Pipelining in Challenging Areas
(Offshore Pipeline Applications)
Presentation to the PHMSA R&D Forum

Marriot Crystal City ● Thursday, June 25, 2009

Presentation by Dr. Chris Alexander (Stress Engineering Services, Inc.)

Taking on your toughest technical problems

STRESS ENGINEERING SERVICES INC.

an employee-owned company

Presentation Topics

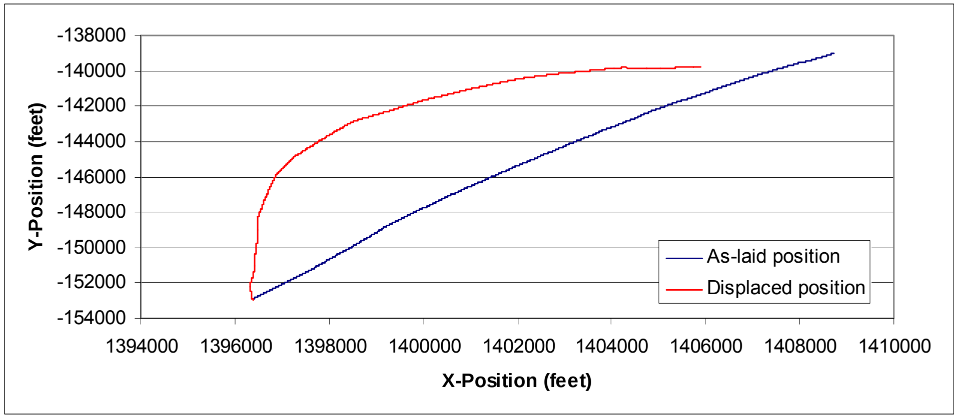
- Types of subsea damage
  - Dropped objects
  - Anchor snags
  - Excessive current and resulting uplift
- Role of analysis and testing
- Developing a proactive response
- Identification of knowledge gaps

Prior Subsea Pipeline Damage Studies

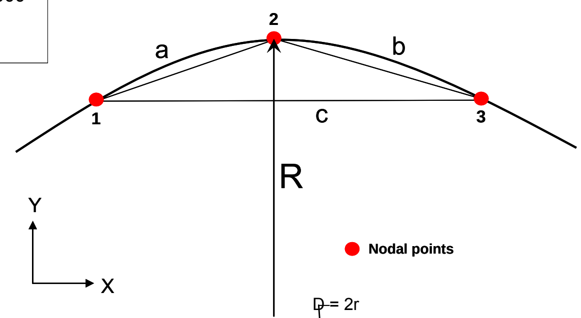
- Williams Gas Pipeline (and Midstream)
- ConocoPhillips
- BP
- Shell Pipeline Company
- ExxonMobil Pipeline Company
- Chevron
- Devon Energy
- Marathon
- Enbridge

Analysis Techniques

Utilizing Survey Data



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.



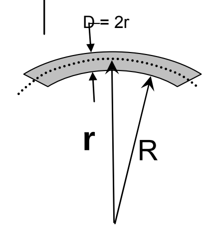
$$a = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

$$b = \sqrt{(x_3 - x_2)^2 + (y_3 - y_2)^2}$$

$$c = \sqrt{(x_3 - x_1)^2 + (y_3 - y_1)^2}$$

$$q = \frac{a^2 + b^2 - c^2}{2ab}$$

$$R = \frac{c}{2\sqrt{1 - q^2}}$$

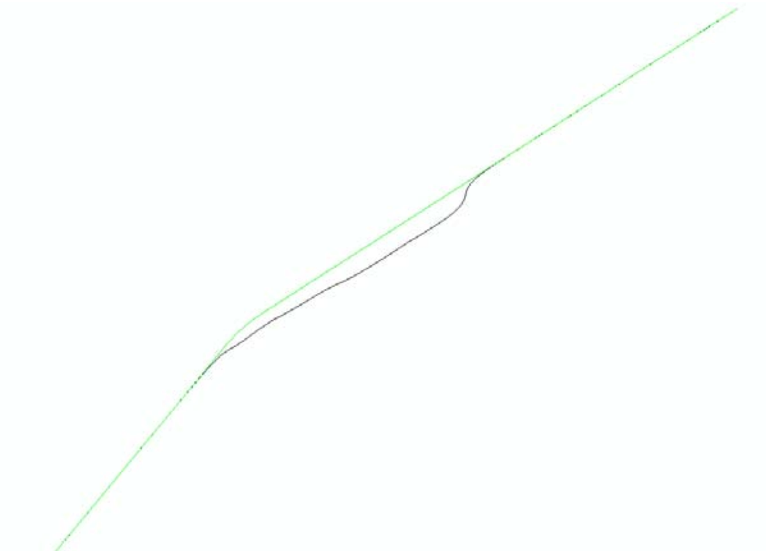


Nomenclature
e – Bending strain
D – Diameter of pipe
r – Radius of curvature (centerline)
R – Radius of **mandrel**

