Centrifugal Pumps Mechanical Design
ANSYS analysis Vibration in Vertical Pumps

Sérgio Loeser - Sulzer Pumps Brazil
Karin Kieselbach - Sulzer Pumps HQ – Switzerland
Prof. Dr. Miguel Mattar Neto - IPEN
PRESENTATION PARTS

• Sulzer, Sulzer Pumps and Sulzer Pumps in Brazil
• Pumps and Vertical Pumps
• Case Study: Vertical Pump in VCP – 3 Lagoas MS
• Conclusion
Sulzer and Sulzer Pumps

Sulzer Pumps
Pumping solutions and services

Sulzer Metco
Surface technology solutions and services

Sulzer Chemtech
Components and services for separation columns and static mixing

Sulzer Turbo Services
Service and repair of thermal turbomachinery

Sulzer Innotec
Contract research and technical services
# Sulzer market

<table>
<thead>
<tr>
<th>Industry</th>
<th>Sulzer Pumps</th>
<th>Sulzer Metco</th>
<th>Sulzer Chemtech</th>
<th>Sulzer Turbo Services</th>
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<tbody>
<tr>
<td>Oil and gas (incl. HPI, CPI, etc.)</td>
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<td>✔️</td>
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<tr>
<td>Pulp and paper</td>
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<tr>
<td>Turbines and power generation</td>
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<td>Automotive</td>
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Sulzer Brasil - Jundiaí

- Pattern Storage: 1400m²
- Office building: 2500m², 2 stories
- Factory: 7200m², 5 bays, 45t lifting cap.
- Canteen
- Component Machining: 2000 m²
- Foundry: 3500 m²
Sulzer Brasil - 2009

Orders received
New Pumps
360 BRL million
<table>
<thead>
<tr>
<th>Overhung</th>
<th>Horizontal</th>
<th>Foot Mounted</th>
<th>CPT, Z</th>
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<tr>
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<td>Centerline Mounted</td>
<td>CAP, OHH, OHL</td>
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<td>Vertical</td>
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<tr>
<td>Vertical</td>
<td>In-Line</td>
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<td>ZAV</td>
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<tr>
<td>Between Bearings</td>
<td>1 &amp; 2 stages</td>
<td>Axially Split</td>
<td>SMN, SMH, HSB, HPDM, ZPP</td>
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<td>Between Bearings</td>
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<td>Radially Split</td>
<td>BBT, BBS, BBT-D, CD, BBS-SC</td>
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<td>Between Bearings</td>
<td>Multistage</td>
<td>Axially Split</td>
<td>MSD, MSE, MSD2</td>
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<td>Between Bearings</td>
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<td>Radially Split-Single casing</td>
<td>MBN, MC, MD, ME</td>
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<tr>
<td>Between Bearings</td>
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<td>Radially Split-Double Casing - Barrel</td>
<td>GSG, CP, HPcp, HPT</td>
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## Sulzer Vertical Pumps

<table>
<thead>
<tr>
<th>Single Casing</th>
<th>Through Column</th>
<th>Diffuser</th>
<th>Volute</th>
<th>Axial Flow</th>
<th>Separate Discharge</th>
<th>Line-shaft</th>
<th>Cantilever</th>
<th>Double Casing</th>
<th>Diffuser</th>
<th>Volute</th>
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<tbody>
<tr>
<td></td>
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<td>TMC BK, BKn, BSm SJT, SJM, JTS</td>
<td>BSD</td>
<td>BPn SJP</td>
<td>ZN</td>
<td>NKP</td>
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Sulzer Vertical Pump

- Motor
- Discharge head
- Shaft and Coupling
- Baseplate
- Column
- Bowls
- Bell
- Strainer
Sulzer Vertical Pumps – Main Types

**SJT** Turbine
Ns 1800 < 5000
nq 35 < 110

**SJM** Mixed Flow
Ns 5800 < 8300
nq 113 < 161

**SJP** Axial Flow
Ns ~ 14,500
nq ~ 280
Vertical Pumps - Hydraulics

Impeller types

CLOSED

SEMI-CLOSED

OPEN
Vertical Pumps - Hydraulics

<table>
<thead>
<tr>
<th>Turbine</th>
<th>Mixed</th>
<th>Axial</th>
</tr>
</thead>
</table>

Types according to flow type
Sulzer Vertical Pumps – 3 main parts

Suction - Bowl

Column

Discharge Head
Vertical Pumps – Field Installation
Sulzer Vertical Pump – BSm at test

Cooling System
Sulzer Vertical Pump – BSm at field

BSm 1400-1s
36'000 m³/h at 14m
310 RPM, 1520 kW
Diam. Discharge
2000mm
Vertical Pump – Static Analysis

→ **Example: São Francisco, BKn2000-1800-1s/030**

Loads and Restraints:

→ **Internal pressure**, applied on "wet surface"

→ Pressure on "cover faces" is applied as equivalent axial force

→ **Motor torque**

→ **Nozzle loads**

→ **Rotor mass** at axial bearing

→ Restraints at bolt locations and pipe
Allowable Membrane Stress: $\sigma_{m,all} = \frac{R_{p,0.2}}{SF}$

