Vorecon – Variable Speed Planetary Gear

Lube Oil System Modeling with GT-SUITE

GT-SUITE User Conference │ Frankfurt │ 2014-10-20
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Introduction and Motivation
Voith Variable Speed Drives

Vorecon Modular Dual Torque Converter
Challenges during Design Process

Predictive Lubrication System Model
System Simulation during Design Process

Model Validation during / after Test Run
Simulation Results vs. Measured Data

Summary and Conclusion
Voith Vorecon ... is a variable speed planetary gear

... combines hydrodynamic power transmission with mechanical parts

... is controlling the speed of compressors, pumps and fans

... is used for oil and gas production and transportation

... operates at output powers up to 40 MW

... has a maximum output speed up to 20,000 rpm

... achieves a total efficiency up to 95%

... is 100% custom designed and optimized on customers requests
Motivation

Describing the system behavior in an early stage of the design process
(Lube- and working oil system, mechanical system, power losses and efficiency)

Oil cooler design data
(Flow rates, pressure losses, temperature)

Pump- and flow component dimensioning
(screw- and centrifugal pumps, valves, filters, pipes)

Identification and evaluation
of system errors during test run

Identification of optimization potentials and risks

Requirement for a suitable tool for multi-physics system simulation
(Calculation of system behavior at variable input parameters)
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## Technical Data

### Vorecon Modular Dual Torque Converter

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Power / max. output speed</td>
<td>18500 kW @ 5775 rpm</td>
</tr>
<tr>
<td>Field of application</td>
<td>Pipeline compressor station, USA</td>
</tr>
<tr>
<td>Total oil amount in base frame</td>
<td>11000 Liter (Lube oil)</td>
</tr>
<tr>
<td></td>
<td>5000 Liter (Working oil)</td>
</tr>
<tr>
<td>Total weight (excluding oil)</td>
<td>71.5 t</td>
</tr>
<tr>
<td>Dimensions (L x W x H)</td>
<td>7.5 m x 3.9 m x 3.2 m</td>
</tr>
</tbody>
</table>
• Implementation of a second torque converter with a different characteristic behavior

• Increasing the operating range with maximum efficiency

• Two hydrodynamic couplings are used for unload motor start-up
Vorecon Modular Dual Torque Converter

Design Process?

Switching of Torque Converters?

Test run results?

Lube and Working Oil System?

System simulation
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Mechanical Model

\[ n_e = \text{const} \]

\[ n_a \neq \text{const} \]

Synchronous Motor | Vorecon | Compressor

Mechanical model (Vorecon drive chain)

Synchronous machine

Working machine (e.g., Compressor)
Results of the Mechanical Model

Rotational speeds during Vorecon start up as function of...

... Inertias
... Gear ratios
... Input / output curves
... Torque Converters and Coupling Curves
... Torque Converters guide vane positions
... Torque Converters and Coupling fillings

End of motor start up $t \approx 7.5$ sec
Switch-over point $(n_{\text{Carrier}} = 0 \text{ rpm})$ @ $n_{\text{out}} \approx -4200 \text{ rpm}$
TC1 to TC2 (draining and filling)
Acceleration due to guide vane positioning
Steady state operating point

Lube oil system?
Housing as Basis for Lube Oil System

→ Import of CAD data with GEM3D
Lubrication System Model

- Lube oil channel
- Heat exchanger and filter
- Main shaft
- Gears
- Connecting shafts
- Output shaft
- Revolving planetary gear
Model Calibration

GT-SUITE model

Internal design tools

Standard calculation methods

Inhouse test bench results

Special measurements

GT-SUITE Support

Characteristic maps / Start-up calculation

Journal bearings

Planet bearings

Pressure losses / Flow rates

Software
Results of Lubrication Model

Total lube oil flow rate during Vorecon start up as function of...

- Rotational speeds
- Bearing loads
- Pressure losses
- Oil properties

Maximum flow rate at maximum output speed is 1849 L/min
(including lube oil for motor and compressor)
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Validation during Test Run
Total Flow Rate at Maximum Output Speed

\[ \begin{align*}
Q_{LO\text{-total,measured}} &= 1789 \text{ L/min} \\
Q_{LO\text{-total,Simulation}} &= 1849 \text{ L/min}
\end{align*} \]

(including flow rate for motor and compressor)

-60 L/min

-3 %
Validation after Test Run

- Transient torque ramp on output shaft instead of compressor curve
- TC1 is filled / TC2 is drained
- Guide vane position of TC1 is constant
- Simulation duration is 265 sec

→ Output speed gets decreased at higher output torques
→ Simulation was done for two lube oil temperatures ($T_1=50^\circ$C, $T_2=55^\circ$C)
Validation after Test Run

Vorecon total lube oil flow rate at given torque ramp

Output Torque = f(Vorecon output speed)

Switch-over Point

4200rpm
Summary and Conclusion

• Starting from scratch with system simulation 2 years ago

• Using GT-SUITE during design process helped minimizing risks and finding optimization potentials

• Model validation after test-run showed very good accuracy in flow rate prediction and mechanical transmission simulation

• Today the first Vorecon Modular Dual Torque Converter runs very safely at our customers compressor station

• For future there are many other interesting questions which are suitable for system simulation, e.g.:
  - working oil system
  - different Vorecon configurations
„Individuals play the game, but teams win the championship“

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