Pumps: Failure Modes and Ways to Investigate the Cause

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Turnover: EURO 42 Mio.
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- Standardized chemical pumps
- Magnetic drive pumps
- Chemical pumps in heavy duty design
- Liquid ring vacuum pump
- Circulation pumps
- Vertical chemical pumps
Quote from Hans-Jürgen Bittermann of Process Technologies:

Wrong operation and wrong selection causes 90 to 95 per cent of pump failures!

Problems can only be avoided if it is understood what caused them!

17.12.2007
Case Examples

- Broken shaft at the coupling end of a vertical pump
- Damaged submerged bearings of a vertical pump
- Cracked mechanical seal of a axial flow propeller pump
- Abnormal increased spare part consumption
- Some more pictures...
Wrong Operation

Broken Shaft at the Coupling End of a Vertical Pump
Vertical Pump for Hot Sulphuric Acid

\[ Q_{\text{Pump}} = 600 \text{m}^3/\text{h} \]

\[ H = 30 \text{m} \]

99,5% \( \text{H}_2\text{SO}_4 \)

\[ T = 220^\circ\text{C} \]
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Complete Metallurgical Analysis of the Shaft
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Wrong Process Operation

Damaged submerged bearings of a vertical pump
Vertical Pump for Ammonium Nitrate Solution

\[ Q_{\text{Pump}} = 55 \text{m}^3/\text{h} \]
\[ H = 39 \text{m} \]
\[ T = 157^\circ \text{C} \]
\[ \text{NPSHA} = 3.5 \text{m} \]
\[ \text{NPSHR} = 3.0 \text{m} \]
Introduction

The AN melt pumps 31P008 A/B and the tank and pumping system have been designed for a normal operation including start-up and shut-down. As the plant now has to operate in idle status very frequently and for extended periods of time, a special instruction covering these operating modes became necessary.

General

Following general rules shall be obeyed:

- Before start-up of the pump a sufficient tank level has to be maintained (min. 30% acc. to operating manual)
- Before start of the pump the tank temperature has to be checked. Depending on the concentration of the AN solution in the tank following temperatures shall not be exceeded:
  
<table>
<thead>
<tr>
<th>Concentration (wt%)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>89</td>
</tr>
<tr>
<td>70</td>
<td>98</td>
</tr>
<tr>
<td>90</td>
<td>119</td>
</tr>
<tr>
<td>92</td>
<td>125</td>
</tr>
<tr>
<td>94</td>
<td>135</td>
</tr>
</tbody>
</table>

  The reason is, that otherwise the NPSH necessary for the AN melt pump cannot be maintained.
Incorrect Operating Data

Cracked Mechanical Seal of an Axial Flow Propeller Pump
Axial Flow Propeller Pump
DN 700 for 9% Phosphoric Acid
Material Alloy 825 (2.4858)

$Q_{\text{Pump}} = 6000 \text{m}^3/\text{h}$
$H = 7 \text{m}$
$T = 130^\circ \text{C}$
$P = 13 \text{ bar}$
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Information from the customer:
- Propeller did not turn anymore
- Leakage at the mechanical seal

After site inspection:
- Cracked seal ring on atmospheric side
- Pump has to be operated at 170°C!
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Vergleich verstärkt / standard

Mediumtemperatur: $T = 170 \, ^\circ C$
Druck: $p = 13 \, \text{bar}$
Abnormal High Spare Part Consumption
Fertilizer Plant in Norway
Various horizontal heavy duty chemical pumps

Nitric and Phosphoric Acid

T up to 135°C

Pumps have been running over 10 years, since 2 years increased spare part consumption
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Step 1: List of the 5 Items with the highest spare part consumption (according to the customer)

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Type</th>
<th>Size</th>
<th>Fluid</th>
<th>Temp.</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>P 3201 / 02</td>
<td>RCE</td>
<td>150/380</td>
<td>H₂O 29%, HNO₃ 5%, H₃PO₄ 15%, Ca(NO₃)₂ 44%, H₂SiF₆ 4%, CaSiF₆ * 2 H₂O 1,5%, SiO₂ 1,5%, (HF - HCL)</td>
<td>65</td>
<td>1.4136S</td>
</tr>
<tr>
<td>P 3206 / 07</td>
<td>RCE</td>
<td>150/380</td>
<td>H₂O 33%, HNO₃ 3%, H₃PO₄ 0,2%, Ca(NO₃)₂ 63,6%, H₂SiF₆ 0,1%</td>
<td>55</td>
<td>1.4136S</td>
</tr>
<tr>
<td>P 3210 / 11</td>
<td>RCE</td>
<td>150/380</td>
<td>H₂O 37%, HNO₃ 30%, H₃PO₄ 10%, Ca(NO₃)₂ 16%, H₂SiF₆ 0,1%, CaSiF₆ * 2 H₂O 0,7%, SiO₂ 1,5%, Cl 0,1%, F 0,5%</td>
<td>10</td>
<td>1.4136S</td>
</tr>
<tr>
<td>P 3212 / 13</td>
<td>RCE</td>
<td>80/200</td>
<td>H₂O 33%, HNO₃ 15%, H₃PO₄ 30%, Ca(NO₃)₂ 16%, H₂SiF₆ 0,8%, CaSiF₆ * 2 H₂O 4%, SiO₂ 1%</td>
<td>20</td>
<td>1.4136S</td>
</tr>
<tr>
<td>P 3216 / 17</td>
<td>RCE</td>
<td>100/260</td>
<td>AN 60%, H₂O 20%, CaPO₄ 3,5%, NH₄H₂PO₄ 8%, (NH₄)₂HPO₄ 5%, CaF₂ 2%, SiO₂ 0,5%</td>
<td>135</td>
<td>1.4136S</td>
</tr>
</tbody>
</table>
Step 2: Preparation of a specific questionnaire sheet

