Dent Screening Assessment Report

L00XX AB-CD

2025-01-28 BHGE CAL Issue 1.0

Feature: DNT 2, GW: 1275

Version: 1.0
Version Date: 21 January 2025

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1 MODEL INPUT

This section provides the foundational data used in the assessment, including pipeline identification, ILI tool information, and key feature attributes. These inputs are critical for dent characterization and assessment.

The asset is operated by XYZ.

Assessment is carried out by AV.

1.1 FEATURE INFORMATION

The dent features in this assessment were identified by the ILI vendor after processing inline inspection tool data. Table 1 provides feature identification details and key dent and pipe attributes. This information forms the basis for characterizing and evaluating the dent feature

Table 1 – Input Variables

Variable	Value	Units
Line	L00XX	-
Segment	AB-CD	-
Girth Weld	1275	-
Feature Name	DNT 2	-
ILI Run	2025-01-28 BHGE CAL Issue 1.0	-
ILI Run Date	29-Jan-2025	-
Feature Absolute Distance	694740.00	mm
Deepest Point Relative Distance	643.30	mm
Deepest Point Orientation	191.00	degree
Feature Depth Reported	8.43	mm
Nominal OD	762.00	mm
Wall Thickness	7.94	mm
Pipe Vintage [Year]	1953.00	-
Dent Age	72.00	year
Pipe Grade	X52_V	-
SMYS [MPa]	360.00	MPa
Minimum UTS [MPa]	460.00	MPa
Yield stress (Mean) [MPa]	386.55	MPa
Yield stress (Std.) [MPa]	21.63	MPa
UTS (Mean) [MPa]	548.28	MPa

1.2 ILI DATA

Table 2 provides the measurement tolerances reported by the ILI vendor for depth, length, and orientation accuracy.

Table 2 – ILI Tool Measurement Tolerances

Variable	Tolerance	Units
ILI depth accuracy	2.5	mm
ILI length accuracy	35.0	mm
ILI orientation accuracy	25.0	mm

1.2.1 Profile

Figure 1 shows ILI reported dent profile.

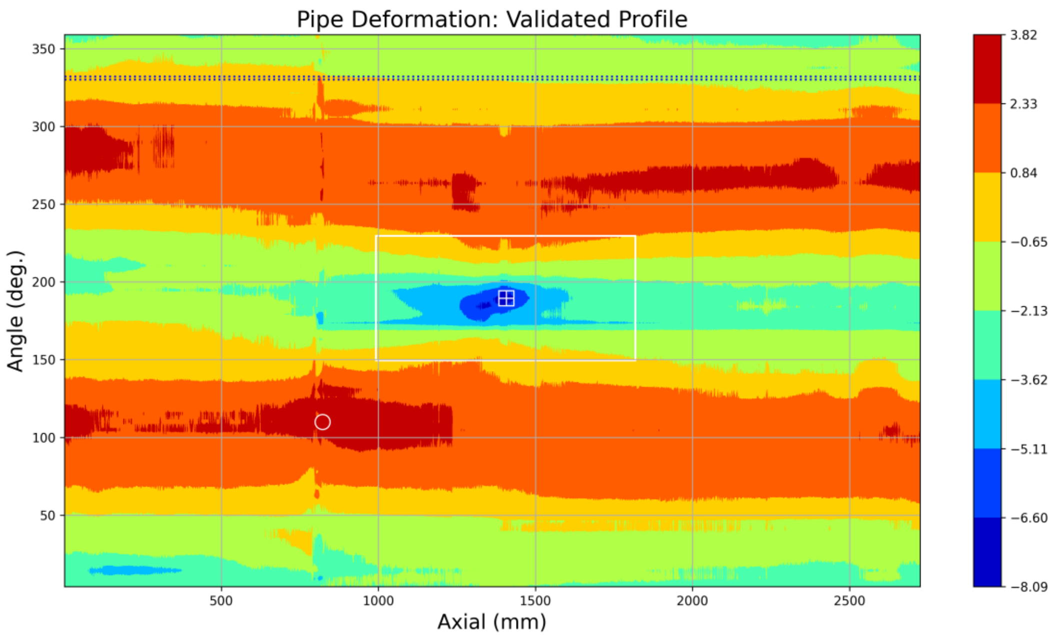

Figure 1: Validated ILI profile

1.2.2 Inertial Measurement Unit (IMU)

Figure 2 illustrates the IMU data recorded by the ILI tool during the inspection.

