Plausible Profiles (Psqr) Model – Improved Corrosion Assessment Model

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Synopsis

- Why did we focus on Corrosion Assessment models?
- What are the operational needs?
- Psqr Model – essentials, sensitivity, validation (Is it safe?)
- Benefits and Implementation guidelines
Impact of Corrosion Assessment Model

• Corrosion is a major threat – Canada - 70% of digs and 80% of ILIs

• **Integrity decisions** that use Assessment models
  o ILI anomalies to excavate?
  o Excavated anomalies to repair?
  o Derate required?

• Decisions are most sensitive to
  o Model error
  o ILI measurement error
  o Growth rates
## Impact of Assessment Model

<table>
<thead>
<tr>
<th>Cluster Dataset</th>
<th># of Features</th>
<th>Excavation decision – # of Features with FPR ≤ 1.25</th>
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<tr>
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<td>B31G</td>
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<tr>
<td>ILI Data</td>
<td>23502</td>
<td>868</td>
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Model has high impact on number of digs, derates and repairs -&gt; Budget (with safety)
**Operational need - Learning and Objectives**

- **Learnings from operations**
  - Large morphologies-caused failures
  - Many excavations/derates with wide corrosion

- **Learnings from RSTRENG Development**
  - River bottom profile-the **worst case** but **unrealistic** for wide corrosion
  - Wide separation & strengthening in between pits **not considered**
  - Numerical solution was not possible in the 1980-90s

- **Objective** - Improve the RSTRENG model for assessing **large corrosion morphologies**
  - reduce **undue conservatism without compromising safety**
Conservatism in Corrosion Idealization

RSTRENG and Psqr

River bottom profile
(most aggressive but not plausible for wide corrosion)

Difference between Psqr and RSTRENG - interacting corrosion is more accurately characterized
Conservatism in Corrosion Idealization

- **Starting point:**
  - Depth-weighted starting point

- **Subsequent points**
  - Interaction window: 6t
  - Likelihood of selection: proximity- and depth-weighted
Pressure Calculation Using Psqr Model

AAC = Axially Aligned Corrosion (where river bottom is plausible – rare in real corrosion)
Burst Tests

- **Fourteen (14) tests in 2015**
  - Naturally-occurring corrosion

- **Sixteen (16) tests in 2018**
  - Two (2) pipes with naturally-occurring corrosion
  - Fourteen (14) pipes with “3D-printed” morphology
  - Designed morphology to test assumptions

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<tr>
<th>OD (NPS)</th>
<th>Number of Samples</th>
<th>NWT (mm)</th>
<th>SMYS (MPa)</th>
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Parameters for Sensitivity Analysis

- starting point
- interaction window width
- likelihood of selection
- number of plausible profiles
- grid size of the ILI output
Initiation Point-Verification

- Von Mises strains capture the initiation location of burst (i.e. the local area with the highest strain)
- Plausible profiles capture initiation of burst
- River bottom profile does not always capture the initiation point
Compared to RSTRENG, Psqr is **more accurate** and **more precise**.
PRCI 2018-2019 : EC-2-9 project – Peer Review of Psqr Model

▪ Objectives
  o Peer review and vet the Psqr model
  o Share benefits – (safety & optimization)
  o Provide method and software for industry

▪ Execution plan
  o Conduct PRCI workshops with related SMEs
  o Obtain peer reviewed report with feedback from official reviewers

➢ John Kiefner, Michael Rosenfeld/Bruce Nestleroth, Ming Gao/Ravi Krishnamurthy, Phil Hopkins, Andrew Cosham and Maher Nessim

  o John Kiefner provided final report to PRCI
Model Validation – Public Test Data

- 177 tests with sufficient information
- Mostly machined flat bottom & simple corrosion
- Uncertainties in measurement and material properties

Applicability limits: same as RSTRENG
Safety checks

Model prediction

In-ditch prediction w/o SF

ILI prediction w/o SF

ILI prediction w/ SF
### Benefit: Expanded Case Studies

ILI by different ILI vendors – low performance coated lines with wide corrosion

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Field-measurements on different pipe sections - with wide corrosion

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**Summary – RSTRENG vs Psqr**

- Users avoided implausible river bottom profiles on an adhoc basis
- Psqr does this with a well validated rigorous process - Checked safety, sensitivity, and extremes, well vetted/reviewed, implementation guidelines
- Removing digs due to implausible profiles reduces unnecessary digs - Right digs (not more) bring safety!
- Accuracy and precision brings safety and economy - in all other variables and specially in modeling outliers that fail (digs required to avoid failures)
Regulatory Implications

To select the corrosion assessment method CFR 192 & 195:

- PRCI PR3-805 report

  - Operator can use more rigorous analysis based upon established principles and practices using the actual profile of the corroded region

• ASME B31G-2012 allows:
  - Level 3 methods shall be able to demonstrate that the objective of a safe and reliable assessment of metal loss can be achieved

• PRCI PR3-805
  - acknowledges the limitation of RSTRENG method and allows the use of multiple profiles by experts.

Based on above Psqr model can be used for both gas and liquid pipelines in USA.

Propose:

- short term - include PRCI Psqr reports as non-mandatory references in ASME B31G
- long term - include Psqr model in ASME B31G
Thank You – Questions?

Acknowledgements

- **TransCanada development team**: Shahani Kariyawasam, Shenwei Zhang, Jason Yan, Terry Huang, Mohammad Al-Amin, Erwin Gamboa
- **TransCanada review team**: Corrosion Threat Teams, Technical Support Teams, Can/US/Liquid BU and Leadership
- **Initial burst testing protocol**: Dynamic Risk - Patrick Vieth and team
- **Burst testing**: C-FER - Tyler Johnson, Mark Stephens and Qishi Chen
- **External reviewer (2017)**: Brian Leis
- **PRCI staff**: Cliff Johnson and Laurie Perry
- **PRCI reviewers (2018/19)**: John Kiefner, Michael Rosenfeld, Bruce Nestleroth, Ming Gao, Ravi Krishnamurthy, Phil Hopkins, Andrew Cosham and Maher Nessim