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PRCI Research Exchange

# A General Engineering Critical Assessment (ECA) Procedure Framework to Manage Dent

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LEADING PIPELINE RESEARCH

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# ECA Is Allowed for Dent Assessment by CSA Z662

**10.10.4.2**

C There is a commentary available for this Clause.

The following dents shall be considered to be defects unless determined by an engineering assessment to be acceptable:

a) dents that interact with a mill or field weld and exceed(s)
   i) a depth of 6 mm in pipe 323.9 mm OD or smaller, unless their measured curvature strain is less than 4% and the interacting portion of the weld passes nondestructive inspection criteria; or
   ii) 2% of the outside diameter in pipe larger than 323.9 mm OD, unless their measured curvature strain is less than 4% and the interacting portion of the weld passes nondestructive inspection criteria;

b) dents that are located on the pipe body and exceed a depth of 6 mm in pipe 101.6 mm OD or smaller or 6% of the outside diameter in pipe larger than 101.6 mm OD, unless their measured curvature strain is less than 6%;

c) dents with a length to depth ratio (L/d) less than 20, unless their measured curvature strain is less than 6%;

d) dents that contain corroded areas with a depth greater than 40% of the nominal wall thickness of the pipe;

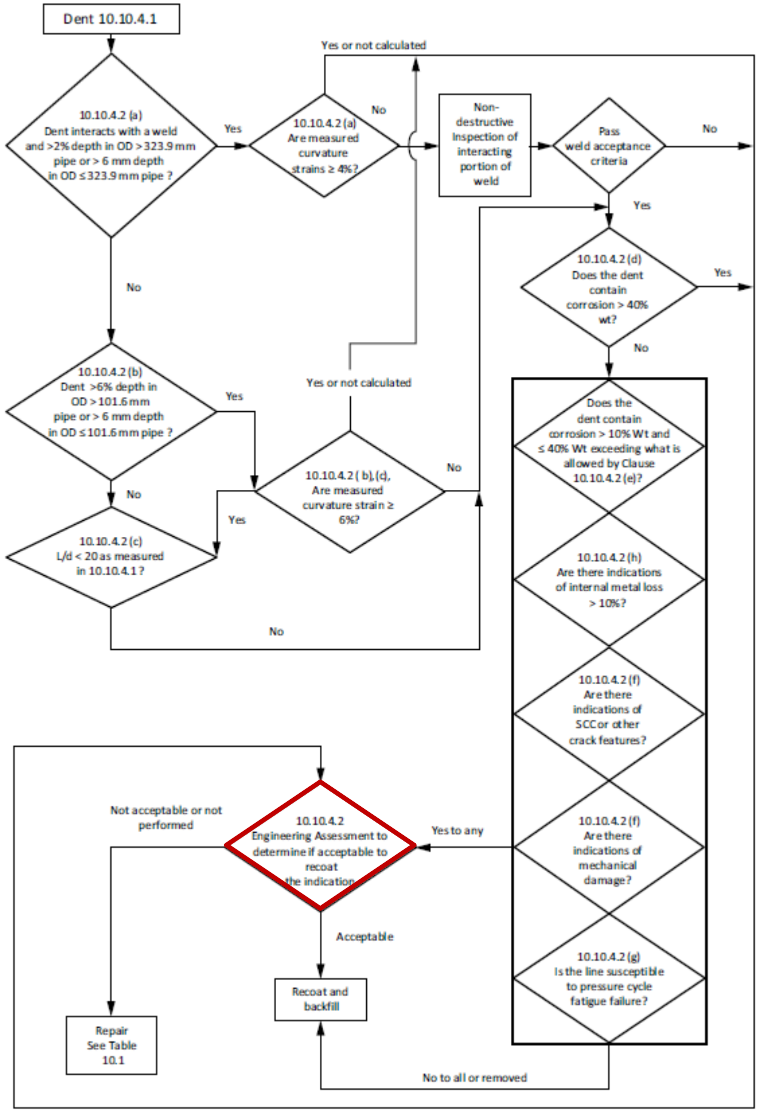
e) dents that contain corroded areas having a depth greater than 10%, up to and including 40%, of the nominal wall thickness of the pipe and a depth and length that exceed the maximum allowable longitudinal extent determined as specified in ASME B31G (Level 0 evaluation);

f) dents that contain stress concentrators (gouges, grooves, arc burns, or cracks);

g) dents that are susceptible to pressure cycle fatigue failure; and

h) dents that contain any internal metal loss greater than 10% of the nominal wall thickness.

**Note:** *Figure 10.2 shows the process for determining whether a dent should be considered a defect.*



# ECA Is Allowed by Special Permit

| Table 1 | | |
|---|---|---|
| **Dent type** | **Critical Dents that Require Action** | **ECA an Option** |
| Plain Dent | Dent of depth > 6% Outside Diameter (OD) or dent strain level exceeding:<br>i. Dent with strain > 6% limit (ASME B31.8, 2018 Edition) **or**<br>ii. Strain Limit Damage (SLD) or Ductile Failure Damage Indicator (DFDI) > 0.6 (per API 1183, IBR Edition or 1st Edition, 2020, if not IBR) | YES |
| Dent Associated with Corrosion | i. Dent depth of > 6% OD with corrosion of any depth** **or**<br>ii. Dent of depth ≤ 6% OD with corrosion depth that is more than 15% of the pipe wall thickness. ** | YES |
| Dent Associated with Metal Loss other than Corrosion | Dent associated with metal loss other than corrosion: gouge, axial or circumferential groove, SCC, fatigue cracks, and/ or other cracks.** | YES |
| Dent Affecting Weld (Girth Weld, Longitudinal Seam Weld or Spiral Seam Weld) | Dent of any depth affecting pipe with: Low Frequency Electric Resistance Welded (LF-ERW), Electric Flash Welded (EFW), Lap Welded, or Longitudinal Joint Factor < 1.0.* | YES* |
| | Dent of depth > 2% OD affecting other types of weld seams, see above, or girth welds with strain level exceeding 4% (ASME B31.8, 2018 Edition). | YES |
| Skewed and/or Multiple Dent Peaks | Any complex dent geometry identified by Operator/CGT or ILI vendor such as skewed dent, two or multi-peak deformations. | YES |