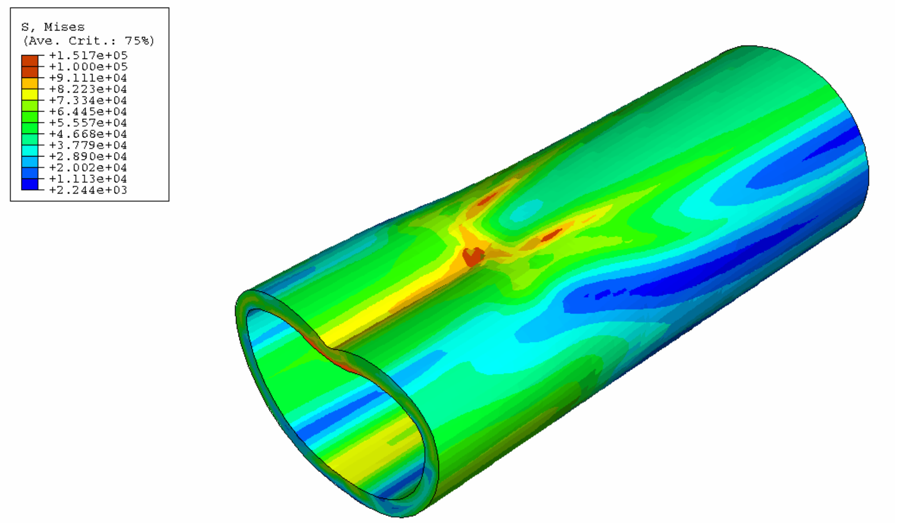
$$\varepsilon = \frac{D}{2R}$$

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

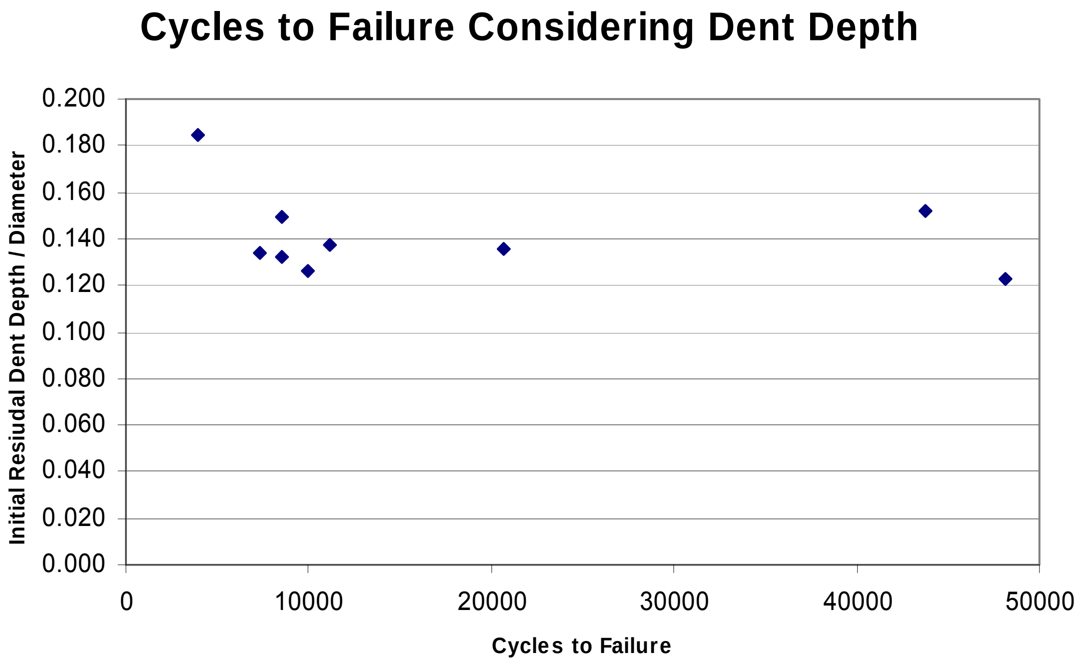
URSA Pipe Dent Study (Test 2/2)

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)

