• Conclusions
Problems of R134a Refrigerant

<table>
<thead>
<tr>
<th></th>
<th>ASHRAE Number</th>
<th>ODP</th>
<th>GWP</th>
<th>Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFC</td>
<td>R134a</td>
<td>0</td>
<td>1300</td>
<td>Safe</td>
</tr>
<tr>
<td>HC</td>
<td>R290</td>
<td>0</td>
<td>&lt;3</td>
<td>flammable</td>
</tr>
<tr>
<td>NH₃</td>
<td>R717</td>
<td>0</td>
<td>&lt;1</td>
<td>Toxic</td>
</tr>
<tr>
<td>CO₂</td>
<td>R744</td>
<td>0</td>
<td>1</td>
<td>Safe</td>
</tr>
</tbody>
</table>

CO₂ is the most promising natural refrigerant because of its low GWP and safety.

Properties of CO₂ [ System ]

CO₂ cycle involves super critical pressure.
CO₂ system is high pressure cooling cycle.
CO₂ system has intercooler to improve the capacity and the coefficient of performance (COP).
## Properties of CO₂ [ Thermophysical ]

at 0°C

<table>
<thead>
<tr>
<th></th>
<th>Latent Heat (kJ/kg)</th>
<th>Density of Saturated Vapor (kg/m³)</th>
<th>Capacity Volume Ratio (kJ/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>232</td>
<td>97.6</td>
<td>22600</td>
</tr>
<tr>
<td>R134a</td>
<td>198</td>
<td>14.4</td>
<td>2860</td>
</tr>
</tbody>
</table>

Capacity Volume Ratio = Latent Heat × Density of Saturated Vapor

Because the capacity volume ratio of CO₂ is 8 times larger than that of R134a, displacement of CO₂ compressor is 1/8 of current R134a compressor.

## Advantage of Scroll Compressor (1)

<table>
<thead>
<tr>
<th>Year</th>
<th>Wobble-type</th>
<th>Swash-type</th>
<th>Scroll-type</th>
</tr>
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<tbody>
<tr>
<td>195</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1960</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1970</td>
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<td>1980</td>
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<tr>
<td>1990</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
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</table>
Advantage of Scroll Compressor (2)

1: High Volumetric Efficiency
2: Low Pressure Loss
3: Low Mechanical Loss
4: Low Noise and Vibration

Scroll Compressor for CO₂ Refrigerant

Loss of Scroll Compressor

- **Pressure Loss**
  - Over Compression Loss

- **Indicative Loss**
  - Leakage and Heat Loss

- **Mechanical Loss**
  - Thrust Bearing Loss
  - Drive Bearing Loss
  - Main Bearing Loss
  - Sub Bearing Loss
  - Oldham Ring Loss
Loss Analysis of CO₂ Scroll Compressor

Technologies for High Efficiency

- **Improvement of Indicative Loss**
  
  Tip contact mechanism is applied to prototype CO₂ scroll compressor

- **Improvement of Mechanical Loss**
  
  Thrust rolling bearing is applied to prototype CO₂ scroll compressor
Loss Analysis [ Prototype ]

Prototype CO₂ Scroll Compressor

<table>
<thead>
<tr>
<th></th>
<th>CO₂ Prototype</th>
<th>Current (R134a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (mm)</td>
<td>135</td>
<td>125</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>23</td>
<td>6</td>
</tr>
<tr>
<td>Displacement (cm³)</td>
<td>13</td>
<td>105</td>
</tr>
</tbody>
</table>
Scroll has higher efficiency especially in high speed because of no suction valve and less pressure drop.

Conclusions

• Tip contact mechanism and thrust rolling bearing are applied to prototype CO₂ scroll compressor for improvement of efficiency.

• Prototype CO₂ scroll compressor achieved high efficiency. (Adiabatic Efficiency = 76%)