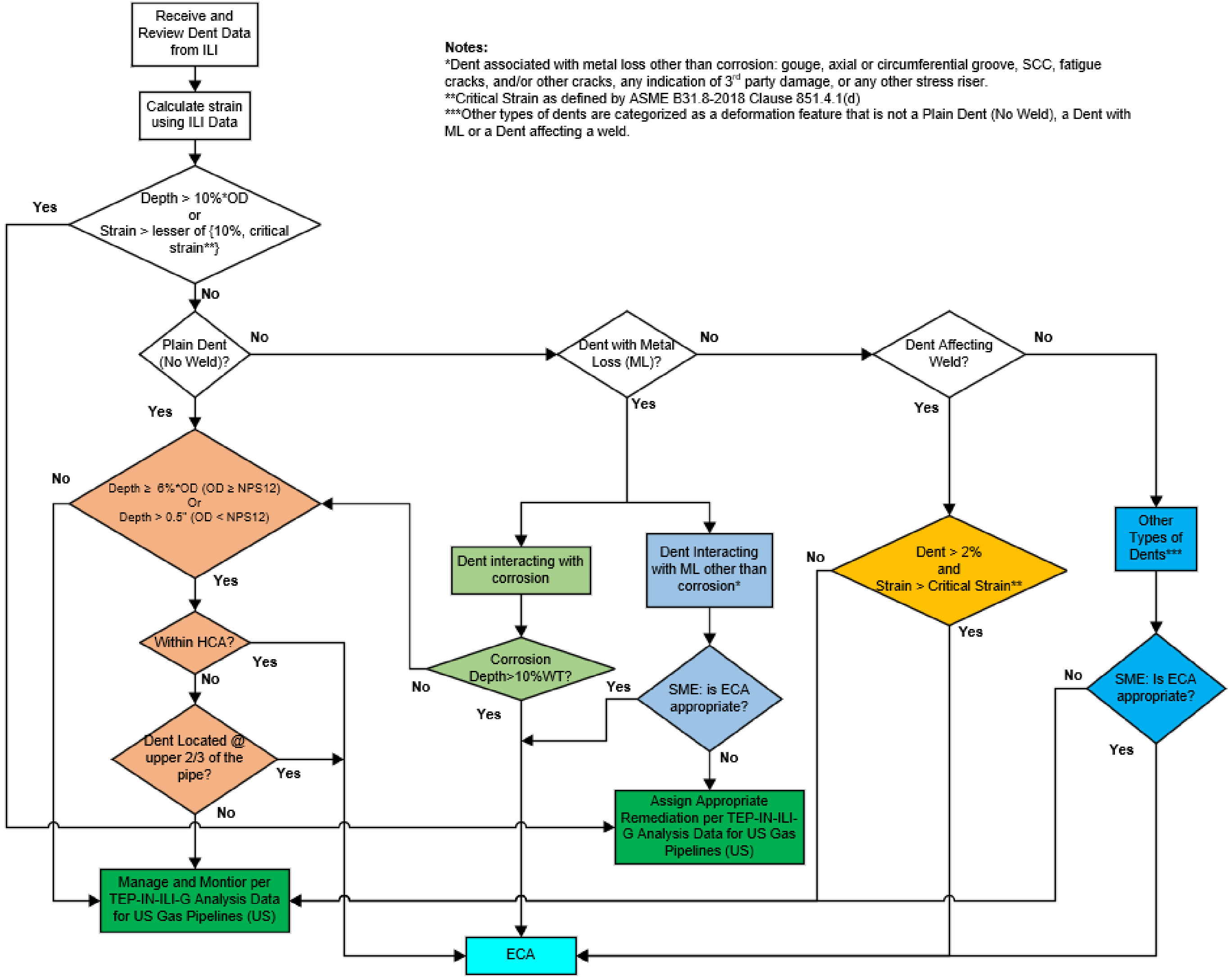
# ECA Is Allowed by 49 CFR 192.712(c)

(c) ***Dents and other mechanical damage.*** **To evaluate dents and other mechanical damage that could result in a stress riser or other integrity impact, an operator must develop a procedure and perform an engineering critical assessment as follows:**

**(1) Identify and evaluate potential threats to the pipe …, external loading, fatigue, cracking, and corrosion.**

**(2) …**

**(11) An operator using an engineering critical assessment procedure, ….**




Notes:
*Dent associated with metal loss other than corrosion: gouge, axial or circumferential groove, SCC, fatigue cracks, and/or other cracks, any indication of 3rd party damage, or any other stress riser.
**Critical Strain as defined by ASME B31.8-2018 Clause 851.4.1(d)
***Other types of dents are categorized as a deformation feature that is not a Plain Dent (No Weld), a Dent with ML or a Dent affecting a weld.

# Objectives

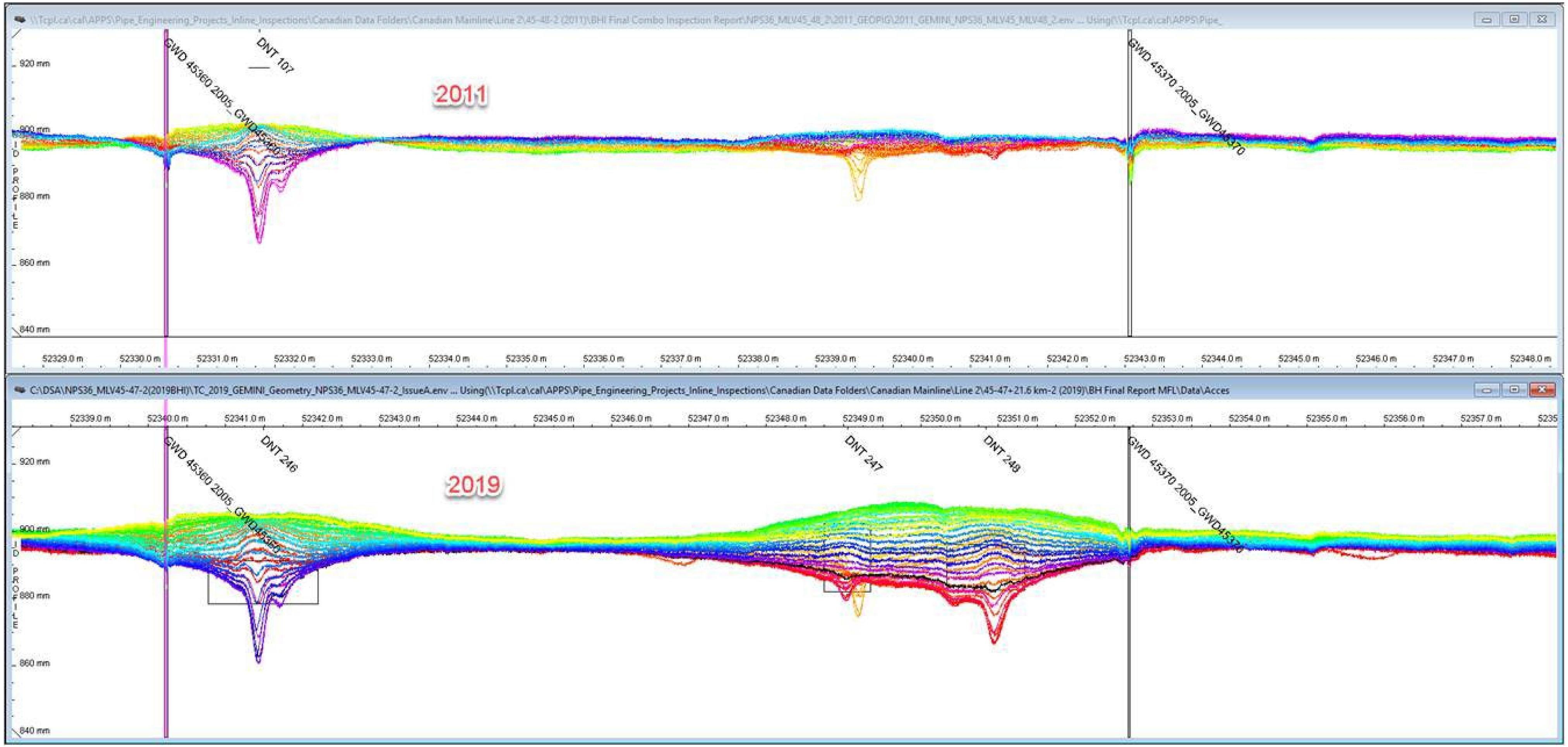
- Share the best practices developed and implemented by TC Energy
- Demonstrate the procedure and work accepted by regulators