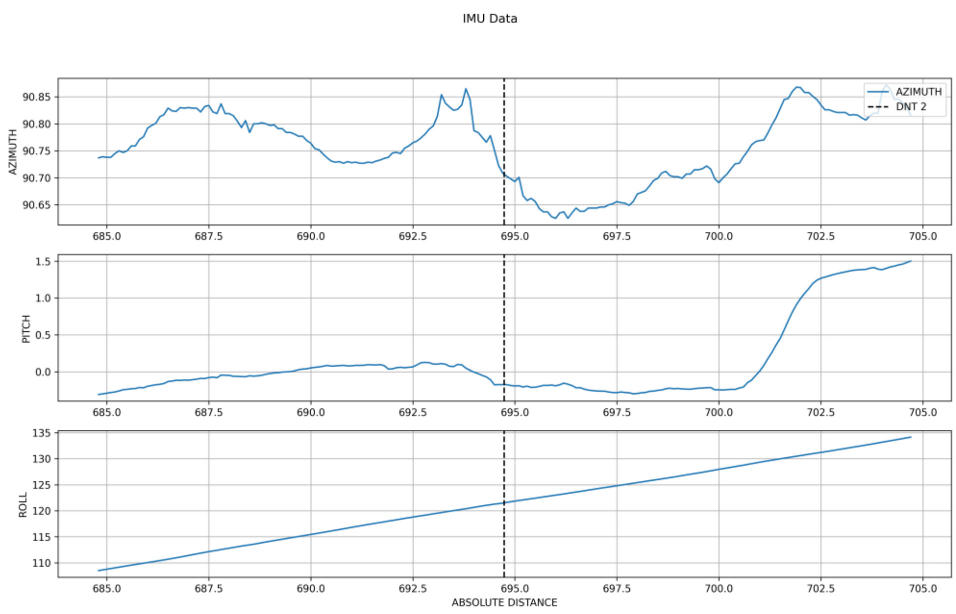

Figure 2: IMU raw data

1.3 Coincident Features

This section provides information on the dent feature's attributes (as reported by the vendor), potential interactions with other reported features (e.g., corrosion, cracks, SCC), and details about the pipe's seam weld type and proximity to girth welds.

Table 3 lists dent feature attributes provided by the vendor. These are represented as Boolean values indicating the presence or absence of specific characteristics.

Table 3 – Feature Attributes

Topside Dent	Multi Apex Dent	Dent in Close Proximity	Dent with Weld	Off-Axis Dent	Dent with Gouge	Dent with Corrosion	Dent with Crack	Dent with SCC	Multiple Dent Interaction
False	False	False	False	False	False	False	False	False	False

Table 4 – Corrosion features in close proximity

Corrosion Feature	Corrosion Depth	Corrosion Length	Corrosion Width, deg	Corrosion Relative Axial Distance	Corrosion Relative Orientation	Corrosion Radial Position
COR 0007	0.50	16.30	5.29	-129.20	17.00	EXTERNAL

Table 5 – Crack features in close proximity

Feature Name	Depth, mm	Length, mm	Width, deg	Relative Axial	Relative Orientation, deg	Radial Position
CAR 0001	1.30	47.90	2.20	-0.60	6	NOT DECIDABLE

The pipe joint is long seam welded. The seam weld orientation is 331.0°.
The joint seam weld type is DSAW
The closest girth weld is located 655.45 mm away.

1.4 Site Information

Table 6 provides the geographical location and class location of the feature.

Table 6 – Feature Location Information

Variable	Value
Country	US
Class Location	Unknown
Pipe Latitude	41.128611
Pipe Longitude	-83.652539

The exact feature location can be viewed on the map:

View Feature Location on Google Maps (Map link).

1.5 Load Information

This section details the operating pressures at the feature's location, which are essential inputs for fatigue and strain (level 3) calculations.
Maximum operating pressure for the joint is 5.37 MPa.
Internal pressure at the deformation feature during the ILI tool run is: 3.76 MPa.
ILI reinspection interval is: 5.00 years.

1.6 Pump Station Information

Table 7 provides details about the nearest upstream pump station and associated parameters.

Table 7 – Pump Station Information

Variable	Value	Units
Upstream Pump Station	AB	-

Distance Pump Station [km]	0.6738	km
Hydraulic Distance [m]	280978.6146	m
Elevation [m]	468.9728	mm
Pressure Correction Factor	1.0	-

2 PROFILE PROCESSING

This section presents the results of the processed ILI profile data. The data was filtered to remove noise, and the axial and transverse cross-sections were analyzed to identify the following:

- Number of peaks in the dent profile.
- Length and area under the profile at different dent depths.

These calculations provide the necessary inputs for API 1183 assessments and further dent evaluations.

2.1 FILTERING

The ILI profile data is processed using FFT and a Gaussian filter to remove systemic and random noise. The resulting filtered data is presented below:

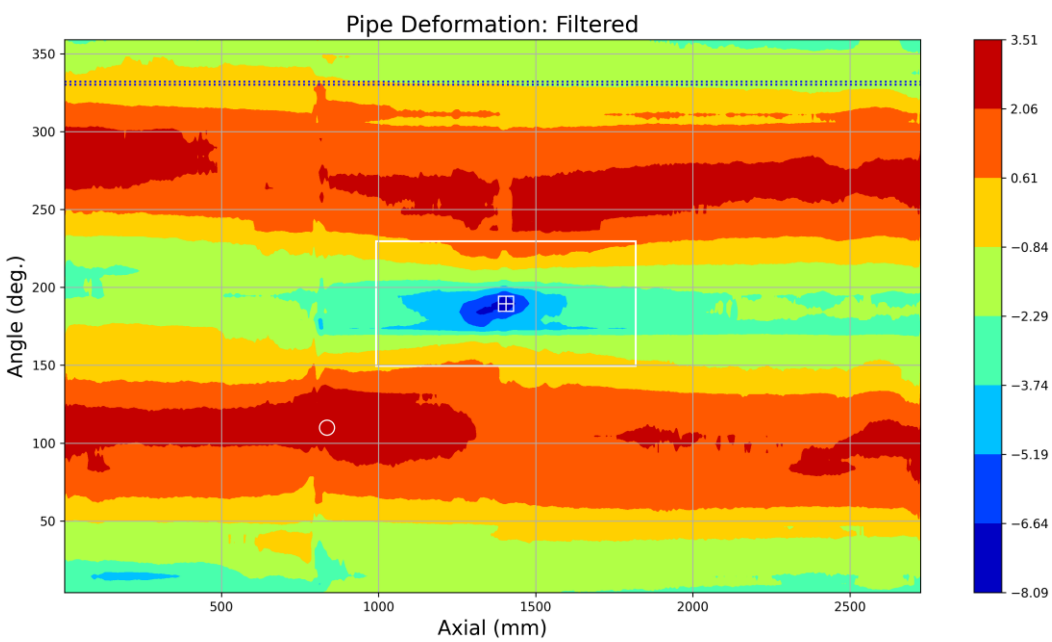

Figure 3: ILI filtered contour plot

The quantified average deviation between the provided and filtered axial profile is 0.08 mm

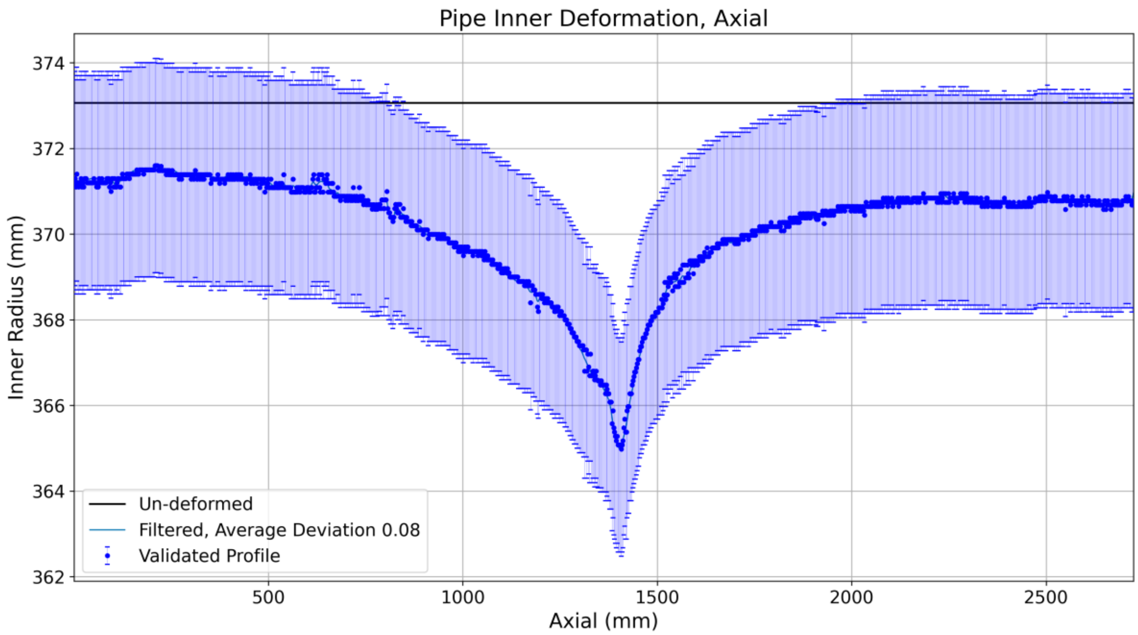

Figure 4: Filtered axial profile

The quantified average deviation between the provided and filtered transverse profile is 0.07 mm

