Updated Performance and Operating Characteristics of a Novel Rotating Spool Compressor

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Performance Evaluation of a 141 kW (40 Tr) Spool Compressor

• Background of spool compressor

• Design targets of the 141 kW compressor

• Modeling results
  • Length to diameter ratio
  • Eccentricity

• Test methodology and initial results

• $\eta_{vol}$ of the Spool Compressor

• $\eta_{o,is}$ of the Spool Compressor

• Conclusions and next steps
141 kW Spool Compressor – R134a

- Rotor
- Suction
- Cylinder Bore
- Discharge
- Vane
Design targets for 141 kW compressor

• Design for maximum efficiency using current medium pressure gas – R134a

• Ability to accommodate future blends and HFO alternatives.

• Nominal tonnage design at 4.4 °C (40° F) SST/ 37.8 °C (100° F) 8.3 °C (15° F) LSC and 11.1 °C (20° F) SSH

• Design Targets required a displacement 40x larger than any previous compressor design.

• Using Modeling tool what would be the best geometry for improved performance?
Modeling Results
Modeling Results

The study yielded a compressor with the following design parameters:

1) Rotor Bore = 138.2mm (5.440”)

2) Eccentricity Ratio (Rotor/Cylinder Diameter Ratio) = 0.811

3) L/D (Axial Length/Cylinder Diameter) = 1.818

4) Volumetric Displacement – 2124.8 cm³/rev (124.8 in³/rev)

5) Maximum predicted efficiency at 4.4°C (40°F) SST/37.8°C (100°F)
   SDT (2.79 Pr) = 84.6%

6) Target Efficiency with valve loss – 80% - 81.2%
Test Methodology

Gas Cycle with 100% redundant measurements.

Fully automated operation.
Figure 4: Volumetric Efficiency vs. Pr at 900 rpm
Volumetric Efficiency vs. Pr at 1750 rpm
Comments on Volumetric Efficiency Comparison

- Compressor volumetric loss rate per pressure ratio at 900 rpm is 2.5% for a condensing temperature of 26.7°C and increases to 3.5% at a condensing temperature of 43.3°C.

- At 1750 rpm the loss rate is consistent at 2.2% per pressure ratio regardless of condensing temperature.

- Clearance leakage paths are small relative to actively sealed paths, tip seals and side seals.

- Slope of volumetric efficiency loss per pressure ratio is 2x better than comparable size compressors.
Figure 6 – Overall Isentropic efficiency vs. Pr at 900 rpm.
Figure 7 – Overall Isentropic efficiency vs. Pr at 1300 rpm.
Figure 8 - Overall Isentropic efficiency vs. Pr at 1750 rpm.
Comments on Overall Efficiency

• Maximum efficiency at 900 rpm occurs at 2 Pr at 78%.

• Due to testing limitations the minimum achievable pressure ratio at 1300 rpm was 2.5 and at 1750 rpm was 3. Peak efficiency could not be reached for either speed.

• Peak efficiency should occur at or below 2 Pr at higher speeds.

• Power loss due to shaft seal was not removed from the calculation.

• Efficiency at low pressure ratios decreased with speed and efficiency at higher pressure ratios increases with speed.
Summary of Overall Efficiency at design point

<table>
<thead>
<tr>
<th>Speed</th>
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<tbody>
<tr>
<td>900</td>
<td>92.5%</td>
<td>77.5%</td>
</tr>
<tr>
<td>1300</td>
<td>93.5%</td>
<td>76.5%</td>
</tr>
<tr>
<td>1750</td>
<td>95%</td>
<td>75%</td>
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</tbody>
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- Gain in volumetric efficiency with speed was not enough to overcome increased torque so $\eta_{o,is}$ is reduced going from 900 to 1750.

- Looking at figures 6 and 8 at the higher speed the compressor becomes insensitive to changes in condensing pressure and efficiency become only a function of Pressure ratio.
Overall Isentropic efficiency vs. speed at 3.24 Pr.
Comment of Overall Efficiency vs. Speed

• Efficiency change less then 2% at 60% reduction in speed.

• Possibility of over-speeding to achieve full load point could yield nearly constant performance at 75% turndown in speed.
Conclusions and next steps.

• 141 kW R134a spool compressor performance is better then current market offerings in that size.

• Due to active sealing elements the volumetric efficiency may be to high, friction is to high, to have maximum overall isentropic efficiency

• Efficiency targets as predicted by the model can be reached with optimization.

• Optimization of frictional elements for better balance between volumetric and overall isentropic efficiency needs to be done.
  • Tip Seals
  • Side Seals
  • Vane Clearance

• Discharge valve performance is unknown. Internal pressure traces to be conducted to evaluate discharge process.
Questions?

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