MANAGING RISK DNV

PIPELINE R&D FORUM

Track 4

Current Status: Defect Characterization

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Defect Characterization

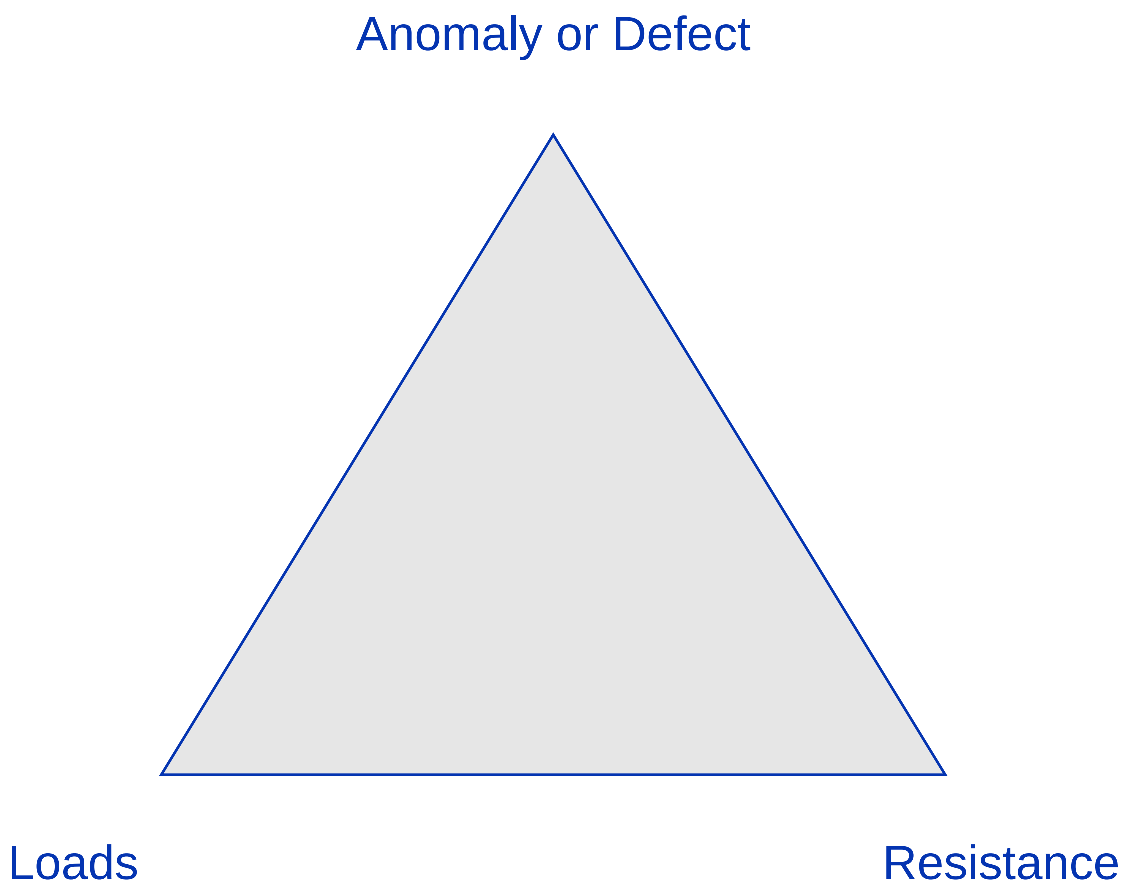
- Simple Definition – To estimate the length, depth, shape, severity, orientation and/or location of an anomaly
- More Complete Definition – To provide enough information to assess the impact of a defect or degradation on integrity
  - What is the impact today?
  - Will it get worse, and if so, how fast?
  - Can operations or maintenance be changed to slow or stop ongoing degradation?
  - Etc. etc. etc.

