High efficiency R744 compressor development for vehicle

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DOOWON Companies for Automotive A/C system

- A/C System
- Heat exchanger
- Compressor
- HVAC Case
- Pipe
- Controller
- Electric system

- Reciprocating type for B/C
- Fixed Swash Plate type (150cc, 170cc)
- Variable Swash Plate type (90cc, 130cc, 160cc)
- R744 Swivel Joint type (DC28)
- Electric Scroll type (DE27)

DOOWON Climate Control Co., Ltd
Doowon Heavy Industry Co., Ltd
Doowon Refrigeration Co., Ltd
Doowon Electronics Co., Ltd

Mass product (1.2 million/year)
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IV. DC28 Vehicle Test

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I. Development Environment of DC28 R744 Compressor

The next generation A/C Compressor – DOOWON Compressor

**DC28 (R744 Compressor)**

- Broad development experience
- Ability to develop the R134a compressor
- Manufacturing Know-how of Mass Production
- Innovative Engineering Company as a R744 technical leader

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### II-1. DC28 R744 Compressor Specifications

The next generation A/C Compressor – DOOWON Compressor

<table>
<thead>
<tr>
<th>MODEL</th>
<th>DC28</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>External Variable Displacement</td>
</tr>
<tr>
<td>Displacement</td>
<td>Max. 28cc/rev (~0-28cc/rev)</td>
</tr>
<tr>
<td>Weight</td>
<td>4.5kg</td>
</tr>
<tr>
<td>Max. rpm</td>
<td>11,000 (9,500-Continuous)</td>
</tr>
<tr>
<td>Clutch Type</td>
<td>Clutchless</td>
</tr>
<tr>
<td>Size</td>
<td>Φ105x220mm</td>
</tr>
</tbody>
</table>

DC28 compressor can change the maximum displacement from 22cc to 33cc.
11-2. DC28 R744 Compressor Structure

1. Resin Pulley for weight reduction
2. External Fin for cooling
3. Controller with Control valve and P-T Sensors
4. Oil Separator for low oil circulation ratio
5. Swivel Joint Mechanism for low friction loss and hysteresis
II-3. DC28 R744 Compressor Advantages – External fins

Boundary Conditions

- Heat output on the inner walls: 600W
- Air speed on the outer walls: 50km/h
II-3. DC28 R744 Compressor Advantages - SJ mechanism

Swash Plate

Swivel Joint

No correlation between valve signal and torque

Correlation between valve signal and torque (2000 rpm)
## 11-3. DC28 R744 Compressor Advantages - Control strategies

The next generation A/C Compressor – DOOWON Compressor

DC28 compressor is having two control strategies

<table>
<thead>
<tr>
<th>Item</th>
<th>w/ Integrated controller</th>
<th>w/o controller</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control logic</td>
<td>Same R134a system control logic</td>
<td>Need to change the control logic</td>
<td></td>
</tr>
<tr>
<td>Advantages</td>
<td>1. Simple Plug-In solution → No Change A/C ECU of R134a, need only electric power 2. Safety mode → control discharge pressure 3. Discharge pressure signal output</td>
<td>1. Low cost 2. Compact size</td>
<td></td>
</tr>
</tbody>
</table>
### III-1. Volume & Overall Efficiency of DC28 R744 Compressor

#### Volumetric Efficiency

<table>
<thead>
<tr>
<th>RPM</th>
<th>Volumetric Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>80</td>
</tr>
<tr>
<td>1000</td>
<td>80</td>
</tr>
<tr>
<td>1500</td>
<td>80</td>
</tr>
<tr>
<td>2000</td>
<td>80</td>
</tr>
<tr>
<td>2500</td>
<td>80</td>
</tr>
</tbody>
</table>

- **DC28 [R744]**
- **R134a [Swash plate]**

#### Overall Efficiency

(=Theoretical Power/Real Power)

<table>
<thead>
<tr>
<th>RPM</th>
<th>Overall Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>60</td>
</tr>
<tr>
<td>1000</td>
<td>60</td>
</tr>
<tr>
<td>1500</td>
<td>60</td>
</tr>
<tr>
<td>2000</td>
<td>60</td>
</tr>
<tr>
<td>2500</td>
<td>60</td>
</tr>
</tbody>
</table>