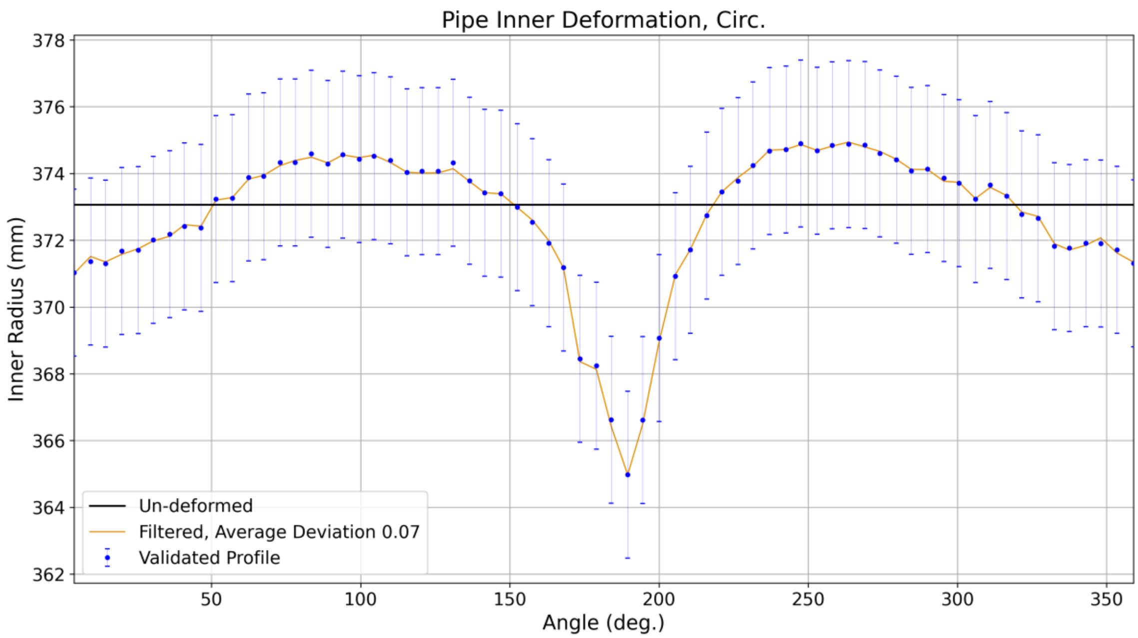

Figure 5: Filtered transverse profile

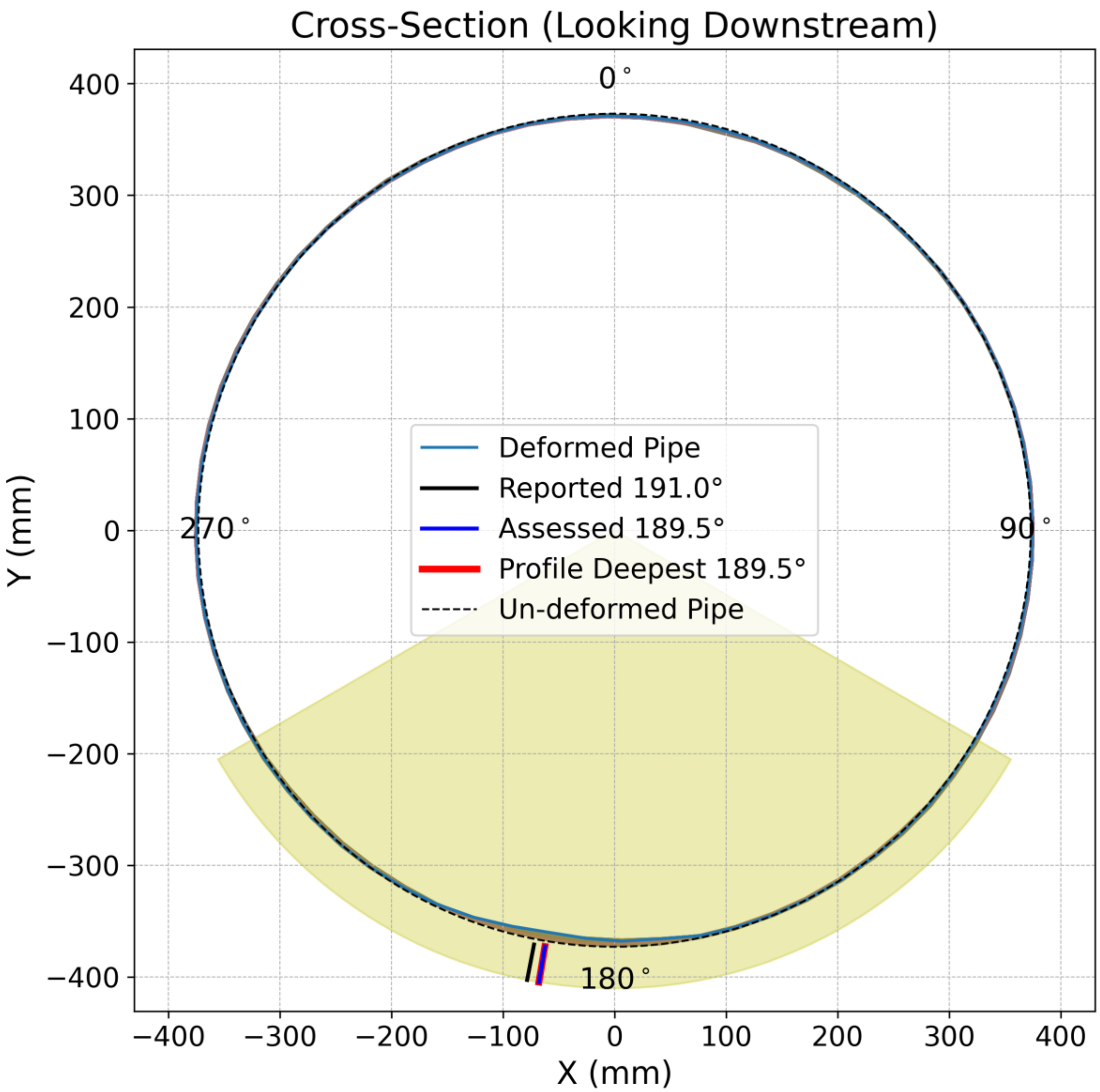

Figure 6: Pipe cross-section identifying dent orientation

2.2 Peak Analysis

This section presents the results of analysis to identify peaks in the axial and transverse profile of the dent feature.