# Key Components in the Process of ECA

- Review multiple caliper inspections and check any changes in depth and shape
- Calculate the curvature-based strain and compare changes in strain
- Review multiple ILI (e.g., MFL, EMAT, Caliper) signal data for coincident damage
- Assessment of dents with ILI-called metal loss
- Assess IMU data (strain) to identify external loads
- FEA for stress/strain, DFDI and SLD
- FEA for fatigue analysis

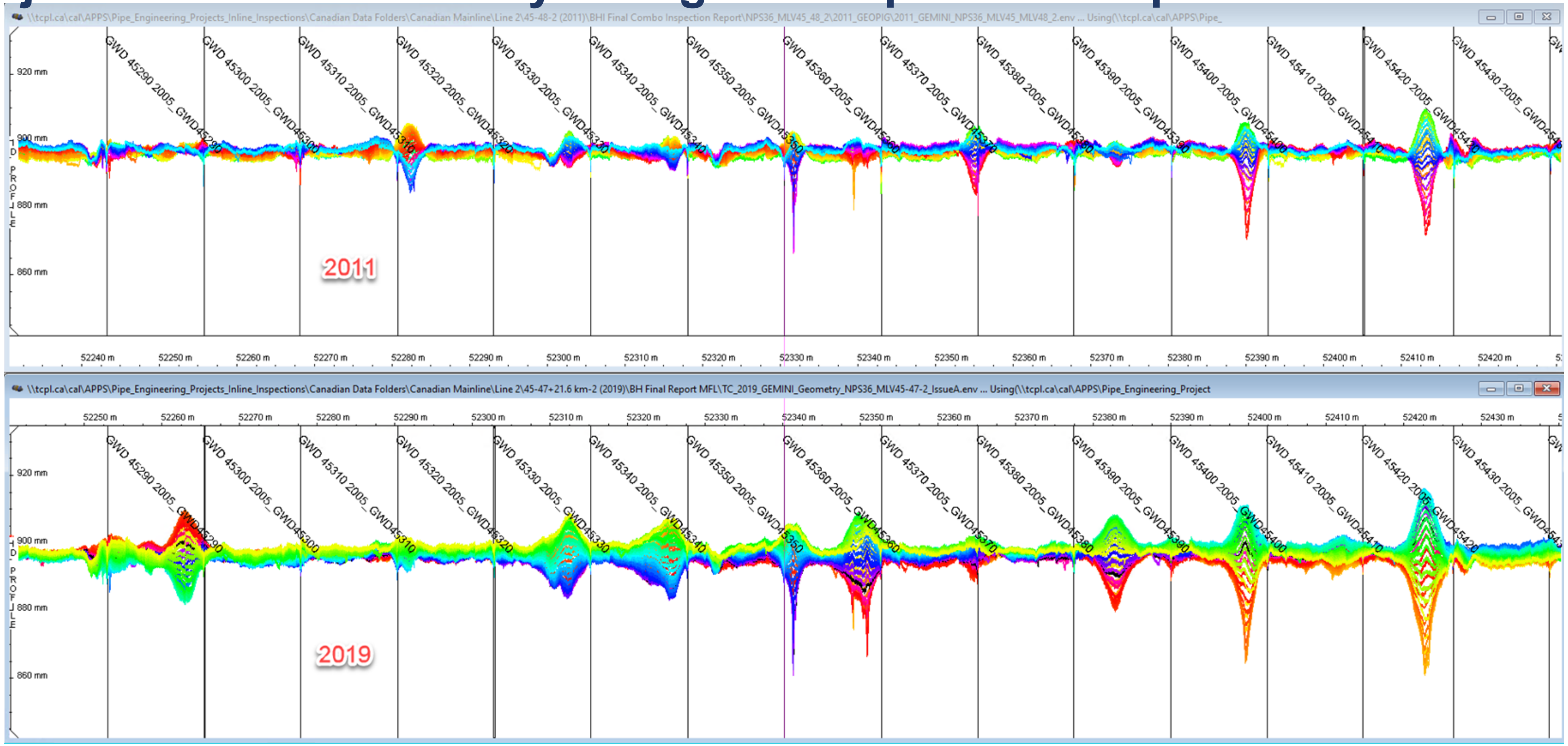
# Example of Review Multiple Caliper Inspections

