Cavitation Resistant Materials

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Cavitation Overview

Cavitation is rapid formation and collapse of vapor bubbles in water with sudden pressure changes

- Ex. water accelerated to high velocities
- Ex. Rapid bends in water direction

A) Pressure of liquid drops to vapor pressure
B) As these vapor bubbles enter area of higher pressure, the bubbles implode/suddenly collapse.
C) High energy shock waves


Cavitation Overview

- Microscopic impacts erode the structural surface
- Micro-fractures the surface and creates pits
- Material failure through fatigue

The Glen Canyon dam spillway damage 1983
Cavitation Overview

Cavitation damage to spillway tunnel of Yellowtail Dam.

Structures Affected by Cavitation

- Turbine runners
- Draft tubes
- Butterfly valves

- Produces rotational force that is converted into power.
- Blades capture the kinetic energy from the water.
- Rust look is from galvanic corrosion-SS weld overlay pops off
Structures Affected by Cavitation

- Turbine runners
- Draft tubes
- Butterfly valves

- Tube fitted at end of runner
- Increases efficiency of the hydro-turbine
- Increases the pressure of exiting fluid by decreasing exit velocity
Structures Affected by Cavitation

- Turbine runners
- Draft tubes
- Butterfly valves

Butterfly valves:
- Used as on-off valves
- Have a rotating leaf (disc)
- Safety and maintenance device for penstocks, turbines
- Cavitation happens as flow velocity changes rapidly
What does Reclamation currently use for Cavitation Resistance?

- Stainless steel
- Stainless steel weld overlays
- Elastomeric cavitation repair material
- Ceramic filled epoxy
Test Procedure Development
FY2016-FY2019
• Development of test procedure
  • ASTM jet cavitation
  • Venturi cavitation apparatus
  • Pressure washer jet test

1. Cumbersome to get operational (standoff distance an issue)
2. Not representative of field sample size and test conditions
• Development of test procedure
  • ASTM jet cavitation
  • Venturi cavitation apparatus
  • Pressure washer jet test

1. Very slow test (180 hrs for single Aluminum sample)
2. Not practical for obtaining enough statistically relevant samples (triplicate for each sample type)
• Development of test procedure
  • ASTM jet cavitation
  • Venturi cavitation apparatus
  • Pressure washer jet test

1. Good rate of testing to allow for many samples
2. Field representable size
3. Can run 2 tests at the same time in tank
4. Jet nozzle fixed in place.
Materials Research
Steel baseline

- 5.0 gal/min
- 40 hrs

- 3.5 gal/min
- 40 hrs
Stainless steel baseline

- 5.0 gal/min
- 40 hrs

- 3.5 gal/min
- 40 hrs
Jet tests on Cold Spray 316 Stainless Steel

- Failure at 60 hrs
- Extensive cracking
- Tested at 5 gal/min
- Needs to be re-run at 3.5 gal/min.
Jet tests on Thermal Spray

• Super Nickel alloy
• Performance: Wore away 7 hrs and 5 hrs
• 5 gal/min
• Needs to be re-run at 3.5 gal/min.
Transition to Cavitation Resistant Coatings Research
• These ran at 2.6 gal/min
• Need re-run at 3.5 gal/min

• Materials tested:
  • Ceramic Epoxies
  • Polyurethane elastomer
  • USACE Vinyl system
2.6 gal/min

Polyurethane Elastomer

3.5 gal/min

Polyurethane Elastomer
FY2020 Results (prior to Covid):
2.6 gal/min - needs to be re-run at 3.5 gal/min

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Average Time to failure (hrs)</th>
<th>Average Thickness (mils)</th>
<th>Average Rate (mils/hr)</th>
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<tbody>
<tr>
<td>Ceramic filled epoxy 1</td>
<td>60</td>
<td>60</td>
<td>1</td>
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<tr>
<td>Ceramic filled epoxy 2</td>
<td>19</td>
<td>55</td>
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<td>Ceramic filled epoxy 3</td>
<td>48</td>
<td>56</td>
<td>1.3</td>
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<tr>
<td>Ceramic filled epoxy 4</td>
<td>100</td>
<td>50</td>
<td>0.5</td>
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<tr>
<td>USACE Vinyl 5EZ new steel</td>
<td>7</td>
<td>12</td>
<td>1.8</td>
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<tr>
<td>USACE Vinyl 5EZ pitted steel</td>
<td>0.6</td>
<td>12</td>
<td>20</td>
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<tr>
<td>Ceramic filled epoxy 5</td>
<td>9</td>
<td>28</td>
<td>3</td>
</tr>
<tr>
<td>Ceramic filled epoxy 6</td>
<td>9</td>
<td>20</td>
<td>2.2</td>
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<tr>
<td>Ceramic filled epoxy 7</td>
<td>16</td>
<td>32</td>
<td>2</td>
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<tr>
<td>Ceramic filled epoxy 8</td>
<td>8.5</td>
<td>20</td>
<td>2.3</td>
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<tr>
<td>Polyurethane Elastomer</td>
<td>Greater than 200 hrs, terminated test due to no degradation</td>
<td>50</td>
<td>--</td>
</tr>
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</table>
FY2021-22 Research:

• Tests revealed no damage to steel after testing at 2.6 gal/min.
• Test revealed that 5.0 gal/min was too aggressive.
• Testing adjustments were made to 3.5 gal/min.
• Focus shifted to elastomer coatings

• Planned tests:
  • Stainless steel weld overlay (CaviTec and 308 stainless steel)
  • 2 Polysulfide epoxy formulas (elastomer)
  • 7 Elastomeric cavitation repair materials
  • Re-run cold spray and thermal spray (if we can get some samples)
Research Conclusions

• Test procedure examines time to failure, since coatings cannot give a useful mass loss amount compared to mass of metal substrate.

• Thermal spray super nickel alloy and cold spray stainless steel samples should be re-run at 3.5 gal/min.

• Elastomers appear to work better than ceramic filled epoxies

• Add high flow adhesion testing to check delamination, which is an issue for some elastomers
QUESTIONS?

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