Number of axial peak: 1

Number of transverse peak: 2.

Angle between peaks is: 174.5

Note: Please verify the other transverse peaks as it may be influenced by pipe ovality (refer to the transverse profile plot for confirmation)

The dent feature is classified as having single peak.

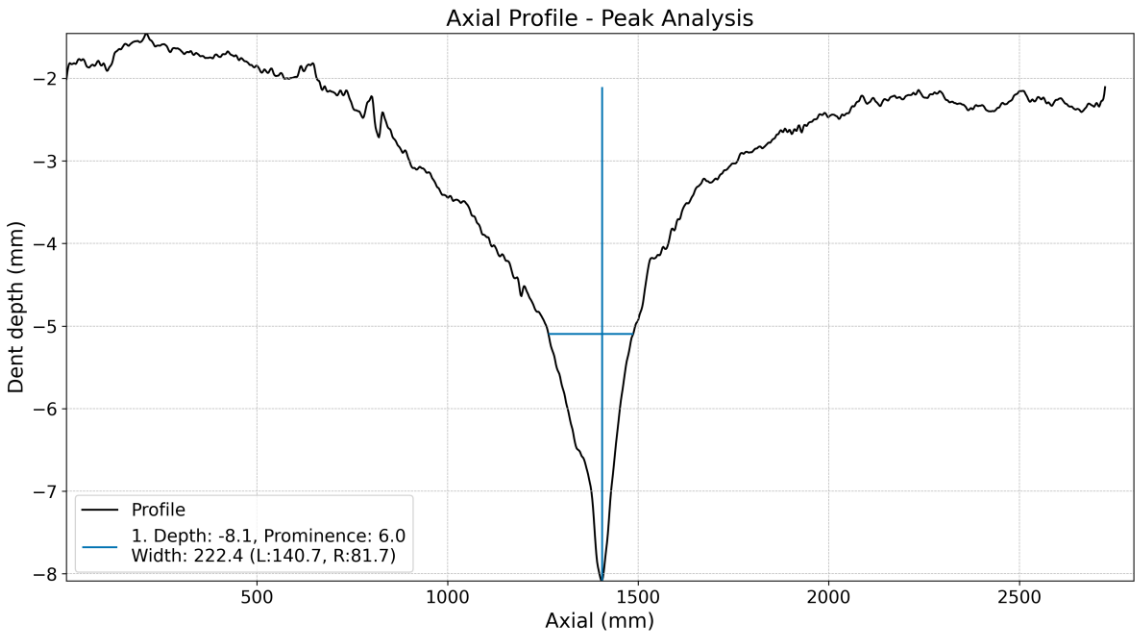

Figure 7: Axial peak analysis plot

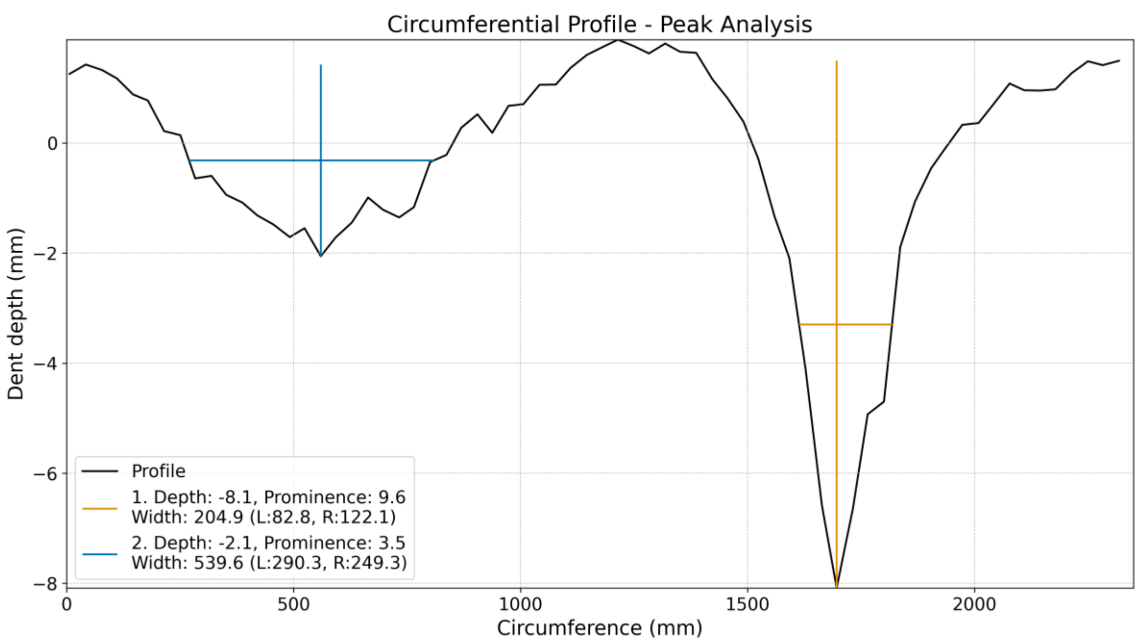

Figure 8: Transverse peak analysis plot

2.3 Length & Area Calculation

Table 8 presents the calculated lengths and areas under the axial dent profile at various dent depths, providing a detailed view of the dent's deformation along the upstream (US) and downstream (DS) directions.