## Objective: overview of any changes in depth and shape



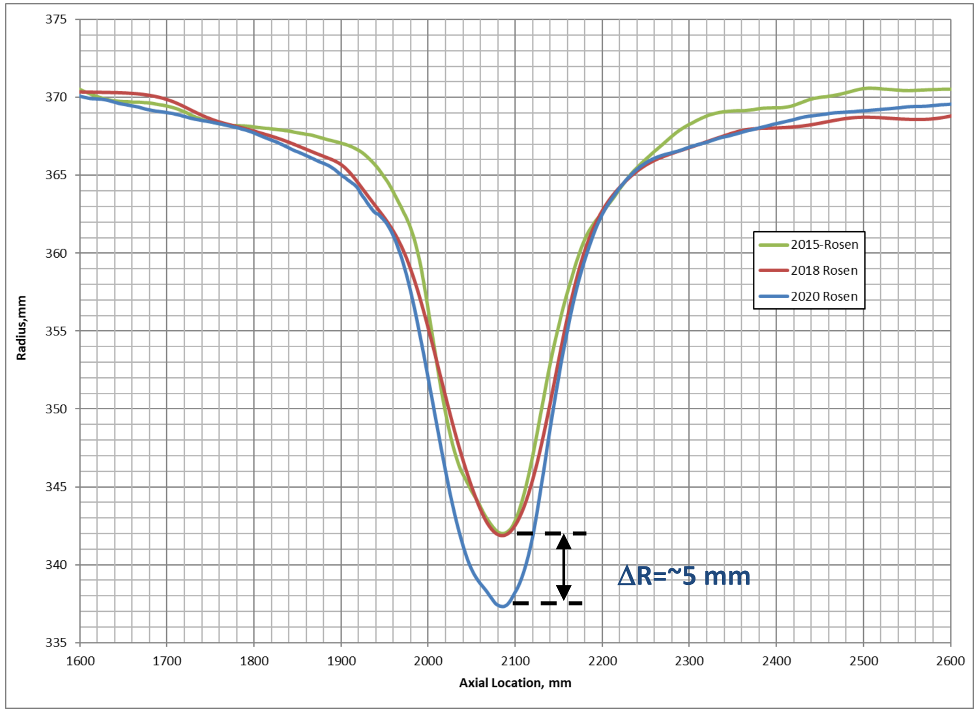
# Example of Review Multiple Caliper Inspections

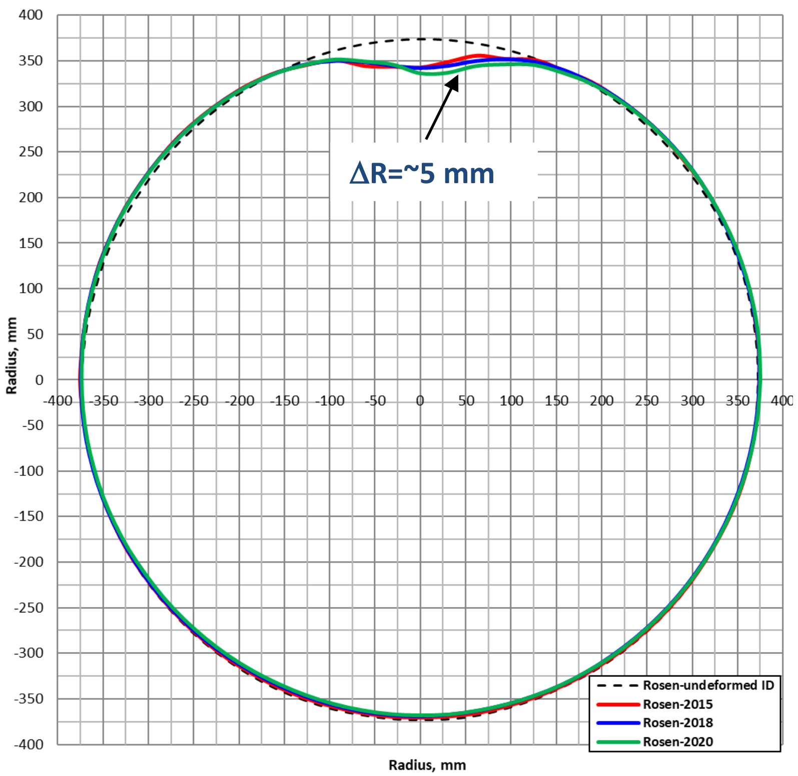
## Objective: overview of any changes in depth and shape



