RIVER WATER PUMP CYCLIC VIBRATION

TOM MANNING, DAVE SERGE

E. I. DUPONT DE NEMOURS
Biographies

Thomas W. Manning Jr. is currently an engineer in the Engineering Mechanics Group at E. I. DuPont in Wilmington DE. His primary role is to work with DuPont business units to improve manufacturing process quality, yield and capacity. In this diagnostic role Tom applies his experience in design, analysis, and dynamic measurements to solve process or equipment problems.

Prior to transferring to the engineering department, Tom spent 16 years in DuPont’s Lycra® business in Waynesboro, VA. During that assignment, he worked on design and development programs for new process equipment, winding equipment, drive systems, and package delivery improvements.

Tom joined DuPont in 1984, when he received his B.S. and M.S. Degrees in Mechanical Engineering from Drexel University, Philadelphia, PA. He is a member of ASME and ASHRAE.

David J. Serge is currently a leveraged reliability & rotating equipment consultant at E. I. DuPont in Wilmington, DE. He supports various sites improving the reliability of rotating equipment by working on vibration analysis, RCFAs and new or repair equipment specifications.

Dave joined DuPont in 2005. Previously he worked at the Delaware City, Delaware refinery as a machinery reliability engineer working for Getty, Texaco, Star Enterprise and Motiva. While there he specified upgrades and replacements for pumps, compressors, turbines and miscellaneous mechanical equipment. He also worked for Conrail at a diesel & electric facility servicing the Metropolitan Transportation Authority of New York City, NY.

Dave received his B.S. from Temple University in Philadelphia, PA and MBAs from Goldey-Beacom College in Wilmington, DE. He is certified by SMRP and is a member of ASME, the Vibration Institute and STLE.
Presentation Topics

- Pump History and Related Reliability
- Pump Capability
- Discovery
- Testing Setup
- Cyclic Vibration
- FEA Analysis
Pump History and Related Reliability
River Water Pump Vault Layout

N

Plant North

Bar Racks

True North

Satellite View

42nd Turbomachinery
29th Pump SYMPOSIA

GEORGE R. BROWN CONVENTION CENTER
9.30 – 10.3.2013
Abbreviated History of Unreliability

• #4 River Water Pump required the assistance of at least one On-Shore pump to maintain the plant requirements.
• Replaced pump on October 23, 2011 with Vibration sensor attached to bowl section.
• Balanced Motor and installed vibration sensors.
• Activated sensors in DCS November 2011.
• Experienced continually increasing vibration on pump motor.
• Had divers inspect & repair the vault area.
• Motor running with high 1X vibration that disappears when power switch is thrown.
Replaced motor with spare
- Vibration changed from high at low vault water level to high at high vault water level.
- Attempted balancing motor due to high 1X vibration but could not influence a change
- Ran motor uncoupled and vibration dropped from 0.42 ips to 0.07 ips
- Pulled pump to look for cause of 1X - potential imbalance with no findings except a small stick and some rope. Changed impeller mounting and hard faced shaft bearing journals. Cleaned layered corrosion from pump sole plate.
- Reinstalled pump and only slight improvement in vibration
- Elicited help from DuPont Corporate Engineering to look further into cause.
#4 River Water Pump

April 8-16
Pump Capability
Head vs. Capacity Curves and Test Data

Pump TDH (ft) vs. Pump Capacity (gpm)

- Bowl TDH (both impellers full trim)
- Bowl TDH Test Results
Head vs. Capacity Curves and Test Data

- Pump TDH (ft)
- Bowl TDH (both impellers full trim)
- Bowl TDH (one impeller trimmed)
- Bowl TDH Test Results

- Pump Capacity (gpm)
Head vs. Capacity Curves and Test Data

Pump TDH (ft) vs. Pump Capacity (gpm)

- **Bowl TDH (both impellers full trim)**
- **Bowl TDH (one impeller trimmed)**
- **Bowl TDH Test Results**
Conclusions

– During the testing period, the #4 river water pump had to be supplemented at times with the onshore pumps.