Axiom #1

- You can't always get what you want; but if you try sometimes you might find you get what you need

  - The Rolling Stones

Characterization Triangle



Characterization Covers Three Facets

- Anomaly or Defect-Related Factors
  - Geometry (length, width, depth, orientation, ID/OD, sharpness, proximity to other anomalies, welds, etc.)
  - Potential for future degradation, degradation rates, mitigating or aggravating factors
- Loads
  - Primary, secondary, residual
  - Time dependency
  - Constraining factors
- Resistance
  - Base material properties (yield, tensile, toughness, etc.)
  - Variations
  - Changes

Characterization Needs

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- What is needed depends on what is to be done…
  - Near-term decisions are typically based on how close an anomaly is to failure and whether a repair needs be done
    - Level 1: Go / NoGo decisions (e.g., B31G)
    - Level 2: Less conservative / more accurate assessments (e.g., RSTRENG)
    - Level 3: Detailed assessments (e.g., finite-element analyses)
  - Longer-term decisions require more understanding of degradation processes and rates
    - Single / Isolated degradation: corrosion and crack growth rates
    - Multiple / interacting degradation: coalescence, combinations
    - System degradation: Risk and reliability

Anomaly or Defect Characterization

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- Basic tools – Near term integrity
  - In-line inspection – detect, identify, and estimate the severity of anomalies
  - In the ditch measurements and NDE - detailed assessment of severity, verification/improvement of in-line inspection results, potential for ongoing degradation
- Additional tools – Longer term integrity
  - Metallurgical, chemical, and other laboratory examinations – verify degradation mechanisms, estimate potential for future degradation, identify contributing factors
  - Above ground surveys and monitoring – effectiveness of mitigation and control strategies

Anomaly or Defect Characterization

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- Metal loss
  - In-line inspection
    - Sizing accuracy (depth) generally considered good enough to make basic (Level 1) assessments of severity.
    - Mature technology with targeted improvements aimed at
      - More accurate (Level 2) severity estimates (profiles)
      - Interactions between anomalies
      - Change detection
      - Growth rates
      - Specific geometries (e.g., metal loss in dents, seam weld corrosion)

Anomaly or Defect Characterization

- Metal loss
  - In-the-ditch measurements and NDE
    - Sizing accuracy generally considered good enough for advanced (Level 2 and 3) assessments
    - Observations considered useful in identifying cause (e.g., stray currents), whether degradation is ongoing, aggravating factors (e.g., degraded coatings, disbonding, shielding)
    - Mature technologies with little or no new developments (as related to metal loss)

Anomaly or Defect Characterization

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- Metal loss
  - Metallurgical, chemical, and other analyses
    - Generally considered good at verifying cause and identifying contributing factors (e.g., microbially influenced corrosion)
    - Results useful in assessing whether degradation is ongoing
    - Useful in providing material properties needed for Level 2 and 3 assessments.
    - Mature technologies with targeted developments related to corrosion growth rates

Anomaly or Defect Characterization

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- Metal loss
  - Above ground surveys and monitoring
    - Generally considered good at evaluating effectiveness of mitigation methodologies (e.g., cathodic protection)
    - Mature technology with targeted improvements aimed at specific problem areas (e.g., cased pipe, congested ROWs)

Anomaly or Defect Characterization

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- Metal Loss – Other Considerations (My opinion)
  - Methods of estimating severity (analysis tools) are mature, with accuracies that approach Mother Nature's inherent variations in material properties, wall thicknesses, etc.
  - Pig and dig technologies provide information needed for Level 1, 2, and 3 assessments.
    - Some problem areas, such as seam weld corrosion, remain
  - Methods for identifying contributing or aggravating factors available, as are methods of controlling future degradation.
  - Predicting corrosion growth rates is an evolving science.
    - Further development is ongoing