# Detailed Comparison of Dent Profiles

## Objective: detailed review of changes in depth and shape by comparing profiles

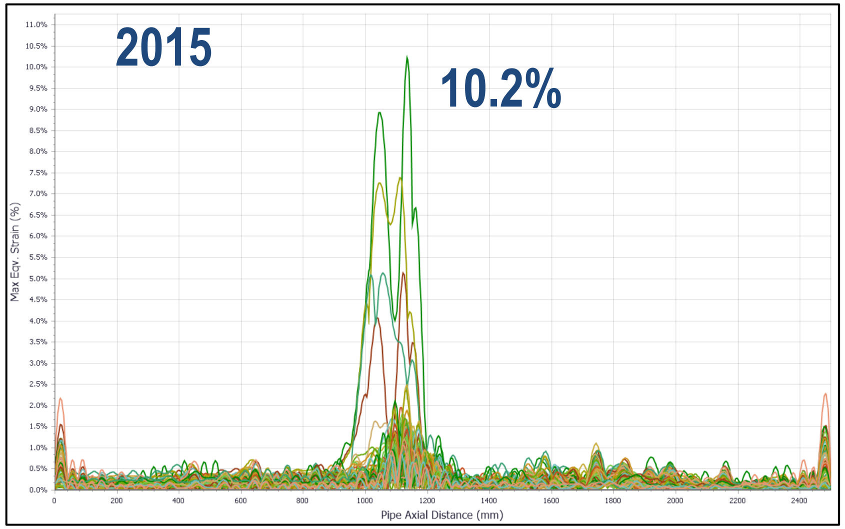


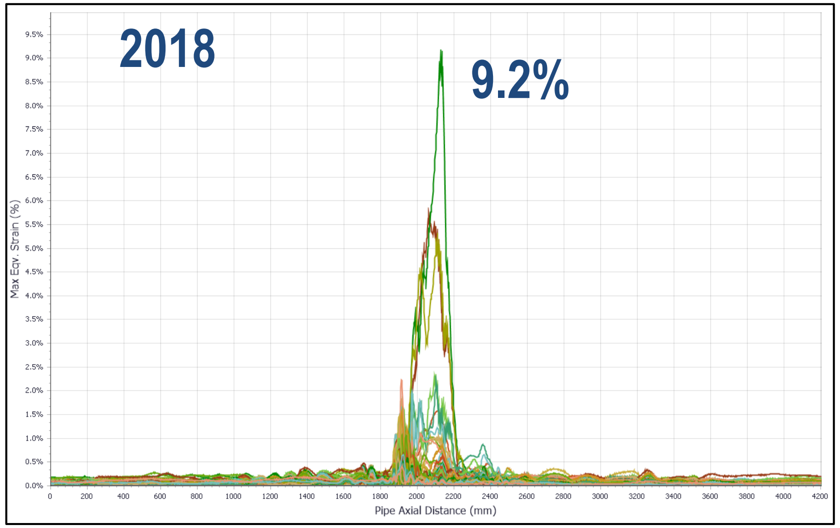



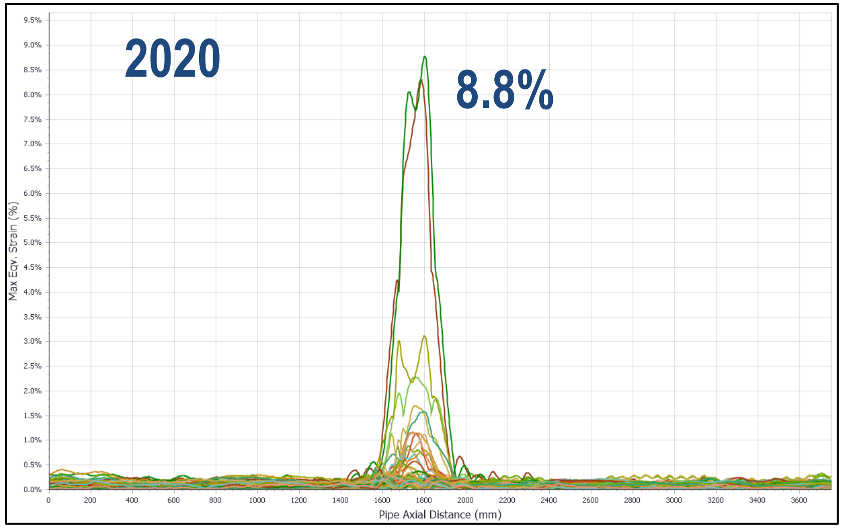

**Minor change in the profile with ΔR ≤ 0.2%OD (within tool tolerance of 0.2%OD)**

# Calculate the Curvature-based Strain per ASME B31.8

## Objective: check the changes in strains and evaluate susceptibility of cracking using DFDI criterion



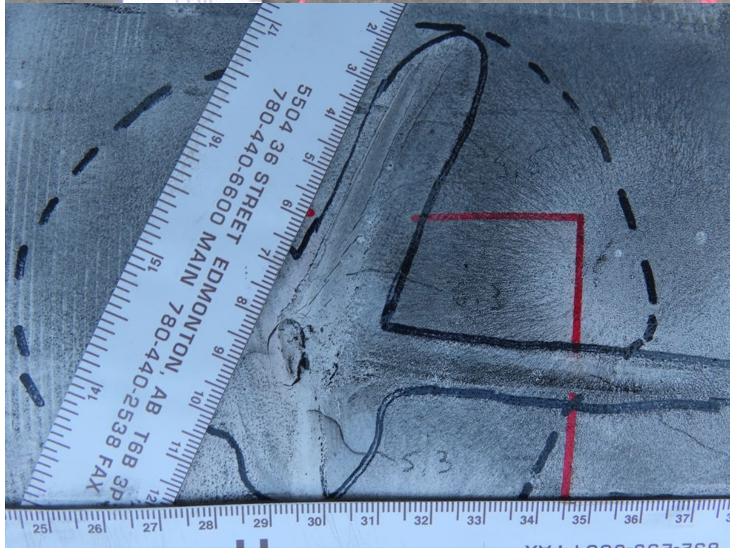




**small variation of dent strain possibly due to different noise level in the caliber data**

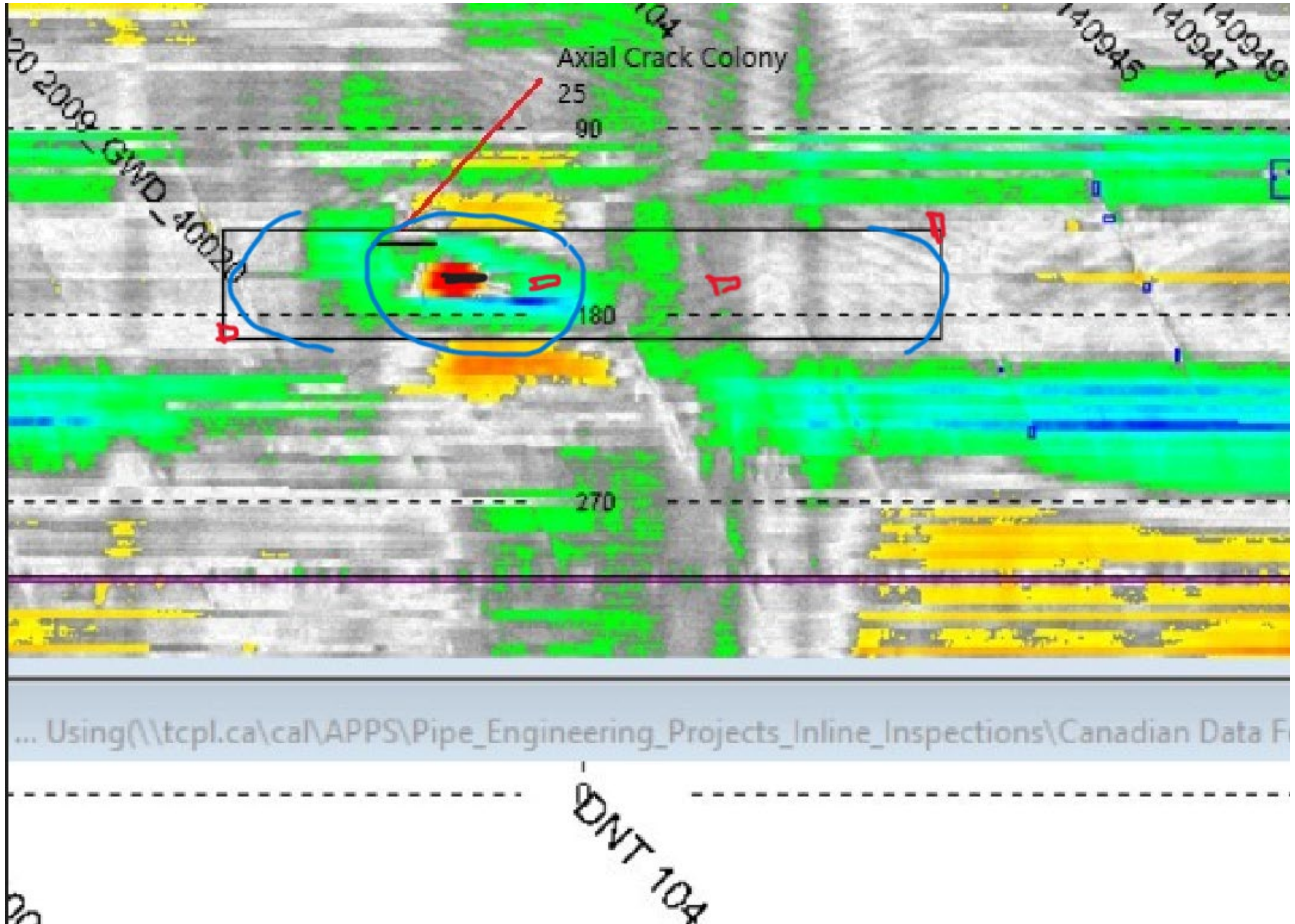
# Example of Review Multiple ILI (e.g., MFL, EMAT, Caliper) Signal Data for Coincident Damage