- Primary Membrane Stress
  $\sigma_{eq} \leq \sigma_{m,all}$

- Local Primary Membrane Stress
  $\sigma_{eq} \leq 1.5 \cdot \sigma_{m,all}$

- Secondary Membrane + Bending Stress
  $\sigma_{eq} \leq 3 \cdot \sigma_{m,all}$
Case Study - Vertical Pump in 3 Lagoas

General Dimensions
\[ D_{\text{nom}} = 508 \, [\text{mm}] \]
Height of Column Pipe = 14500 [mm]
Height of Motor Stool = 1985 [mm]
Height of Motor = 2500 [mm]
Total Height = 18985 [mm]

Performance Data
Rated Flow \( 2218 \, [\text{m}^3/\text{h}] \)
Rated Head \( 49 \, [\text{m}] \)
Rated Speed \( 1186 \, [\text{rpm}] \)
Pumped Fluid Water

Masses and Inertias

<table>
<thead>
<tr>
<th>Component</th>
<th>( m ) [kg]</th>
<th>( I_p ) [kgm(^2)]</th>
<th>( I_t ) [kgm(^2)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impeller</td>
<td>165.9</td>
<td>7.23</td>
<td>3.85</td>
</tr>
<tr>
<td>Motor</td>
<td>2'790</td>
<td>17.6</td>
<td>-</td>
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<tr>
<td>Axial Bearing</td>
<td>76.9</td>
<td>0.57</td>
<td>-</td>
</tr>
</tbody>
</table>

Other data
Impeller diameter: 567mm - nq 47
Weights (kg):
Pump: 5400 - Baseplate: 256
Motor: 2790 - Total: 8446

Material Data
Pipes: A36
Flanges: A36
Motor Stool: A36
Pump Bowl: 0.7040
Bellmouth: 0.6025
• Shaft diameter: 70mm
• Bearing span: 2000mm
• Bearing span according to API 610: max2250mm
Case Study - Vertical Pump in 3 Lagoas

Pumps A and B speed 100% = 1186rpm = 19.8Hz => 2218m³/h – 49m – 370kW

Pump C speed 70% - 80% - 90% => 13.8Hz - 15.8Hz - 17.8Hz (1067rpm) => 1035m³/h
Case Study - Vertical Pump in 3 Lagoas

**Pump Min. Operating Water Level**

<table>
<thead>
<tr>
<th>Rising Pipe Natural Frequencies [Hz]</th>
<th>about Y-axis</th>
<th>about X-axis</th>
<th>Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mode (1&lt;sup&gt;st&lt;/sup&gt; classic bending mode)</td>
<td>1.1</td>
<td>1.1</td>
<td>Figure B-1</td>
</tr>
<tr>
<td>2. Mode (2&lt;sup&gt;nd&lt;/sup&gt; classic bending mode)</td>
<td>6.7</td>
<td>6.8</td>
<td>Figure B-2</td>
</tr>
<tr>
<td>3. Mode (3&lt;sup&gt;rd&lt;/sup&gt; classic bending mode)</td>
<td>18.6</td>
<td>18.7</td>
<td>Figure B-3</td>
</tr>
<tr>
<td>4. Mode (4&lt;sup&gt;th&lt;/sup&gt; classic bending mode)</td>
<td>35.1</td>
<td>35.2</td>
<td>Figure B-4</td>
</tr>
</tbody>
</table>

Model: without shaft, sleeves and intermediary rubber bearings.

Water mass added to model
Without shaft, sleeves and rubber bearings

Campbell Diagram
## Case Study - Vertical Pump in 3 Lagoas

### Pump Min. Operating Water Level

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<tbody>
<tr>
<td>1. Mode (1st classic bending mode)</td>
<td>0.9</td>
<td>0.9</td>
<td>Figure C-1</td>
</tr>
<tr>
<td>2. Mode (2nd classic bending mode)</td>
<td>5.5</td>
<td>5.6</td>
<td>Figure C-2</td>
</tr>
<tr>
<td>3. Mode (3rd classic bending mode)</td>
<td>14.2</td>
<td>14.2</td>
<td>Figure C-3</td>
</tr>
<tr>
<td>4. Mode (4th classic bending mode)</td>
<td>36.1</td>
<td>36.3</td>
<td>Figure C-4</td>
</tr>
</tbody>
</table>

**Model:** with shaft, sleeves and intermediary rubber bearings, but not Rotordynamic effect included.

**Water mass added to model**
With shaft, sleeves and rubber bearings
Case Study - Vertical Pump in 3 Lagoas

Vibration measurements at field: No resonance at 90% rated speed, but high vibration at 80% rated speed
Case Study - Vertical Pump in 3 Lagoas

Two possible solutions:

1) Increase Natural frequency from ~14Hz to above 23Hz, by adding ribs in the column in order to increase stiffness

2) Modify Mode shape, by fixing column to concrete structure
Natural frequency increased, but not enough.

Solution 1
New Mode Shapes

Campbell Diagram

Critical Speed = 974 rpm

Solution 2
Case Study - Vertical Pump in 3 Lagoas

Conclusions

1. Learning: guidelines to Sales => orientation to customer in case of pumps in parallel with different speeds;

2. Optimum model => closest to reality, that means, enough information that explain what is happening at field;

3. To modify natural frequency taking in account separation margin: not ever to increase, but according to each configuration of project.
Case Study  - Vertical Pump in 3 Lagoas

Gracias  Merci
Obrigado
Danke  Thank you
Grazie