Table 8 – Characteristic Axial, Length and Area

Deformation Depth (%)	US Length	DS Length	US Area	DS Area
5.00	-	-	-	-
10.00	-	-	-	-
15.00	-	-	-	-
20.00	1141.06	-	-	-
30.00	573.63	581.76	2138.57	2555.64
40.00	441.48	263.83	1456.56	884.69
50.00	280.13	160.10	733.82	422.58
60.00	162.60	99.13	306.18	193.01
75.00	87.19	45.17	103.17	44.41
85.00	33.20	26.56	17.10	14.23
90.00	22.55	19.02	5.88	6.46
95.00	16.43	11.47	2.20	2.04

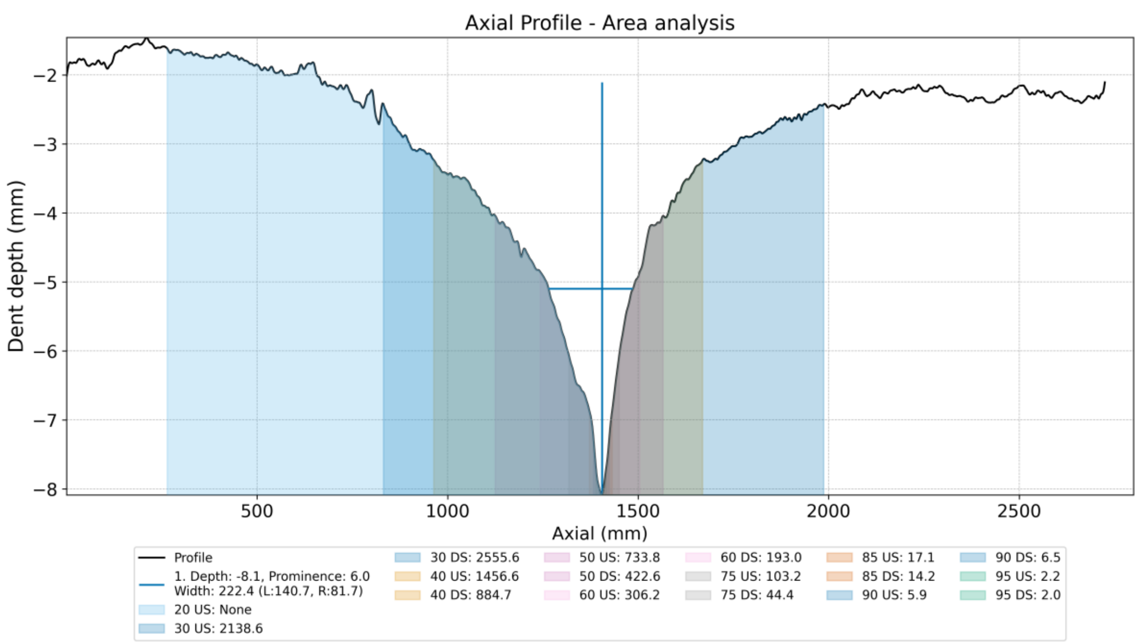

Figure 9: Axial length and area plot

Table 9 presents the calculated lengths and areas under the transverse dent profile at various dent depths. These parameters describe the deformation along the counter-clockwise (CCW) and clockwise (CW) directions.

Table 9 – Characteristic Transverse, Length and Area

Deformation Depth (%)	CCW Length	CW Length	CCW Area	CW Area
10.00	154.79	187.64	635.19	712.51
15.00	140.98	166.73	537.43	564.25
20.00	124.67	150.83	428.81	458.12
30.00	98.28	133.19	266.77	349.19
40.00	83.94	122.87	191.40	294.95
50.00	69.60	112.55	127.64	249.05
60.00	57.63	80.40	84.01	139.28
70.00	45.89	54.46	50.77	61.97
75.00	40.02	46.76	37.72	44.87
80.00	34.15	39.07	27.02	30.89
85.00	26.19	30.05	15.88	18.22
90.00	17.46	20.03	7.06	8.10