- Objective: demonstrate the effectiveness of using multiple datasets
- Example:
  - 2020 ILI: top side dent 1.75%OD with 28%wt ML
  - No signal indication from 2012 MFL/Caliper and 2015 EMAT/AFD
  - MS expansion done in 2017 near this location
  - Very likely to be MD created between 2015 and 2020
  - MD was confirmed In the ditch


# Assessment of Dents with ILI-called Metal Loss

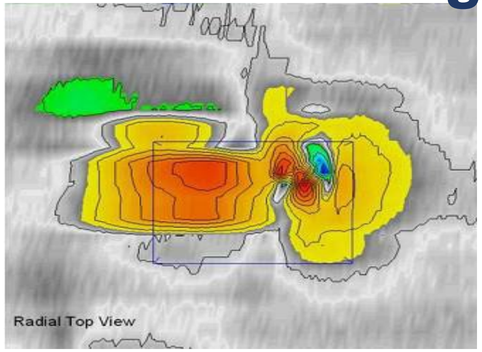
## Objective: review ILI signal to distinguish ILI-called metal loss features (corrosion vs gouge vs crack)

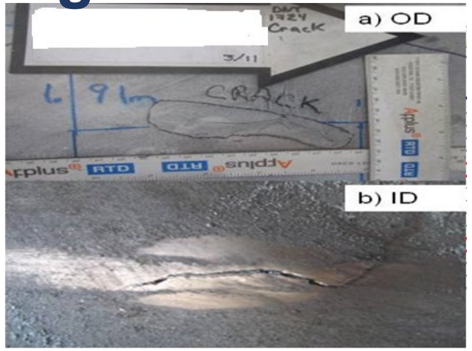


# Assessment of Dents with ILI-called Metal Loss

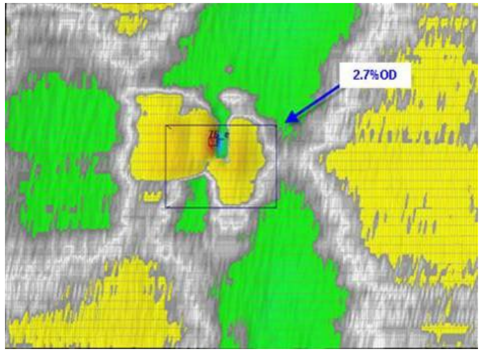
## Objective: validation of ILI assessment using dig data

- ILI
  - Depth: 4.1%OD
  - No interactive anomaly reported
  - Bottom of the pipe
  - DFDI = 0.8
- In-ditch finding
  - Dent associated with through-wall crack



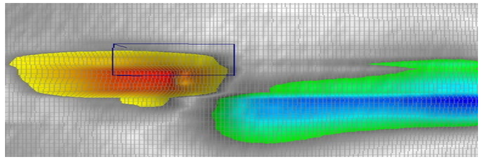



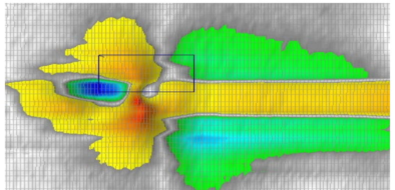

- ILI
  - Depth: 2.7%OD
  - 76%wt ext. ML
  - Bottom of the pipe
  - DFDI = 1.0
- In-ditch finding
  - Dent associated with branched non-through-wall crack





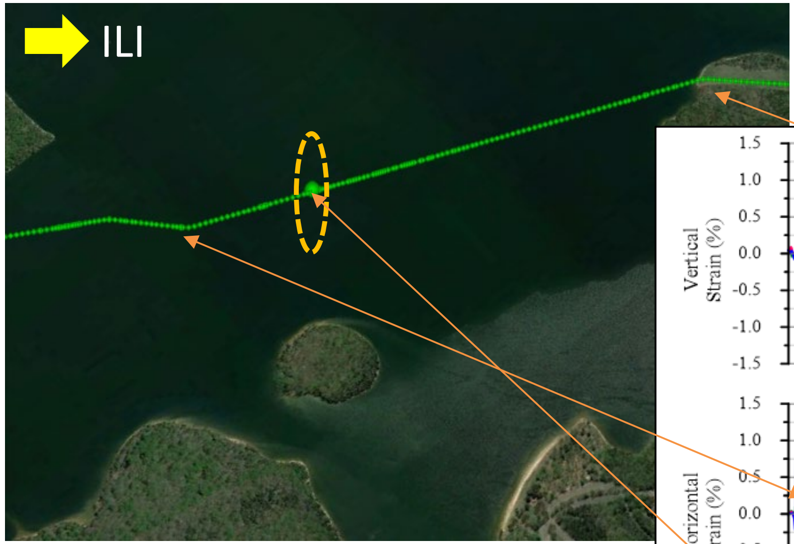
- ILI
  - Depth: 3%OD
  - No interactive anomaly reported
  - Top of the pipe
  - DFDI = 1.7
- In-ditch finding
  - Dent associated with MD