Anomaly or Defect Characterization

- Cracks
  - In-line inspection
    - Detection and sizing of some types of cracks used for limited basic (Level 1) assessments.
    - Improvements needed and aimed at
      - Better depth sizing individual cracks, especially when near or in welds, dents, corrosion, etc.
      - Better discrimination and differentiation
  - In-the-ditch measurements and NDE
    - Detection good.
    - Depth sizing has significant weaknesses, especially when dealing with tight cracks and cracks in or near welds, dents, etc.
    - Methods of identifying specific forms of cracking developing but not widely used (e.g., in situ metallography)

Anomaly or Defect Characterization

- Cracks
  - Metallurgical, chemical, and other analyses
    - Generally considered good at verifying cause (e.g., near-neutral pH SCC) and identifying contributing factors
    - Evolving area with targeted developments aimed at relating laboratory results to crack initiation and growth
  - Above ground surveys and monitoring
    - Not a mature technology. Evolving use of above ground surveys in conjunction with robust data integration to identify "higher susceptibility" areas.
    - Monitoring pressures considered good for some mechanisms (fatigue) but further development needed for variable loading effects

Anomaly or Defect Characterization

- Cracks – Other Considerations (My opinion)
  - Methods of estimating the severity of cracks and crack colonies are available but not widely used or understood.
    - Analysis methods require material property information not always available
      - Toughness values
      - Fatigue crack growth rates
    - Basic fatigue and fracture mechanics analyses are time tested, but there is less experience and familiarity with issues associated with crack coalescence and growth

Anomaly or Defect Characterization

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- Cracks – Other Considerations (My opinion)
  - In-line inspection and in-the-ditch technologies do not yet provide proven accuracies of dimensions needed for higher level analyses (Level 2 or 3)
    - Significant problems exist with regard to detecting and sizing cracks in dents and welds
    - Experience and learning is needed as new technologies are introduced
    - In-the-ditch sizing is highly inspector dependent.
  - Methods of estimating crack growth evolving, as are approaches to controlling future cracking.

Anomaly or Defect Characterization

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- Mechanical Damage
  - In-line inspection
    - Geometry (dent and ovality) measurements generally considered good. Detection of metal loss in damage sometimes considered good.
    - Improvements aimed at identifying critical damage (e.g., gouges with associated metallurgical damage)
  - In-the-ditch measurements and NDE
    - Inherent problems exist with regard to measuring dent and crack depths
    - Ability to identify metallurgical damage exist but not widely used

Anomaly or Defect Characterization

- Mechanical Damage
  - Metallurgical, chemical, and other analyses
    - Ability to identify metallurgical damage exist and used on case-by-case basis.
    - Changes in mechanical properties not well characterized
  - Above-ground surveys and monitoring
    - Ability to detect coating holidays useful but not fully developed for mechanical damage
    - Driving forces (pressures) understood, but local stress concentration effects variable and not well understood.

Anomaly or Defect Characterization

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- Mechanical Damage – Other Considerations (My opinion)
  - Methods of estimating severity not widely available
    - Inherent variabilities may override ability to assess severity in a cost-effective manner
  - In-line inspection provides good detection of some types of damage (dents) but not others.
    - In-the-ditch technologies needed to supplement in-line inspection. Methods needed to accurately identify and assess the impact of metallurgical damage.
  - Methods of predicting future degradation problematic

Summary and Conclusions

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- The Role of Technology and R&D
  - Technology provides tools to help assess and/or manage a system, e.g.,
    - In-line inspection systems, in-the-ditch techniques, methods of estimating severity, metallurgical and other laboratory techniques, degradation mechanisms and rates, etc.
  - The Role of Technology and R&D
- R&D provides improvements and development of tools
  - More capable inspection techniques and equipment
  - Better understanding of degradation mechanisms
    - Factors that drive the process
    - Degradation rates
    - Failure modes and effects
- R&D, along with engineering, provides the balance between what is needed, what can be done, and what should be done.

Closing Comment (Personal Opinion)

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- When evaluating current and future needs, consider all aspects of characterization
  - Dimensions
  - Degradation
  - Loading
  - Resistance
- Accept and deal with uncertainties. Balance the need for more complete information with potential improvements in measurement and inspection technologies