UNCERTAINTY REDUCTION IN FATIGUE LIFE VALIDATION TESTING FOR DRILLING TOOLS WITH A UNIVERSAL RUNOUT COMPENSATOR

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Agenda

• Application Background
• Rotating Bending Fatigue Testing
• Issues and General Mitigation Approaches
• Theories and Equipment Design Improvements
• Modeling and Simulations
• Results and Discussion
• Conclusions
Application Background

• Oil Well Drilling String
• Directional Drilling
• High Dog-Leg-Severity Jobs
• Drill Collar Connection Improvements
Rotating Bending Fatigue Testing

- Fatigue Test Machine

\[
\text{Bending Moment } F_s L_s + F_w L_w
\]

![Diagram showing key components and calculations related to rotating bending fatigue testing.](image)
Issues and General Mitigation Approaches

• Runout Issues
  • Bending moment miscalculated
  • DUT falling off
Possible Mitigations

• Eccentric Shims
  • Straight forward
  • One for each DUT with specific runout
  • Not reliable – falling off

• Universal Runout Compensator (URC)
  • Adjustable for any runout
  • Reliable – no falling off
URC Theoretical Analysis

• Runout Compensation
  • Eccentric bushing-I
  • Eccentric bushing-II
  • Total eccentricity compensation

\[ E_t = E_1 + E_2 \]

\[ E_t = \sqrt{E_1^2 + E_2^2 - 2E_1E_2\cos\theta} \]

\[ \theta = \arccos\left(\frac{E_1^2 + E_2^2 - E_t^2}{2E_1E_2}\right) \]

\[ \alpha = \pi - \arccos\left(\frac{E_1^2 + E_t^2 - E_2^2}{2E_1E_t}\right) \]
URC Theoretical Analysis

- Total Runout Compensation $E_t$ VS Relative Angular Displacement $\theta$
  - $E_1 = E_2 = 1.0$
  - $E_t = 0$, when $\theta = 0$ or $2\pi$
  - $E_t = 2.0$ when $\theta = \pi$
URC Design

- DUT Extension
- Bushing-I
- Bushing-II
URC On Test Machine

• Test Setup
Numerical Modeling & Simulations

• Model setup
Numerical Modeling & Simulations

• Deformation
• Contact pressure
Numerical Modeling & Simulations

- FEA Mesh Refinement
  - Results variation < 5%

<table>
<thead>
<tr>
<th>Mesh Nominal Size</th>
<th>0.2”</th>
<th>0.12”</th>
<th>0.08”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Nodes</td>
<td>492,621</td>
<td>903,061</td>
<td>1,263,906</td>
</tr>
<tr>
<td>Average Contact Pressure Variation</td>
<td>22%</td>
<td></td>
<td>1.2%</td>
</tr>
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![Graph showing average contact pressure variation with number of nodes](image-url)
Results and Discussion

• Uncertainty Source Analysis

\[ \delta N = \left( \frac{\partial N}{\partial E_c} \right) \delta E_c \]

\[ \frac{\delta N}{N} = \left( \frac{\partial N}{\partial E_c} \right) \frac{\delta E_c}{N} \]
Results and Discussion

• Test Fatigue Testing
Results and Discussion

• Bending Moment vs Eccentricity

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<th>Eccentricity (in)</th>
<th>Bending Moment Variation</th>
<th>Estimated Fatigue Life (cycle)</th>
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<td>0.000</td>
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Results and Discussion

• Fatigue Life vs Eccentricity

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Conclusions

• URC in RBF tests could decrease the bending moment variation by 15%, which could reduce fatigue life uncertainty by 44%,
• Finite element method used for development of the URC ensured its structural integrity, and
• URC prevents DUT from slipping out of the test machine because of excessive runout, thereby improving safety of the test setup.
Further Discussion

• Questions and comments