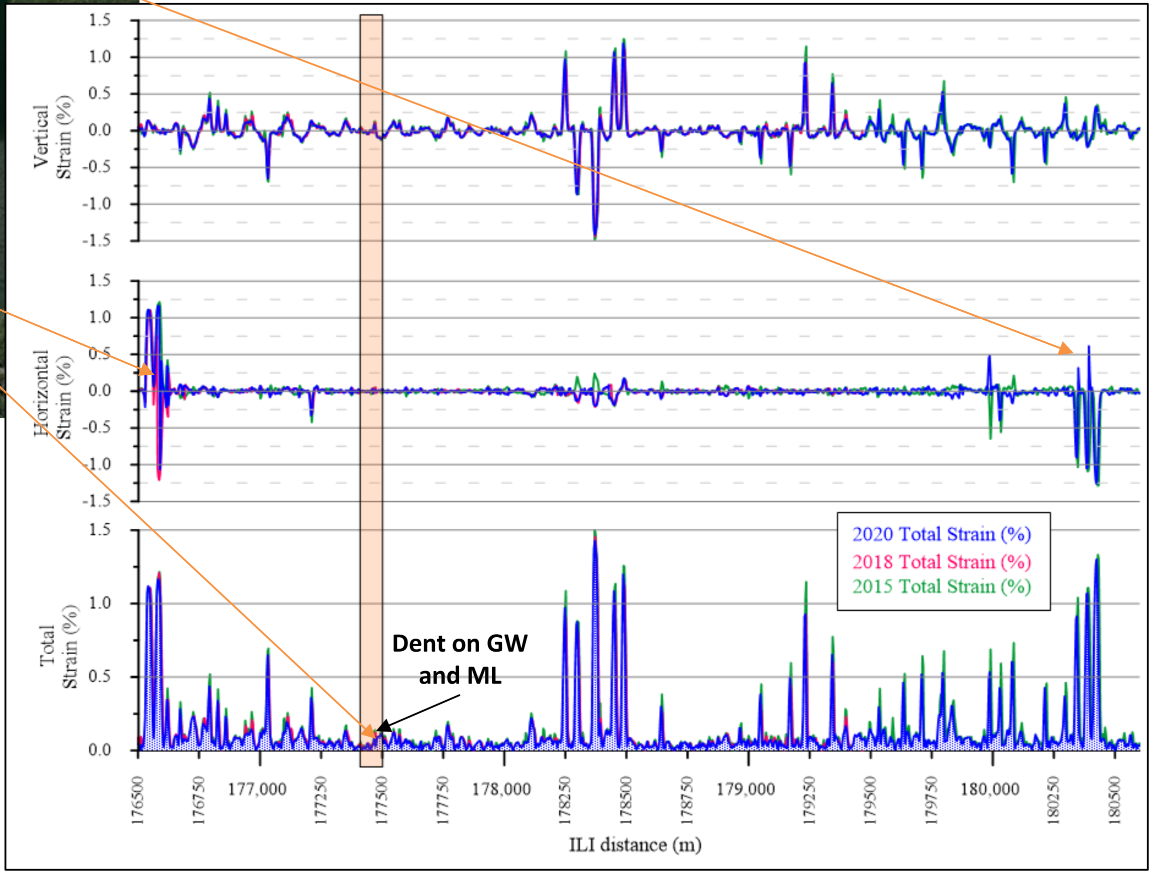




# Assess IMU Data

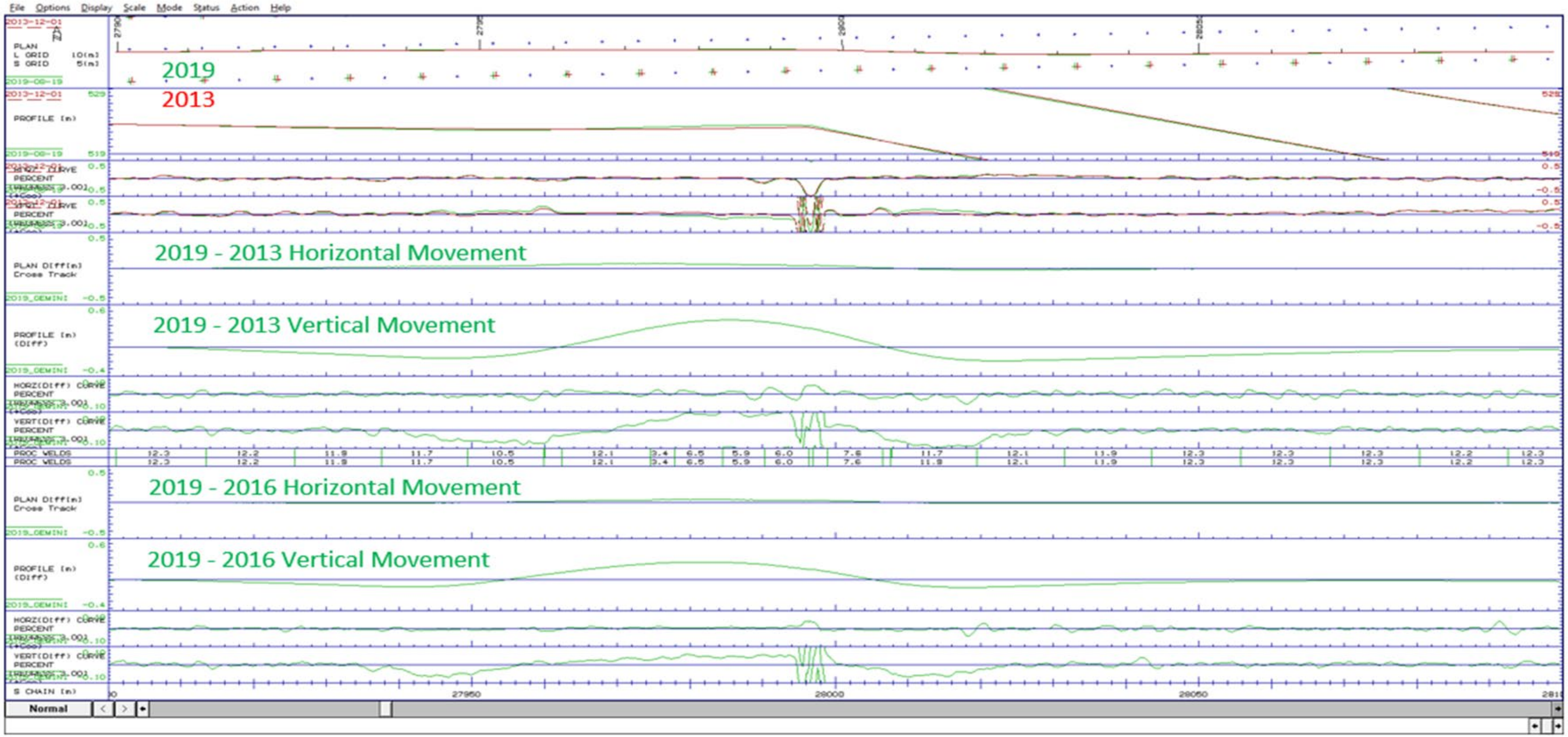
## Objective: identify external loads at the dent location




- IMU strain is comparable between the ILI runs
- No significant change in IMU strain at the dent location, indicating no evidence of pipe movement (no large external load).

