High temperature heat pump with twin screw compressor for industrial heating (2455)

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● Backgrounds
● Compressor Modifications
● System Description
● Experimental Research
● Conclusions
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Heat pumps were widely used for its high heating efficiency and heat recovery function.

- Working fluids:
  - R134a, R124, R245fa, CO₂, NH₃
- Air-source
- Water-source
- Ground-source

- Heating COP: 3.0~4.5
Backgrounds

- Heat pumps
  - Temperature offered: 45-70°C
  - Heating capacity: 20-50kW
- Industrial heating
  - Temperature needed: 80-120°C
  - Heating capacity: 1500-3000kW

Little heat pumps met industrial heating demands.
Backgrounds

- High temperature heat pump features:
  - Temperature offered: 85-95°C
  - Compressor: twin screw compressor
  - Refrigerant: pure refrigerant
  - Heating capacity: 1700 kW
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Compressor modifications

- Structure of Motor
- Motor Power Capacity
- Built-in volume ratio
- Bearings
Compressor modifications

➢ Structure of Motor (CFD based Analysis)

Models of compressor motor and refrigerant flow channel

Meshing generation of flow channel
Compressor modifications

- Structure of Motor

Inlet refrigerant temperature: 30°C
Input power consumption: 44kW
Maximum temperature: 63°C
Minimum velocity: 0.5 m/s

Inlet refrigerant temperature: 30°C
Input power consumption: 67.8 kW
Maximum temperature: 81°C
Minimum velocity: 0.5 m/s

Temperature and refrigerant velocity distribution
Compressor modifications

Structure of Motor

Temperature and refrigerant velocity distribution

Inlet refrigerant temperature : 40°C
Input power consumption : 46kW
Maximum temperature : 64 °C
Minimum velocity : 0.5m/s

Inlet refrigerant temperature : 40°C
Input power consumption : 69kW
Maximum temperature : 107 °C
Minimum velocity : 0.5m/s
Compressor modifications

- MOTOR POWER CAPACITY
  
  Motor power capacity was *enlarged* for high evaporation temperature.

- BUILT-IN VOLUME RATIO
  
  Built-in ration changed with displacement area based on refrigerant properties.
Compressor modifications

- **Bearings**
  - Bearings was changed to keep work stability at higher discharge temperature and a extra oil injection port was placed to cool down the bearings.
• Backgrounds
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• System description
• Experimental research
• Conclusions
System description

Schematic diagram and picture of high temperature heat pump
System description

- High temperature heat pump features:

<table>
<thead>
<tr>
<th>Component</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor</td>
<td>Two twin screw compressors each with motor capacity, 206 kW and discharging volume: 1122 m³/hr</td>
</tr>
<tr>
<td>Condenser</td>
<td>Shell and tube heat exchanger with heat transfer area: 93.5 m²</td>
</tr>
<tr>
<td>Evaporator</td>
<td>Shell and tube heat exchanger with heat transfer area: 77 m²</td>
</tr>
<tr>
<td>Expansion valve</td>
<td>Manually-operated valve</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>R245fa</td>
</tr>
<tr>
<td>Water pump</td>
<td>Motor capacity: 12.5 kW, volume flow rate: 50 m³/hr</td>
</tr>
</tbody>
</table>

- Temperature offered: 80-95 °C
System description

- Protection measure:
  - Motor temperature
  - Discharge temperature
  - Suction temperature
  - Oil temperature

PLC Controller

- Water flow rate in evaporator
- Refrigerant injection rate
- Water flow rate in oil cooler
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Filed test was operated in an oil treatment station.

The water temperatures at the condenser and evaporator inlet and outlet are measured by Mercury thermometer (WH55-150) with an accuracy of ±0.5°C. The refrigerant temperature at the compressor inlet and outlet is measured by type-T thermocouples with an accuracy of ±0.5°C. The same type of thermocouples is also used to monitor the temperature of the compressor motors and lubricating oil.
The compressor power is measured by the power meter (YOKOGAWA WT500) with an accuracy of ±0.2% of full scale (0-500 kW) while the water flow rate is monitored by a turbine flow meter (LWGY-80) with an accuracy of ±0.5% of full scale (16 – 100 m³/hr).

Data was recorded every two hours and a typical 72 hours running date was used for discussion.

\[
Q_h = m_h c_{p-w} (T_{w-out} - T_{w-in})
\]

\[
P_{total} = P_{comp1} + P_{comp2} + P_{pump} + P_{other}
\]

\[
COP = \frac{Q_h}{P_{total}}
\]
Experimental Research

Condenser inlet and outlet water temperature

Evaporator inlet and outlet water temperature

Condenser outlet water temperature changed from 90-96°C with evaporator inlet water temperature changed from 62-68 °C. This temperature meet oil heating requirement well.
Experimental Research

Total heating capacity varied from 1400kW to 1800kW with COP changing from 3.5-4.3. Heating efficiency was much higher than fuel-fired boilers and electrical heating.
Motor temperature of two compressors

Lubrication oil temperature

Motor temperature was lower than 90°C and the lubrication oil temperature was lower than 65°C during running time.
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Conclusions

- High temperature heat pump could provide up to 95°C hot water and met industrial heating demands well.
- Twin screw compressor worked well during the test period and the modification made on compressor was effective.
- In oil treatment station, the 1700kW heating capacity with COP changed from 3.5-4.3 made high temperature heat pump a competitive heating equipment to replace the traditional heating equipment.
Thanks!