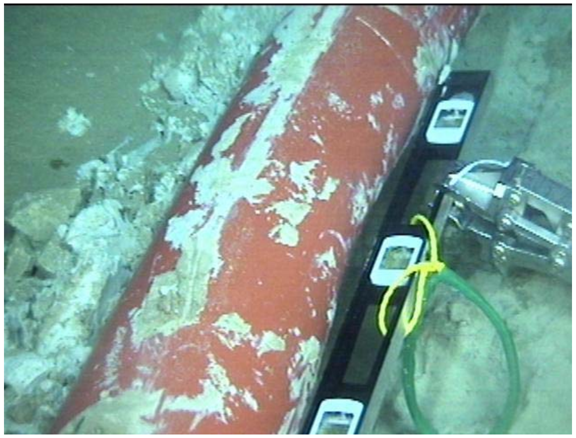
Anchor snag damage to subsea pipeline



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

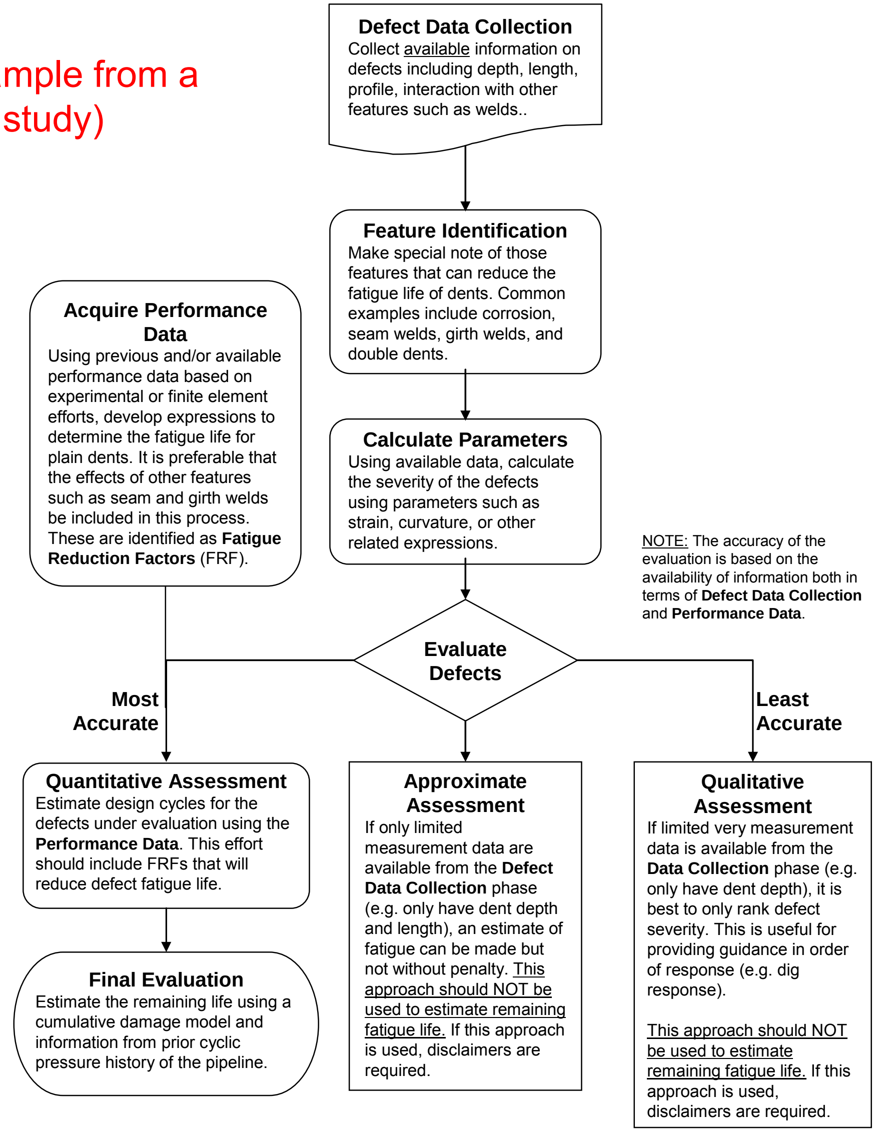
Preliminary Grading Tool

- 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)



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

Source: D. Raghu, R. Swanson, and C. Alexander, (May 2008), “Methodology to Establish the Fitness for Continued Service of a Hurricane Damaged Export Pipeline in 1000 m of Water,” Paper No. OTC-19653-PP, 2008 Offshore Technology Conference, May 5–8, 2008, Houston, Texas.

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