Numerical Simulation Applied to a Compressor

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York Compressor
Numerical Simulation Example
Experimental / Simulation Example

Numerical Simulation Example

1. Measurements on running compressor
2. FE modal analysis of compressor housing
3. Experimental modal analysis
4. FE Forced response analysis
5. BEM acoustic radiation analysis
6. Design sensitivity study
Task 1 Measurements on Running Compressor

Numerical Simulation Example

- Measure Sound Power
- Operating Deflection Shapes
Measured Sound Power

Numerical Simulation Example

Pumping Frequencies

Sound Power (dB)

0 500 1000 1500 2000 2500 3000 3500 4000

Frequency (Hz)

10 dB
Task 2 FE Modal Analysis of Compressor Housing

Numerical Simulation Example

- Developed from defeatured ProE model
- Imported into ANSYS
FE Meshing Process

Numerical Simulation Example

Pro-E Model

FE Model

125,848 Nodes
79,307 Parabolic Tetrahedral Elements
Rigid Element Connections???
Task 3 Experimental Modal Analysis

Numerical Simulation Example

Complete Compressor

- Hit normal to plane → Measured on the back and top planes

Housing Only

- Hit normal to plane → Measured on the back and top planes
## Mode Comparison

Numerical Simulation Example

<table>
<thead>
<tr>
<th>Mode</th>
<th>FE</th>
<th>In Situ Normal Strike</th>
<th>% Damping In Situ</th>
<th>Housing Only Normal Strike</th>
<th>% Damping Housing Only</th>
<th>Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>593</td>
<td>548</td>
<td>2.0</td>
<td>593</td>
<td>1.4</td>
<td>Top Bending</td>
</tr>
<tr>
<td>2</td>
<td>618</td>
<td>604</td>
<td>2.9</td>
<td>633</td>
<td>0.6</td>
<td>Lateral Bending</td>
</tr>
<tr>
<td>3</td>
<td>741</td>
<td>740</td>
<td>1.8</td>
<td>744</td>
<td>0.4</td>
<td>Torsional</td>
</tr>
<tr>
<td>4</td>
<td>979</td>
<td>980</td>
<td>2.0</td>
<td>979</td>
<td>0.5</td>
<td>Cylinder</td>
</tr>
<tr>
<td>5</td>
<td>1054</td>
<td>1051</td>
<td>0.4</td>
<td></td>
<td></td>
<td>Cylinder</td>
</tr>
<tr>
<td>6</td>
<td>1144</td>
<td>1143</td>
<td>0.9</td>
<td></td>
<td></td>
<td>Cylinder</td>
</tr>
<tr>
<td>7</td>
<td>1214</td>
<td>1098</td>
<td>1.8</td>
<td>1226</td>
<td>0.9</td>
<td>2nd Top Bending</td>
</tr>
<tr>
<td>8</td>
<td>1348</td>
<td>1427</td>
<td>2.7</td>
<td></td>
<td></td>
<td>2nd Lateral Bending</td>
</tr>
<tr>
<td>9</td>
<td>1735</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Left Base Bending</td>
</tr>
<tr>
<td>10</td>
<td>1789</td>
<td>1758</td>
<td></td>
<td></td>
<td></td>
<td>Left Base Torsion</td>
</tr>
<tr>
<td>11</td>
<td>1885</td>
<td></td>
<td>1.8</td>
<td>1714</td>
<td>0.4</td>
<td>Cylinder - In Phase</td>
</tr>
<tr>
<td>12</td>
<td>1958</td>
<td>1968</td>
<td>1.0</td>
<td>1907</td>
<td>0.4</td>
<td>Cylinder</td>
</tr>
</tbody>
</table>
Mode 1 (593 Hz)

Numerical Simulation Example
Mode 4 (979 Hz)

Numerical Simulation Example
Mode 8 (1348 Hz)

Numerical Simulation Example
Mode 12 (1958 Hz)

Numerical Simulation Example
Task 4 FE Forced Response Analysis

Numerical Simulation Example

Forces were applied to suction and discharge bearing surfaces and were scaled from the actual measured values.

- 1 N Force on Suction Bearings
- Other forces were scaled accordingly
Input Pressures
Numerical Simulation Example
Operational Deflection Shapes

Numerical Simulation Example

- 2\textsuperscript{nd} Pumping Frequency (980 Hz)
Task 5  BEM Acoustic Radiation Analysis

Numerical Simulation Example

Shrink-Wrapped in Pro-E
Transfer Functions

Numerical Simulation Example

Sound Power/Force^2 (dB)

Frequency (Hz)

10 dB
Model Validation

Numerical Simulation Example

- Measured sound power (the response)
- Used power transfer function from simulation to predict the input pressure

### Difference Between Simulation and Measured Input Pressure

<table>
<thead>
<tr>
<th>Difference (dB)</th>
<th>1st (490 Hz)</th>
<th>2nd (980 Hz)</th>
<th>3rd (1470 Hz)</th>
<th>4th (1960 Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>
Task 6 Sensitivity Study

Numerical Simulation Example

Baseline

Thicker Cylinder

Lateral Longitudinal Rib

Circumferential Rib

Top Longitudinal Rib
Transfer Functions

Numerical Simulation Example

Frequency (Hz)

Sound Power/Force^2 (dB)

Baseline
Thicker Cylinder
Circumferential Rib
Top Longitudinal Rib
Lateral Longitudinal Rib

10 dB
Model Validation

Numerical Simulation Example

- Measured sound power (the response)
- Used power transfer function from simulation to predict the input pressures
- Predicted input pressures within 2 dB of measured results