Modulation Techniques for Compressors – Part II

Performance and Efficiency Behavior of Screw Compressors – Comparison between Slider Unloading System and Frequency Inverter Operation

Hermann Renz – Director Application Engineering
Bitzer Kuehlmaschinenbau GmbH – Sindelfingen, Germany
Modulation Techniques for Compressors – Part II

– Agenda –

- Introduction
- Compressor Design Features
- Comparison of Modulation Systems
  - Slide Valve for Infinite or Step Unloading
  - Variable Speed Drive (VSD) with Frequency Inverter
- Test Conditions
- Full and Part Load Behaviour with
  - Slide Valve vs. VSD
- Summary
Compressor Design Features

- Twin Screw Type CSH6561-60Y
- Semi-Hermetic, Suction Gas Cooled
- Displacement 7244 CFH (3500 RPM)
- Motor RLA 108 Amps

- Double-walled, pressure compensated rotor housing
- Integral Oil Separator and Oil Management
- Slider Unloading System
Comparison of Modulation Systems
– Slide Valve for Infinite or Step Unloading –

Suction Gas

Discharge Gas

Sliding ECO-Port

Oil Pressure

CR1

CR2

CR3

CR4
Compressor Housing & Position of Slide Valve

Position of Slide Valve
Screw Rotors with Slide Valve
Comparison of Modulation Systems – VSD with Frequency Inverter –

Components for Performance Tests

- Frequency Inverter KIMO Type 75FEP
  - max. Operating Current 105 Amps
- Screw Compressor CSH6561-60Y
  - Frequency Range 25 .. 80 Hz

![Diagram](image)
Basic Test Conditions
– Slider Unloading System –

- Power supply with fixed frequency (60 Hz)
- Capacity modulation by axial movement of unloading slider
  - Vi-Control at part load conditions
    ➔ by adaptation of discharge port
- Capacity steps during test: 100 – 75 – 50 – 25%
  - 75 – 50 – 25% are nominal values
  - real capacity steps depend on SST and SDT
Vi-Control at Part Load Conditions – with Slider Unloading System –

![Graph showing Vi Adaptation with Slide Valve](image-url)
Basic Test Conditions
– VSD with Frequency Inverter –

- Capacity control by VSD with frequency modulation
  - Compressor slide valve at 100% position
  - Ratio Voltage / Frequency U / f \( \Rightarrow \) constant
    \( \Rightarrow \) torque remains constant with speed change
- Capacity steps during test
  - 100% for comparison with “direct power supply 60 Hz”
  - Nominal 75 – 50 – 25% steps
    \( \Rightarrow \) by speed adaptation to reach identical cooling capacities as with slider control
  - Trans-synchronous speed range with U / f \( \Rightarrow \) constant
    \( \Rightarrow \) voltage lift for test above power supply (transformer)
    - real systems \( \Rightarrow \) motor: e.g. 460V at max. frequency
VSD with Frequency Inverter – Power & Torque with Winding Layout 230V-3-60 Hz

[Graph showing Power Supply to Inverter 460V-3-60 Hz with Torque and Power percentage vs. [Hz] and [Volt].]

Torque w/o voltage lift

Power Supply to Inverter 460V-3-60 Hz

Torque

Power

0 20 40 60 80 100 120

0 20 40 60 80 100 120

0 230 460

ModTechniques II_ASHRAE01.2003 – 11
Power Consumption of CSH Screw
– VSD vs. Direct Power Supply –

Full Load Conditions 60 Hz

Relative Power with Inverter [%]

SST [°C]

R407C

SDT 52°C (125°F)

SDT 40°C (105°F)

SDT 32°C (90°F)

35°F
Performance Behaviour of CSH Screw – Slider Unloading vs. VSD –

Fixed Operating Conditions

Cooling Capacity [%] vs. Power Input [%]

- Proportional
- Slider +2/40°C (35/105°F)
- VSD +2/40°C (35/105°F)
- Slider +2/52°C (35/125°F)
- VSD +2/52°C (35/125°F)

SST / SDT based on dew points

R407C
Performance Behaviour of CSH Screw
– Slider Unloading vs. VSD –

SST / SDT Varying vs. Load – LWT 6.7°C (44°F) / EDB 35°C (95°F)

- R407C

100% Load:
- SST 2°C (35°F)
- SDT 52°C (125°F)
- based on dew points

Proportional - fixed conditions

Slider -- SST / SDT varying vs. Load

VSD -- SST / SDT varying vs. Load

Power Input [%]

Cooling Capacity [%]
Performance Behaviour of CSH Screw – Slider Unloading vs. VSD ⇒ 80 Hz –

Fixed Speed Compr. with Larger Displacement vs. VSD ⇒ 80 Hz

- R407C
- SST / SDT based on dew points

- CSH65 VSD max. 80 Hz +2/52°C (35/125°F)
- CSH75 / 60 Hz +2/52°C (35/125°F)
- CAP [%]

- VSD 80 Hz
- CSH65 VSD 60 Hz
- CSH75 60 Hz

Power Input [%]

Relative CAP [%]

ModTechniques II_ASHRAE01.2003 – 15
Modulation Techniques for Compressors – Part II
– Summary (1) –

- CSH Screw Compressors with slider modulation
  - Allow for infinite and step-wise capacity control
  - Show favourable part load efficiencies
  - Cost effective modulation technique

- VSD from 60 Hz to lower frequencies
  - Show higher energy demands than slider control
    - inverter and motor efficiency losses
    - reduced rotor tip speed – resulting in
    - increased internal leak losses during compression
  - Inverter cost much higher than slider arrangement

Conclusion
- No convincing solution
VSD for trans-synchronous speed ranges

- in comparison to a larger displacement fix speed compressor

Pro’s

- Wider modulation range than with slider system
- Smaller compressor, lower weight, simpler design (no slider)
  - Lower compressor cost, potential for high reliability
- Soft starting, low inrush current
- No need for Power Factor correction
Con’s

- Efficiency penalty against compressor with larger displacement
  - increased tip speed but higher throttling losses
- Very high inverter cost
  - exceeds (in the lower capacity range) compressor cost savings by far
- Bearing life is in direct counter-proportion to speed
- Increased sound levels with high speed

Conclusion

- Both modulation techniques offer specific benefits – the deciding factors for a final solution are therefore dependant on:
  - the entire system configuration, reliability, energy efficiency, investment and maintenance cost