– The pump was ordered as a direct replacement per the original design. The bowl section used was the spare for the cooling tower pumps. Per records, the #4 river water pump is intended to have full size impellers for both stages to meet head requirements.

– The cooling tower pumps on site have the 2nd stage impeller trimmed to minimize amp load on the drive motors.
A literature search was done in parallel with our preparation to instrument the pump for experimental analysis.

Other instances of column resonance have been documented in industry.

At first it was not clear how a resonance would explain the scalloped time plots.

We recognized that we needed a way to attach an accelerometer to the bottom of the pump but the only access was through an 8” hole through the 24” thick floor . . . .
Testing Setup
Lower Pump Accelerometer Installation

- Installed 20’ catheter to guide and attach an accelerometer to bottom of pump
  - Catheter was made from ¾” SS Tubing
  - Attached through 8” Access hole in floor
- Attached accelerometer to end of nylon tube to seal signal wire from water
- Accelerometer was attached to pump with magnet
- In hindsight, we could have added a weight to the end of the catheter so it could be used as an impact hammer
- Hammer would be operated by pushing down on nylon tube and then releasing
Water Level Sensor, Accelerometer Catheter

Time of flight displacement sensor used to measure float position. Plate was clamped to floor with threaded rod.
Data Acquisition

We set up to measure many parameters since the cause was initially unknown.
Vibration measured at bottom of pump and water level measured in vault. Vibration amplitude changes with water level. Peak vibration level occurs near high tide.
FFT of Time Trace
Contour Plot of FFT

Natural frequency changes with tide and intersects running speed of pump. Tide measurement was represented as a modulating frequency in FFT plot to correlate data.
Pattern repeats every tide cycle
Natural frequency of RWP #4 changes with water level. Excitation is from RWP #5.
FEA Analysis
FEA Analysis

• Pump geometry was modeled to explore design changes.
• Weight of internal water was added by adjusting the density of internally wetted metal parts.
• Density of parts wetted by external water were adjusted to match measured frequency.
• Calibrated model was used to recommend design change.
Standard Pump Low Tide
20.75 Hz
Standard Pump High Water Level
19.31 Hz
Shortened Column, SS Impeller Low Level

23.55 Hz

Displacement Mag (WCS) (in)
Deformed
Max Disp: +1.0000E+00
Scale: 3.3603E-01
Mode 3: +2.355E+01
Shortened Column, SS Impeller High Level
21.60 Hz
## FEA Summary

<table>
<thead>
<tr>
<th>Condition</th>
<th>Model</th>
<th>Column Length</th>
<th>Column Diameter</th>
<th>Level</th>
<th>Frequency</th>
<th>RPM</th>
<th>% Running Speed (1180) RPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Low Tide</td>
<td>W3061052</td>
<td>211</td>
<td>14</td>
<td>Low</td>
<td>20.75</td>
<td>1245</td>
<td>106%</td>
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<tr>
<td>Standard High Tide</td>
<td>W3061052</td>
<td>211</td>
<td>14</td>
<td>High</td>
<td>19.31</td>
<td>1158.6</td>
<td>98%</td>
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<tr>
<td>Short Low Tide</td>
<td>W3060146</td>
<td>199</td>
<td>14</td>
<td>Low</td>
<td>23.55</td>
<td>1413</td>
<td>120%</td>
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<tr>
<td>Short High Tide</td>
<td>W3060146</td>
<td>199</td>
<td>14</td>
<td>High</td>
<td>21.60</td>
<td>1296</td>
<td>110%</td>
</tr>
</tbody>
</table>
Recommendation

• Replace trimmed impeller in #4 river water pump with full size impeller. Consider using duplex stainless steel as material of construction for increased resistance against river silt abrasion and salt attack.

• Reduce pump column length by 12” so that natural frequency will remain above running speed. The pump installed inadvertently had the column section increased by 12” but matched the original design for the pump.
Actions

• Ordered a complete new pump with a 12” shorter column length and proper diameter CD4MCUN impellers. Impellers were sized to meet head requirements but not overload the 400 HP motor.
• Installation planned for late fall 2013