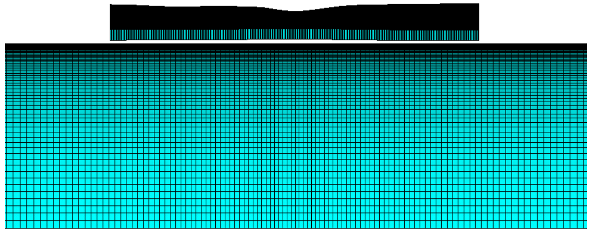
# Assess IMU Data



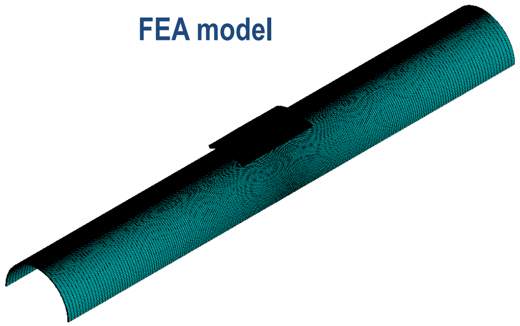

**Large vertical movement from 2013 to 2019**

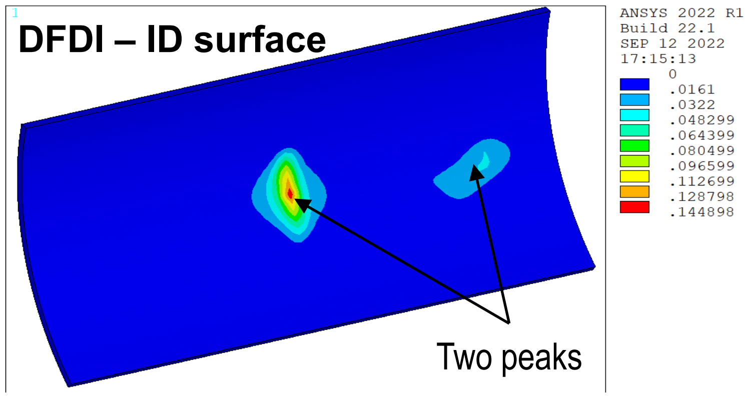
# FEA for Strain Assessment

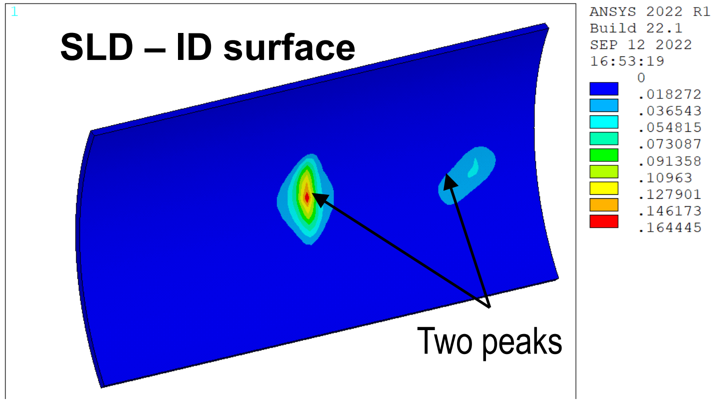
## Objective: evaluate Stress/Strain, DFDI and SLD



FEA model





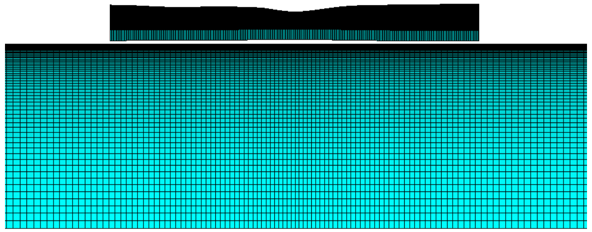




| Condition | Maximum Plastic Equivalent Strain | Maximum DFDI | | | | Maximum SLD |
|---|---|---|---|---|---|---|
| | | $\varepsilon_0 = 0.3$ | $\varepsilon_0 = 0.4$ | $\varepsilon_0 = 0.5$ | $\varepsilon_0 = 0.6$ | |
| Dent depth = 2.5% | 5.27% | 0.19 | 0.14 | 0.12 | 0.10 | 0.16 |
| Dent depth = 2.7% (w/ tool tolerance) | 5.32% | 0.20 | 0.15 | 0.12 | 0.10 | 0.17 |

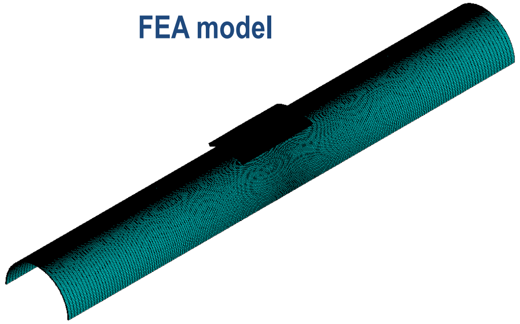
**DFDI < 0.6 and SLD < 1, indicating it is not susceptible to cracking.**

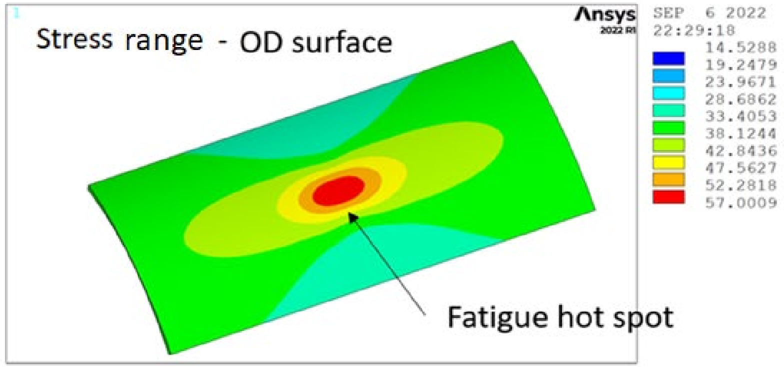
# FEA for Fatigue Life Assessment

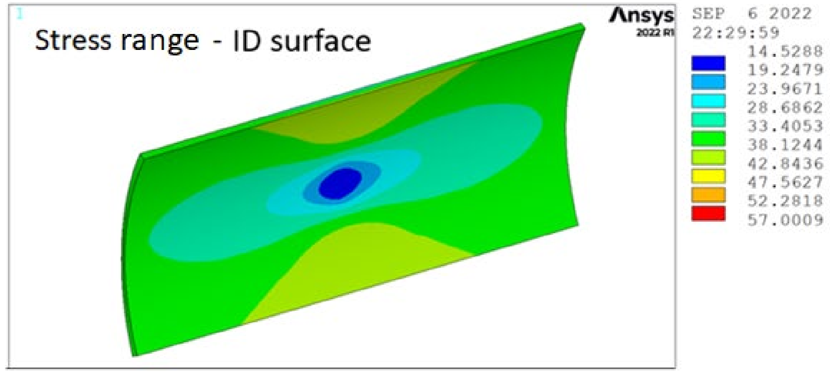
## Objective: evaluate the fatigue life



FEA model






| Methodology | Number of cycles to failure | Equivalent number of cycles for pressure range (0 to MAOP per year) | Predicted Fatigue Life (years) | Fatigue Life after applying safety factor of 2 (years) |
|---|---|---|---|---|
| API 1156 | 6992 | 0.31 | 22,555 | 11,277 |
| PRCI Fatigue Life Equation | 8110 | | 26,161 | 13,080 |

# Summary

- A general ECA process was developed to comply with regulations
- Some best practices were described and illustrated using real life examples
  - Usage of all available datasets (including ILI, geospatial data, etc.)
  - Expertise of SMEs
  - Effectiveness (safety and economy)
- Continuous improvements by including new R&D outcomes

thank you

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