Crane Useful Life Assessment and Maintenance

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Forestay Failure
Boom Hanger Failure
Trolley Support Failure
Overview

Failures do occur!
Fatigue design philosophy
Useful life analysis & structural maintenance
Repair examples
Fatigue Design Philosophy

Safe Life Design

Damage Tolerant Design

Space Station

1 in $10^6$

Cranes

1 in 50 without inspection

1 in 1,000 with inspection
How to Minimize the Effect of Fatigue Cracks

Proper design
Proper material selection
Proper fabrication and quality control
Proper attachments
Structural maintenance program
Fatigue Crack Growth

Stress range

Number of cycles

Detailing

Workmanship and quality control

Cleavage fracture rather than slip lines.
You Have an Aging Crane: What are Your Options?

Do nothing and ignore risks

Useful structural life assessment
  Prolong life with inspection and repair
  Reduce use and/or relocate
  Dispose
Steps of a Useful Life Analysis

- Structural condition survey
- Useful life estimate before inspection
- Inspection program
- Structural inspection
- Useful life estimate after inspection
Structural Condition Survey

Look for

Distress
Suspect details
Attachments

Make photo record for the NDT inspection
Useful Life Estimate Before Inspection

Calculate cumulative damage to date

Estimate remaining cumulative damage for expected operation

Convert to useful life

Owner can decide best course of action
## Useful Life Analysis: Example

<table>
<thead>
<tr>
<th>Description</th>
<th>Design</th>
<th>Crane 1</th>
<th>Crane 2</th>
<th>Crane 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loads</td>
<td>tons</td>
<td>tons</td>
<td>tons</td>
<td>tons</td>
</tr>
<tr>
<td>Trolley Wt</td>
<td>13.0</td>
<td>13.0</td>
<td>13.0</td>
<td>13.0</td>
</tr>
<tr>
<td>Head block</td>
<td>3.1</td>
<td>3.1</td>
<td>3.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Spreader</td>
<td>12.0</td>
<td>12.0</td>
<td>12.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Rated Load</td>
<td>40.0</td>
<td>40.0</td>
<td>40.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Design Fatigue Load</td>
<td>30.0</td>
<td>30.0</td>
<td>30.0</td>
<td>30.0</td>
</tr>
<tr>
<td>Avg Container Wt (root mean cubed)</td>
<td>30.0</td>
<td>30.0</td>
<td>20.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Years in operation (Through 2003)</td>
<td>15.0</td>
<td>15.0</td>
<td>15.0</td>
<td>15.0</td>
</tr>
<tr>
<td>No. of cycles</td>
<td>1,500,000</td>
<td>1,500,000</td>
<td>2,250,000</td>
<td>1,500,000</td>
</tr>
<tr>
<td>cycles/year</td>
<td>100,000</td>
<td>100,000</td>
<td>150,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Predicted future usage rate (cycles/year)</td>
<td>100,000</td>
<td>150,000</td>
<td>150,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Des cycles/yr</td>
<td>100,000</td>
<td>100,000</td>
<td>100,000</td>
<td>100,000</td>
</tr>
</tbody>
</table>

### Cumulative Damage

<table>
<thead>
<tr>
<th>R (act)</th>
<th>2.942E+11</th>
<th>2.942E+11</th>
<th>2.504E+11</th>
<th>4.737E+11</th>
</tr>
</thead>
</table>

| Cumulative damage ratio R | 0.750 | 0.750 | 0.638 | 1.208 |

### Predicted No. of fatigue cracks /crane

| No. of std deviations below mean | 2.554 | 2.554 | 2.865 | 1.636 |
| Reliability                      | 0.9947 | 0.9947 | 0.9979 | 0.9491 |
| No. of joints/crane             | 1500   | 1500   | 1500   | 1500   |
| Predicted fatigue cracks/crane  | 7.9    | 7.9    | 3.1    | 76.4   |

### Predicted Fatigue Cracks / Crane

| 5 to 10   | 5 to 10   | 0 to 5   | 60 to 90 |

### Structural Useful Life in present condition

<table>
<thead>
<tr>
<th>Years in operation</th>
<th>15.0</th>
<th>15.0</th>
<th>15.0</th>
<th>15.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remaining structural life = Years&lt;sub&gt;left&lt;/sub&gt; (predicted rate)</td>
<td>5.0</td>
<td>3.3</td>
<td>7.2</td>
<td>-4.2</td>
</tr>
</tbody>
</table>

| Estimate of remaining useful life prior to NDT inspection | 5 | 3 to 4 | 7 to 8 | zero |
Structural Maintenance & Inspection Program

Inspection manuals

Details to be inspected

Classification: FCM or NFCM

Inspection method: VT, MT, UT, RT

Acceptance criteria

Inspector’s qualifications

Reporting procedures

Inspection frequencies
Inspection Program:
Typical General Arrangement

Joint 5BJ
Joint 16DH
Inspection Frequency

Not all joints need inspection at the same interval

More frequent inspection:
- Fracture critical members (FCMs)
- Joints with higher stress ranges

Less frequent inspection:
- Non-fracture critical members (NFCMs)
- Joints with lower stress ranges
- Joints in secondary members
Example Inspection Intervals

<table>
<thead>
<tr>
<th>Component</th>
<th>Fracture Critical?</th>
<th>No. of Moves</th>
<th>Interval (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trolley Girder</td>
<td>Yes</td>
<td>300,000</td>
<td>3</td>
</tr>
<tr>
<td>Hanger</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forestay</td>
<td>Yes</td>
<td>600,000</td>
<td>6</td>
</tr>
<tr>
<td>Lower Legs</td>
<td>No</td>
<td>1,200,000</td>
<td>12</td>
</tr>
<tr>
<td>Portal Beam</td>
<td>No</td>
<td>2,400,000</td>
<td>24</td>
</tr>
</tbody>
</table>

This example is not suitable for all cranes.
Structural Inspection

Inspect and compare predictions with findings

Repair procedures
Useful Life Estimate After Inspection

Review inspection reports

Identify fatigue cracks

Compare identified cracks with prediction

Reevaluate the reliability and useful life based on inspection

Owner can decide best course of action
Fatigue Crack Repairs

Example: Repair Original Detail

Toe Crack in weld connection between Backstay Connection Plate and Top Flange of Girder, Crane No.3
Fatigue Crack Repairs
Example: Modify and Repair Detail
Forestay Failure Profile

Crack Initiation

Failure Profile
Modified Detail: Plate Flexing

0.5t ACTUAL
(5t IDEAL)

2t REPAIRED
Modified Detail: Stress Analysis

Original

Modified

S_{22} = -15.1 \text{ t/cm}^2

S_{22} = -10.6 \text{ t/cm}^2
Crack Occurrence and Maintenance

- Poor initial details repaired
- More attention during repair
- Threshold stress range
Summary

Fatigue cracks will occur and can be catastrophic if not repaired

Cracking can be controlled with proper design, workmanship, quality control, and a proper structural maintenance program

Crack repairs are inexpensive

Useful life analysis can be used to predict future cracking so the owner can decide the best course of action
This presentation is available for download

www.liftech.net

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