- **DC28 [R744]**
- **R134a**

#### Remarks

- **Test Conditions**
  1. **R134a**
     - Discharge Pressure: 15 bar
     - Suction Pressure: 2 bar
     - Suction SH: 10 °C
  2. **DC28 (R744)**
     - Discharge Pressure: 120 bar
     - Suction Pressure: 40 bar
     - Suction Temp.: 30 °C
III-2. VDA Durability Test

Test Conditions

- 70 hours per one cycle
- Full durability test: 10 cycle 700 hours
- Speed range 700 to 9700rpm (11,000rpm 10 min)

Test Result

- Passed full durability test on Jan. 2007
- There was 1.0~2.0% volumetric efficiency reduction between before and after VDA durability test. (at Ps=30bar, Pd=120bar, Rpm=1000~3000rpm)
## IV-1. Vehicle and R744 A/C System

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicle</strong></td>
<td><strong>Type</strong></td>
</tr>
<tr>
<td></td>
<td>SUV</td>
</tr>
<tr>
<td></td>
<td>2700 cc</td>
</tr>
<tr>
<td></td>
<td>175ps</td>
</tr>
<tr>
<td></td>
<td>Auto</td>
</tr>
<tr>
<td><strong>R744 A/C system</strong></td>
<td><strong>Type</strong></td>
</tr>
<tr>
<td>Compressor</td>
<td>DC28 External Variable type [DWHI]</td>
</tr>
<tr>
<td>Gas Cooler</td>
<td>Parallel Flow type [DCC]</td>
</tr>
<tr>
<td>Evaporator</td>
<td>Parallel Flow type [DCC]</td>
</tr>
<tr>
<td>IHX</td>
<td>Co-axial type [DCC]</td>
</tr>
<tr>
<td>Accumulator</td>
<td>600 cc Al type [DCC]</td>
</tr>
<tr>
<td>PXV</td>
<td>Mechanical type [Obrist]</td>
</tr>
</tbody>
</table>

* Doowon Climate Control Co. install R744 A/C system in test vehicle
IV-2. Vehicle A/C Pull Down Test with DC28 R744 Compressor

- R134a A/C system: 170cc Fixed Swash Plate type Compressor
- Test condition: Ambient 35°C, 60%RH, 800W/m², Recycle Air, Blower Max. with SUV Vehicle

**Conclusion**

- Initial Cooling: Better than R134a
- Driving Condition: Similar to R134a
- Idle Condition: Better than R134a
### IV-3. Bench Test with DC28 R744 Compressor

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Comparison of mechanical power and C.O.P. on the same cooling capacity at 2000rpm.

R134a A/C System : 160cc Internal Variable Swash Plate Type Compressor

![Graph showing cooling capacity and COP comparison between R744 and R134a at different test conditions.](image)

**Conclusion**

- On the same cooling capacity,
  DC28 COP is superior than R134a in the all test conditions.

(Excluded 40℃ High load)
Operating Conditions: SUV Car, In Dubai, T\(_{\text{amb}}\) 35°C, A/C Controller 22°C auto setting

Conclusion

- **Highway Condition**
  - Stable controllability

- **Idle Condition**
  - Stable controllability

- **City Condition**
  - In spite of changing speed, suction pressure had stabilized within ±1.5 bar
IV-5. Off mode test in vehicle with DC28 R744 Compressor

Test conditions: T_amb 12 °C, A/C Off, Free driving speed

In spite of changing vehicle speed, the pressure difference between suction and discharge is 2.0~3.5 bar. This pressure value can not open PXV expansion valve.

Conclusion
IV-6. Vehicle Durability Test with DC28 R744 Compressor

- Target: 100,000 km with SUV (2 cars)
IV-6. Vehicle Durability Test with DC28 R744 Compressor

The next generation A/C Compressor – DOOWON Compressor

Mileage: 100,000 km (2007.07.18)

Temperature [°C] vs. Mileage (km)

Day (yy/mm/dd):
- 07/3/22
- 07/4/1
- 07/4/11
- 07/5/1
- 07/5/11
- 07/5/21
- 07/6/10
- 07/6/20
- 07/6/30
- 07/7/10
- 07/7/20

Amb. Temp. [°C] and Mileage (km)
Thank you for your interest.