Pipelining in Challenging Areas
(Offshore Pipeline Applications)
Presentation to the PHMSA R&D Forum
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Taking on your toughest technical problems
Presentation Topics

• Types of subsea damage
  ▪ Dropped objects
  ▪ Anchor snags
  ▪ Excessive current and resulting uplift
• Role of analysis and testing
• Developing a proactive response
• Identification of knowledge gaps
Prior Subsea Pipeline Damage Studies

- Williams Gas Pipeline (and Midstream)
- ConocoPhillips
- BP
- Shell Pipeline Company
- ExxonMobil Pipeline Company
- Chevron
- Devon Energy
- Marathon
- Enbridge
Use survey data to determine **membrane** and **bending strains** using elongation and curvature calculations. Use API RP 1111 for establishing in-place bending strain limits.

\[
\begin{align*}
a &= \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \\
b &= \sqrt{(x_3 - x_2)^2 + (y_3 - y_2)^2} \\
c &= \sqrt{(x_3 - x_1)^2 + (y_3 - y_1)^2} \\
q &= \frac{a^2 + b^2 - c^2}{2ab} \\
R &= \frac{c}{2\sqrt{1 - q^2}}
\end{align*}
\]

**Nomenclature**
- $e$ – Bending strain
- $D$ – Diameter of pipe
- $r$ – Radius of curvature (centerline)
- $R$ – Radius of mandrel

\[
\varepsilon = \frac{D}{2R}
\]
Analysis Techniques

Use survey/caliper data to construct FEA models

Global model used to evaluate generalized strains in pipeline based on displaced configuration

Local model used to calculate strains in specific region of damage to evaluate mechanical integrity including potential for subsea collapse
Dropped Object Work (Test 1/2)
Testing Program on Chevron Pipeline Protection System
URSA Pipe Dent Study (Test 2/2)
Anchor snag damage to subsea pipeline

Photographs of damage to Shell 20-inch URSA pipeline and fixture used to create simulated pipeline damage
URSA Pipe Dent Study (Test 2/2)
Anchor snag damage to subsea pipeline

Photograph of pressure cycle fatigue unit and resulting cycles to failure for the nine (9) dented pipeline fatigue samples

Cycles to Failure Considering Dent Depth

Photograph of pressure cycle fatigue unit and resulting cycles to failure for the nine (9) dented pipeline fatigue samples
Preliminary Grading Tool

• Determine whether a subsea dent is
  ▪ Acceptable
  ▪ Requires further evaluation
  ▪ Can be repaired
  ▪ Should be removed from service.
Example Assessment Flowchart

(Provided only as an example from a prior Stress Engineering study)

Defect Data Collection
Collect available information on defects including depth, length, profile, interaction with other features such as welds.

Feature Identification
Make special note of those features that can reduce the fatigue life of dents. Common examples include corrosion, seam welds, girth welds, and double dents.

Calculate Parameters
Using available data, calculate the severity of the defects using parameters such as strain, curvature, or other related expressions.

Evaluate Defects
NOTE: The accuracy of the evaluation is based on the availability of information both in terms of Defect Data Collection and Performance Data.

Acquire Performance Data
Using previous and/or available performance data based on experimental or finite element efforts, develop expressions to determine the fatigue life for plain dents. It is preferable that the effects of other features such as seam and girth welds be included in this process. These are identified as Fatigue Reduction Factors (FRF).

Quantitative Assessment
Estimate design cycles for the defects under evaluation using the Performance Data. This effort should include FRFs that will reduce defect fatigue life.

Approximate Assessment
If only limited measurement data are available from the Defect Data Collection phase (e.g. only have dent depth and length), an estimate of fatigue can be made but not without penalty. This approach should NOT be used to estimate remaining fatigue life. If this approach is used, disclaimers are required.

Qualitative Assessment
If limited very measurement data is available from the Data Collection phase (e.g. only have dent depth), it is best to only rank defect severity. This is useful for providing guidance in order of response (e.g. dig response).

This approach should NOT be used to estimate remaining fatigue life. If this approach is used, disclaimers are required.

Least Accurate

Final Evaluation
Estimate the remaining life using a cumulative damage model and information from prior cyclic pressure history of the pipeline.
API 579 FFS Approach

- **Level 1** – using damage tolerance guides given in the design codes (e.g. ASME B31.8)
- **Level 2** – Using actual damage dimensions and published methodology (e.g. API 579, EPRG) to compute fatigue life and burst/collapse pressure
- **Level 3** – Rigorous finite element analysis of the damaged pipeline section to determine fatigue life and burst/collapse
- **Level 4** – Full scale testing to validate Level 2 and 3 analyses

Knowledge Gaps

• Need to develop a unified evaluation process for evaluating damage to subsea pipelines
• As with onshore pipelines, a grading tool is essential to provide operators with prioritizing their responses
• ILI tools can be used to provide useful information about the position of displaced pipelines and geometry of damage
• Avoid overly-conservatively responses that can lead to the “Chicken Little” syndrome
• Use testing to reduce uncertainty