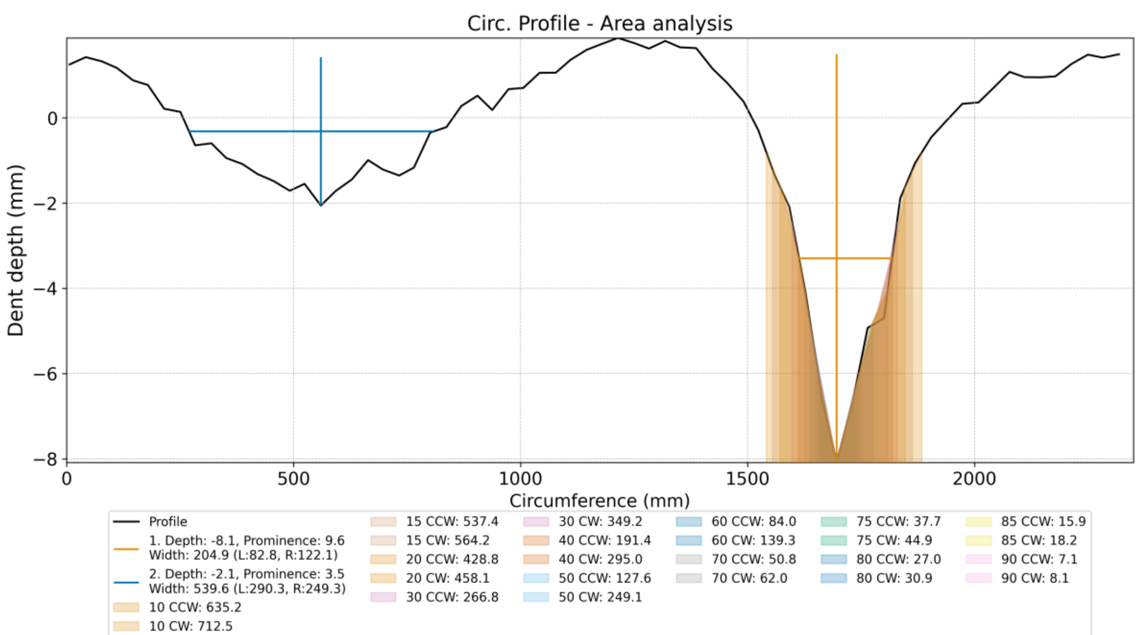

Figure 10: Transverse length and area plot

3 GEOMETRY CHARACTERISATION

This section presents the results of the API 1183 assessment, focusing on feature geometry characteristics and their classification as dents. The assessment, conducted on 21 January 2025 evaluates whether the feature meets the criteria for dent classification based on:

- Predefined geometry signatures.
- The angle formed between the dent axis and the pipe's longitudinal axis.
- Restraint parameters as defined in API 1183 guidelines.

3.1 IS DENT?

The following geometry criteria are applied to determine whether a feature is classified as a dent. If any one of the criteria is satisfied, the feature is classified as a dent. Additionally, magnetic signatures associated with localized pipe wall plasticity may also be used to identify a dent.

Conclusion: The feature is classified as a dent based on geometry parameters.

3.1.1 Formation Strain

Formation strain calculation could not be performed.

3.1.2 Sharpness

Sharpness calculation could not be performed.

3.1.3 Out of Roundness

The feature exhibits an out-of-roundness value of 1.25%. The feature meets the out of roundness criterion and is classified as a dent based on this parameter.

3.1.4 Depth vs Ovality

The feature depth exceeds the ovality depth, meeting the depth criterion. The feature is classified as a dent based on this parameter. The calculated feature ovality is 1.05 %.

