INTERNAL AXIAL CORROSION IN OFFSHORE PIPELINES: INSPECTION & ASSESSMENT

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AGENDA
Topics

1. Introduction: Long Axial Corrosion
2. Impacts of Long Axial Corrosion on ILI and FFP
3. DNV Method: Assessment of Long Axial Corrosion Defects
4. Summary & Conclusions
Characteristic Observations

typical type of corrosion in crude oil and water injection pipelines:

- internal corrosion along six o’clock position
- coherent corrosion areas of up to several kilometers length
- often high corrosion growth rates (> 1 mm/year)
- synonyms: channeling, channeling corrosion, six o’clock corrosion, bottom-line corrosion

- different shape of corrosion anomalies:
  - smooth and uniform WT reduction (e.g. corrosion/erosion)
  - rough surface, irregular and complex shaped geometry (e.g. MIC)
LONG AXIAL CORROSION: EXAMPLE 1
Smooth and Regular Shape, Groove-like
LONG AXIAL CORROSION: EXAMPLE 3

Chain of Corrosion Pits (Early Stage of Channeling)
Characteristics of channeling corrosion
⇒ impacts on ILI and assessment:

- **ILI technology**
  → UT

- **Cleaning**
  → modification of standard procedures

- **Re-processing/filtering of ILI data**
  → eliminate outliers

- **Reporting & assessment**
  → next slides
coherent corrosion over several km: usually reported as one anomaly per pipe joint (length = joint length, depth = peak depth)
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⇒ peak depth & length: no meaningful description of complex anomalies
• different codes/standards for calculation of safe operating pressure \( P_{\text{safe}} \) of metal loss anomalies

• **list-based methods:**
  – e.g. B31.G, DNV-RP-F101 single
  – input: maximum depth, total length
  – same \( P_{\text{safe}} \) for anomalies 1 & 2

• **data-based methods:**
  – e.g. RSTRENG (Effective Area), DNV-RP-F101 complex
  – anomalies described by actual remaining wall thickness profile (river-bottom profile, RBP)
  – well suited for assessing complex shaped anomalies

• **all conventional methods:** impact of continuous metal loss (many bad joints) on system PoF not accounted for
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Topics

1. Introduction: Long Axial Corrosion
2. Impacts of Long Axial Corrosion on ILI and FFP
   - Inspection Technology
   - Cleaning
   - Data Processing
   - Reporting
   - Assessment
3. DNV Method: Assessment of Long Axial Corrosion Defects
   - Main Ideas
   - Application Examples
4. Summary & Conclusions
JIP (DNV, Statoil, DONG Energy) → “Assessment of long axial corrosion defects – Specification”

- results will be incorporated in revised DNV-RP-F101
- NDT Global involved in testing & reviewing of algorithms
- DNV method gives guidance on
  - extraction of RBPs from UT ILI data
  - calculation of pipeline pressure capacity
  - determination of corrosion growth rates
  - extrapolation of pressure capacity
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rugged corrosion anomalies and rough internal pipe surface

- echo loss (missing data) and/or outliers in UT WT data

- important: identification & replacement of erroneous WT values before calculation of RBPs

- use of stand-off (SO) data:
  - strong signal (1\textsuperscript{st} echo)
  - usually no echo loss/outliers

- WTSO = WT + SO
  - = distance sensor – outer pipe wall, ideally constant
  - WT missing or outlier $\rightarrow$ WTSO outside tolerance band
  $\rightarrow$ WT replaced by $\text{RWT}_{SO} = \text{WTSO}_{\text{median}} - SO$
Filtering of WT Data & Extraction of RBPs: Example
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Requirements:

- complex corrosion anomalies → assessment based on RBPs
- standard methods: $P_{\text{safe}}$ (pipeline) = $P_{\text{safe}}$ (worst joint)
- however: minimum $P_{\text{safe}}$ not sufficient to describe condition of pipeline
- example: $P_{\text{safe}}$ histograms with same minimum $P_{\text{safe}}$ but different number of “bad” joints
- many bad joints (e.g. channeling) → “system effect” → higher PoF
Requirements:

- assessment based on RBPs
- account for potential increase in PoF

DNV Method:

- basis: DNV-RP-F101 Complex Shaped Defects Method (Part A)
- affected area divided into subsections
- $P_{\text{safe}}$ calculated for all subsections
- $P_{\text{safe}}(\text{section } i) \rightarrow \text{PoF(} \text{section } i \text{)}$ for considered assessment pressure
- total PoF(pipeline) calculated from PoF of all sections $i$
- PoF(pipeline) vs. max. allowable PoF (safety class)
  $\rightarrow P_{\text{safe}}(\text{pipeline})$
Example:

- water injection pipeline affected by channeling corrosion
- assessment based on 190 pipe joints with remaining WT < threshold
- RBPs extracted according to DNV method
- $P_{\text{safe}}$ calculated for sections of 1.7m length (DNV-RP-F101 complex)
- $P_{\text{safe}}$(pipeline) = 260 bar
- $P_{\text{safe}}$(worst joint) = 268 bar
- $P_{\text{safe}}$(pipeline) is 8 bar (3%) below $P_{\text{safe}}$(worst joint) → system effect
- more joints with low $P_{\text{safe}}$ → higher system effect
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ASSESSMENT OF LONG AXIAL CORROSION

Corrosion Growth Analysis (CGA)

- basis: results of consecutive UT ILIs
- list-based CGA (\(\rightarrow\) change in peak depth): not sufficient for long complex corrosion features

- Level 4 of DNV Method: calculation of corrosion growth rates from comparison of RBPs, i.e. data-based CGA
Corrosion Growth Analysis: One Pipe Joint

Distance to USGW [m]

Wall thickness [mm]

RBP(2014)
CWT(2014)
ASSESSMENT OF LONG AXIAL CORROSION

Corrosion Growth Analysis: One Pipe Joint

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**Wall thickness [mm]**

- **RBP(2014)**
- **RBP(2011)**
- **CWT(2014)**
- **CWT(2011)**

**Distance to USGW [m]**

**Corrosion growth rate [mm/year]**

- **2011->2014**

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ASSESSMENT OF LONG AXIAL CORROSION

Corrosion Growth Analysis: One Pipe Joint

Wall thickness [mm]
Distance to USGW [m]

Corrosion growth rate [mm/year]
Distance to USGW [m]
2010->2011  2011->2014

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Corrosion Growth Analysis: Results for 190 Pipe Joints

- Average
- 95% quantile
- Section
- Joint average
- Moving average

Corrosion growth rate [mm/year] vs. Distance [km]
Extrapolation of Pressure Capacity: $P_{\text{safe}}$ vs. Growth Rate

low $P_{\text{safe}}$ + high growth rates!
ASSESSMENT OF LONG AXIAL CORROSION

Extrapolation of Pressure Capacity: Results

\[ P_{\text{safe}} \text{(pipeline)} \text{ reaches MAOP} \]
\[ 5.2 \text{ – 7.5 years after latest ILI} \]
SUMMARY & CONCLUSIONS

- long axial corrosion → impacts on ILI & assessment
- can be reliably detected & sized using UT ILI
- feature list information not sufficient to characterize complex anomalies → data-based assessment methods (pressure & corrosion growth) required
- methodology specifically designed for assessment of long axial corrosion was developed by DNV:
  - filtering of WT using SO, especially helpful in case of non-optimum data quality
  - accounts for higher PoF resulting when many pipe spools are affected by severe corrosion
  - NDT experience: DNV method proved good applicability
THANK YOU!