SEMINAR 8: Impact of Regulatory and Market Trends on Compressor and System Design

Alberto Scala
Ingersoll Rand
Alberto.scala@irco.com
608-787-2717

Compressor Modulation (Twin Screw)
Learning Objectives

• Describe the major market and regulatory trends impacting chiller and compressor design.

• Explain how design choices for compressor, heat exchangers and other major components are inter-related.

• Define how compressor design is impacted by part load efficiency focus. Including modulation via speed and mechanical means.

• Describe the impact of new refrigerants on compressor design.
Ingersoll Rand and Jay Johnson, Compressor Group Leader, for giving permission to present test results.
Outline/Agenda

• Capacity and Vi control devices
  • Capacity Slot Valve
  • Capacity Lift Valve
  • Capacity SV regulating discharge port
  • Vi Slide Valve
  • Vi Lift Valve
  • Variable speed
• Mechanical Unload + Variable Vi
• VFD + Mechanical Unload
• VFD + Variable Vi
• VFD + Economizer
Capacity Slot Valve

- Piston or turn valve that gradually opens a number of slots following the rotor helix and facing one or both rotor bores
Capacity Lift Valve

- Valve facing one or both rotor bores and delaying the actual start of compression when opened.
- Radial or axial action. The valve can provide a bypass flow.

To Suction
• Valve having a sliding action parallel to the rotor bores that controls the discharge radial port while controlling the suction opening.
• Capacity reduction goes together with a lower built in volume ratio. The delayed discharge process can partially compensate it.
• The built in volume ratio at part load condition is not always satisfactory.
Vi Slide Valve

- Valve, having a sliding action parallel to the rotor bores, situated within the high pressure cusp region, facing one or both rotor bores and controlling the radial discharge port.
- The axial port is usually designed for the highest Vi required.
Vi Lift Valve

- Valve at the discharge region, facing one or both rotor bores and opening a radial or axial port when a lower Vi is required.
Variable Speed

- Capacity controlled by rotor speed variation.
- Combined performance: VFD, motor, compressor.
Variable Speed – Part Load with No Pressure Relief

<table>
<thead>
<tr>
<th></th>
<th>Option A</th>
<th>Option B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part Load Efficiency</td>
<td>75%</td>
<td>100%</td>
</tr>
<tr>
<td>Full Load Efficiency</td>
<td>75%</td>
<td>50%</td>
</tr>
<tr>
<td>High Max Capacity</td>
<td>25%</td>
<td>25%</td>
</tr>
</tbody>
</table>

Overall spec power

- Option A
- Option B

m/s

Overall spec power [%]
VFD + Mechanical Unload

- Mechanical unloading can supplement VFD unloading when the load request is beyond the minimum rpm range required for compressor reliability.
- Mechanical unloading can complement VFD unloading by changing the built in volume ratio to improve part load efficiency.
VFD + Variable Vi - IPLV AHRI Standard 550/590

<table>
<thead>
<tr>
<th>Option A</th>
<th>Option B</th>
</tr>
</thead>
<tbody>
<tr>
<td>High max capacity</td>
<td>Full load efficiency</td>
</tr>
<tr>
<td></td>
<td>Part load efficiency</td>
</tr>
</tbody>
</table>

- **Male Rotor Tip Speed [m/s]**
  - Option A: 42/98, 42/88, 42/75, 42/70
  - Option B: 100% IPLV - High Vi, 75% IPLV - High Vi, 50% IPLV - Low Vi, 25% IPLV - Low Vi

Graph showing the relationship between W/ftm Norm and Male Rotor Tip Speed [m/s].

Legend:
- Green squares: Option A
- Red circles: Option B
- Solid black line: 100% IPLV - High Vi
- Dashed black line: 75% IPLV - High Vi
- Dotted black line: 50% IPLV - Low Vi
- Dotted-dashed black line: 25% IPLV - Low Vi
VFD + Economizer

- Economizer open at 100% load, only.

<table>
<thead>
<tr>
<th>Equal max RPM</th>
<th>Equal min RPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% more capacity</td>
<td>Full load efficiency</td>
</tr>
<tr>
<td>No benefit on part load (IPLV)</td>
<td></td>
</tr>
</tbody>
</table>

Equal max RPM

Equal min RPM

[Graphs showing specific power vs. m/s for VFD and VFD+Economizer at different RPM levels]

- Full load efficiency
- No benefit on part load (IPLV)
- 10% more capacity

- Economizer open at 100% load, only.
Conclusion

• The screw compressor is a very flexible machine, probably better than other compressor typologies. Suitable for a wide pressure ratio and speed range in order to accomplish very specific needs.

• Despite the fact the screw compressor is a mature design there are still opportunities to be competitive with centrifugal and scroll technology, especially at part load condition.

• VFD technology and variable Vi together appears to be the way to approach part load efficiency, the flexibility for handling a larger variety of refrigerants.

Questions?

Alberto Scala
Alberto.scala@irco.com