Effects of Low Suction Temperature on the Boil-off Gas compressor

Bin Zhao
Xi’an Jiaotong University, China

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Research background

●Global demand for natural gas grew rapidly in recent years
   ◆ 1 m³ LNG=625 m³ natural gas
   ◆ LNG boils and evaporates in the container

●Compressor is the key facility to recycle the excessive BOG (boil-off gas)
   ◆ Excessive BOG was reliquefied after pressurized

●Effects of Low suction temperature on BOG compressor is necessary to be investigated
   ◆ temperature distribution of cylinder
   ◆ temperature coefficient
   ◆ volumetric coefficient
FEM model

- Simplified FEM model of BOG compressor
  - Suction/Discharge pressure  0/1.5MPa
  - Suction temperature  30 °C~ -162 °C
  - Cylinder / Bolts  cast iron containing 35% Nickel / austenitic stainless steel
Boundary conditions

- **Natural convection**
  - between ambiance and outer surface of cylinder
- **Forced convection**
  - between gas and inner surface of cylinder
- **Heat conduction**
  - between middle body and cylinder
Boundary conditions

- Convection heat transfer coefficient
  - In the compression chamber -- Woschni formula \[1\]
    \[
    h = 2817 \times D^{-0.214} \times (V_p \times P_i)^{0.786} \times T_i^{-0.525}
    \]
  - In the suction and discharge chamber -- Dittus–Boelter correlation formula \[1\]
    \[
    Nu = 0.023 Re^{0.8} Pr^{1/3}
    \]
Temperature distribution

- At suction temperature of -162 °C
Stress distribution

- At suction temperature of -162 °C
  - While the bolts are pretightened
Stress distribution

- At ambient temperature
  - While the bolts are pretightened
Displacement distribution

- At suction temperature of -162 °C
  - While the bolts are pretightened
Experimental set-up

- Thermal couples are arranged to measure the temperature distribution
Effects of Low Suction Temperature on the Boll-off Gas compressor

Experimental set-up

Experimental conditions

<table>
<thead>
<tr>
<th></th>
<th>Condition.1</th>
<th>Condition.2</th>
<th>Condition.3</th>
<th>Condition.4</th>
<th>Condition.5</th>
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<tbody>
<tr>
<td>Suction temperature, °C</td>
<td>-142.2</td>
<td>-123.8</td>
<td>-88.8</td>
<td>-73.5</td>
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<td>Suction pressure, MPaG</td>
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<td>Exhaust pressure, MPaG</td>
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</table>
Experimental result

Temperature distribution at -162°C

- Simulated and measured temperature distribution

![Graph showing temperature distribution vs. suction temperature]
Experimental result

Temperature distribution

- at suction temperature of -88 °C

When the suction temperature decreased to -142.2 °C, the maximum temperature difference on the cylinder outer surface was up to 76 °C.
Experimental result

- Simulated and measured suction coefficient

![Graph showing the relationship between suction temperature and suction coefficient with experimental and simulation values.](image-url)
Experimental result

● Simulated and measured temperature coefficient

![Graph showing the relationship between suction temperature and temperature coefficient. The graph includes experimental data points and simulation values.](image-url)
Experimental result

Simulated and measured volumetric coefficient
Conclusions

● When the BOG compressor operated steadily with a suction temperature of -162°C, with an average temperature of -109°C in suction chamber, -60°C in discharge chamber;

● The maximum stress at low suction temperature was 354MPa, which occurred at the thread of the nut and the bolt engaging on suction side while the value was only 270MPa at the ambient temperature. The maximum displacement at low suction temperature (-162°C) was 1.117mm.

● The suction coefficient decreased from 0.825 to 0.615 with the decrease of suction temperature from -54.2°C to -142.2°C, and the temperature coefficient decreased from 0.96 to 0.72. The above two coefficients made a great contribution to the decrease of volumetric coefficient, and the volumetric coefficient decreased from 0.8 to 0.61.
References

Thank you for your attention!