Item number:                      
Service name:                    
Pump type:                       
Pump size:                       
FRH R-Number:                   
Serial number:                  
Main material of construction:

Actual operating conditions monitored in the plant:
Medium (complete description inclusive composition):

Remarks and comments from operators:
(e.g. vibrations under certain operating conditions, cavitation, noise, fluctuating head or capacity):

Operating conditions specified for the first installation:
Medium (complete description inclusive composition):

Capacity: [m³/h]
Delivery head: [m]
Temperature: [°C]
Density: [kg/m³]
Viscosity: [cP]
Speed: [min⁻¹]
NPSHA: [m]
Impeller diameter: [mm]
Power consumption: [kW]
Pressure suction side: [bar]
Pressure discharge side: [bar]

(to be filled by FRH)
Step 3: Collect information on the plant site

Information such as:

• Serial-Number
• Installed Impeller Diameter
• Information Regarding the Fluid
• Current Operating Conditions
• Pipe Layout
Step 4: Analysis of the information

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Analysis of the information</td>
</tr>
</tbody>
</table>

Analysis:

- **Original Data Sheet**
- **Compare the Provided Information**
- **Analysis of the Duty Point**
### Step 5: Current and differential pressure measurements

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Pumpe Size</th>
<th>Installed Impeller Dia. [mm]</th>
<th>Density [kg/dm³]</th>
<th>min. Tank Level [m]</th>
<th>max. Tank Level [m]</th>
<th>Suction Pressure [bar]</th>
<th>Discharge Pressure [bar]</th>
<th>Differential Pressure [bar]</th>
<th>Calculated Pump Head [m]</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>P 3201 / 02</td>
<td>RCE 150/330</td>
<td>380</td>
<td>1,6</td>
<td>6,5</td>
<td>9</td>
<td>1,4</td>
<td>10</td>
<td>8,5</td>
<td>54,79</td>
<td>Bypass operation</td>
</tr>
<tr>
<td>P 3205 / 07</td>
<td>RCE 150/380</td>
<td>220</td>
<td>1,6</td>
<td>3,5</td>
<td>3,5</td>
<td>0,35</td>
<td>3,4</td>
<td>3,05</td>
<td>19,43</td>
<td></td>
</tr>
<tr>
<td>P 3210 / 11</td>
<td>RCE 150/380</td>
<td>220</td>
<td>1,45</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>26,12</td>
<td></td>
</tr>
<tr>
<td>P 3212 / 13</td>
<td>RCE 80/200</td>
<td>200</td>
<td>1,55</td>
<td>2</td>
<td>2</td>
<td>0,1</td>
<td>6</td>
<td>7,9</td>
<td>51,95</td>
<td></td>
</tr>
<tr>
<td>P 3216 / 17</td>
<td>RCE 100/260</td>
<td>254</td>
<td>1,5</td>
<td>4,5</td>
<td>7,5</td>
<td>0,64</td>
<td>14</td>
<td>13,36</td>
<td>90,79</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>P 3201 / 02</td>
<td>RCE 150/330</td>
<td>250M</td>
<td>1450</td>
<td>1480</td>
<td>106</td>
<td>100</td>
<td>80</td>
<td>1,33</td>
<td>0,96</td>
<td>0,56</td>
<td>73,03</td>
</tr>
<tr>
<td>P 3205 / 07</td>
<td>RCE 150/380</td>
<td>250M</td>
<td>1450</td>
<td>1480</td>
<td>82,5</td>
<td>100</td>
<td>80</td>
<td>1,03</td>
<td>0,95</td>
<td>0,335</td>
<td>58,78</td>
</tr>
<tr>
<td>P 3210 / 11</td>
<td>RCE 150/380</td>
<td>250M</td>
<td>1450</td>
<td>1480</td>
<td>75,5</td>
<td>100</td>
<td>80</td>
<td>0,95</td>
<td>0,61</td>
<td>0,338</td>
<td>52,03</td>
</tr>
<tr>
<td>P 3212 / 13</td>
<td>RCE 80/200</td>
<td>180M</td>
<td>2900</td>
<td>2945</td>
<td>37,1</td>
<td>40,6</td>
<td>32,4</td>
<td>1,15</td>
<td>0,86</td>
<td>0,9</td>
<td>36,32</td>
</tr>
<tr>
<td>P 3216 / 17</td>
<td>RCE 100/260</td>
<td>315S</td>
<td>2900</td>
<td>2982</td>
<td>104</td>
<td>190</td>
<td>152</td>
<td>0,65</td>
<td>0,86</td>
<td>0,838</td>
<td>71,81</td>
</tr>
</tbody>
</table>
Step 6: Analysis of the result and plant visit
Some more Pictures...
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Thank You!