The Selection of Screw Rotor Geometry with Compressor Speed as a Design Variable

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Introduction

- ASHRAE 90.1-2015 proposes 17%-26% improvements in IPLV.
- Speed unloading is one option to achieve these requirements.
- What if speed was used as a design variable?
Design Study

- Optimization of 50T R-410a screw at AC conditions
- Isight - Commercial optimization code
- In-house codes used for geometry and thermodynamic analysis
- Limits placed on rotor geometry
- Motor windage based on Vrancik (1968)
- Bearing power based on SKF moment model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Min</th>
<th>Max</th>
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<tbody>
<tr>
<td>Male Rotor Diameter (mm)</td>
<td>25.4</td>
<td>152.4</td>
</tr>
<tr>
<td>Wrap (deg)</td>
<td>200</td>
<td>350</td>
</tr>
<tr>
<td>L/D</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Vi</td>
<td>2.5</td>
<td>3.5</td>
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\[ P = M \times N \]
\[ M = M_{rr} + M_{sl} \]
\[ W = C_D \pi \rho \omega^3 r^4 L \]
Results

- Rotor geometry characteristics as a function of speed.
- Resultant mesh length and port area.
**Specific Speed & Diameter**

- Turbomachinery often characterized by specific speed, diameter and flow coefficient.
  - $N$, speed
  - $D$, diameter
  - $Q$, volume flow
  - $H_{ad}$, adiabatic head rise

- $H_{ad}$ for positive displacement compressors is independent of $D$ and $N$.

- $\varphi$ is a valid relationship for both turbomachinery and both positive displacement compressors.

- Based on design requirements;
  - $N = 20,381$ rpm (14,000 rpm)
  - $D = 42.2$ mm (60 mm)
  - Tip speed = 45 m/sec

\[
N_s = \frac{N Q^{1/2}}{H_{ad}^{3/4}} \quad D_s = \frac{D H_{ad}^{1/4}}{Q^{1/2}} \quad \varphi = \frac{Q}{N D^3}
\]
Summary & Conclusions

• A rotor optimization (minimizing power) was performed across a speed range for various rotor lobe combinations.

• At each speed there is a unique combination of rotor diameter, L/D, and wrap angle to meet the volume flow requirements.

• Mesh line leakage and discharge port pressure drop are competing rotor loses with speed.

• Motor windage must be accounted for because it’s a cubed function of speed.

• Predictions show optimizing compressor speed result in a 4% decrease in power.

• Use of Blajé’s specific speed and diameter will yield the correct tip speed but could steer you toward a lower rotor diameter and higher speeds.