Table 10 – API 1183 Depths

Variable	Depth, mm
Total depth	9.55
Dent depth	6.36
Ovality depth	3.19

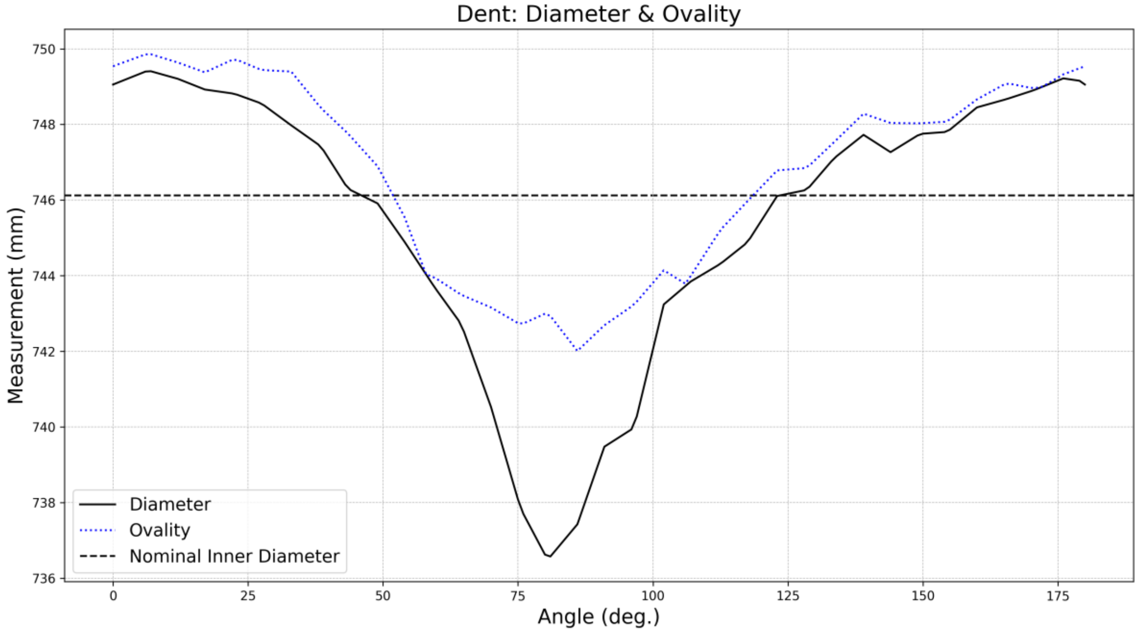

Figure 11: Ovality plot

3.2 Is Off-Axis?

The angle formed between the dent axis and the pipe's longitudinal axis is -12.58° The dent is NOT classified as off-axis as the orientation angle is less than 30°.

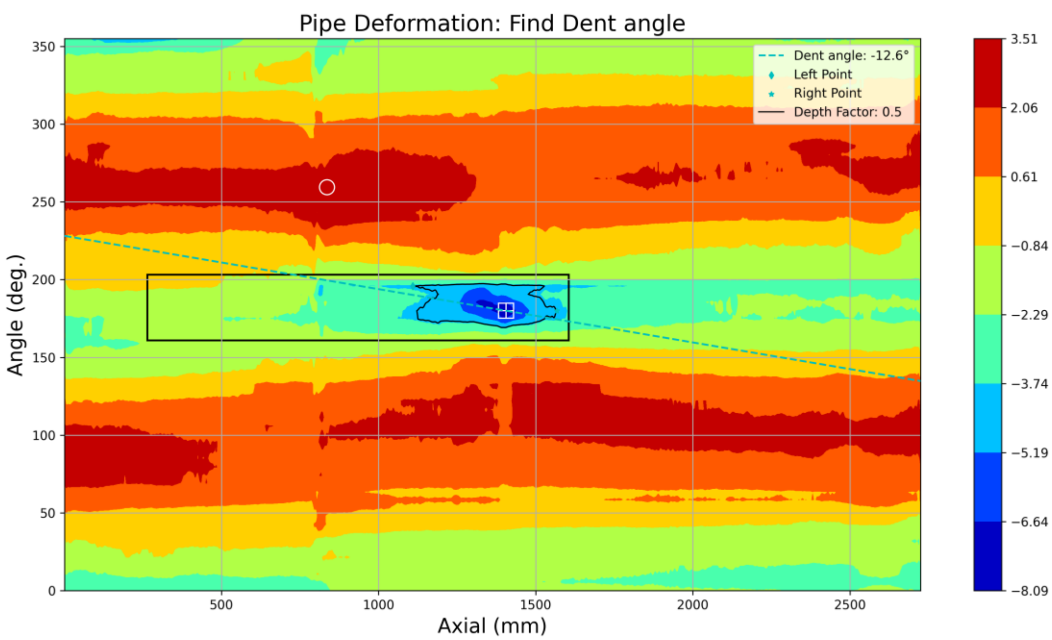

Figure 12: Dent orientation relative to pipe axis

3.3 RESTRAINT PARAMETER

The restraint condition of the dent feature is assessed based on API 1183 guidelines.

The dent is classified as "Restrained" based on clock position.
The calculated restraint parameter is invalid and requires further verification (All NaN).
The dent feature is assessed as "Restrained".

3.4 CHARACTERISTICS

This section summarizes the key characteristics of the feature, load, and pipe properties, as derived from the assessment. Table 11 presents the detailed data.

Table 11 – Feature, Load, and Pipe Characteristics

Variables	Values	Units
Feature Depth, Profile (Raw)	8.09	mm
Dent Depth to OD ratio	1.1	%
Deepest Orientation, Profile (ILI)	189.50	degree
Deepest Relative Distance, Profile	1405.33	mm
OD to Wall Thickness	96.00	-
MOP % SMYS	71.5	%

4 INTERACTING FEATURE

Based on the dent restraint condition, the dent interaction region, as defined by API 1183, extends 413.12 mm in the axial direction and spans 40.00 degrees in the transverse direction. This section summarizes interacting corrosion, crack, and weld features relevant for fatigue and strain assessments.

This subsection presents corrosion features interacting with the dent feature for fatigue and strain assessments. The interaction details are provided in Table 12.

Table 12 – Corrosion Interaction

Corrosion Feature	Depth, mm	Depth, %	Remaining Wall, mm	Fatigue Interaction	Strain Interaction
COR 0007	0.50	6.30	7.44	True	False

This subsection presents crack features interacting with the dent feature. The interaction details are provided in Table 13.

Table 13 – Crack Interaction

Crack Feature	Interaction	Depth, mm	Depth, %	Remaining Wall, mm
CAR 0001	True	1.30	16.38	6.64

Interacting features are plotted relative to the dent feature and are shown in Figure 13.

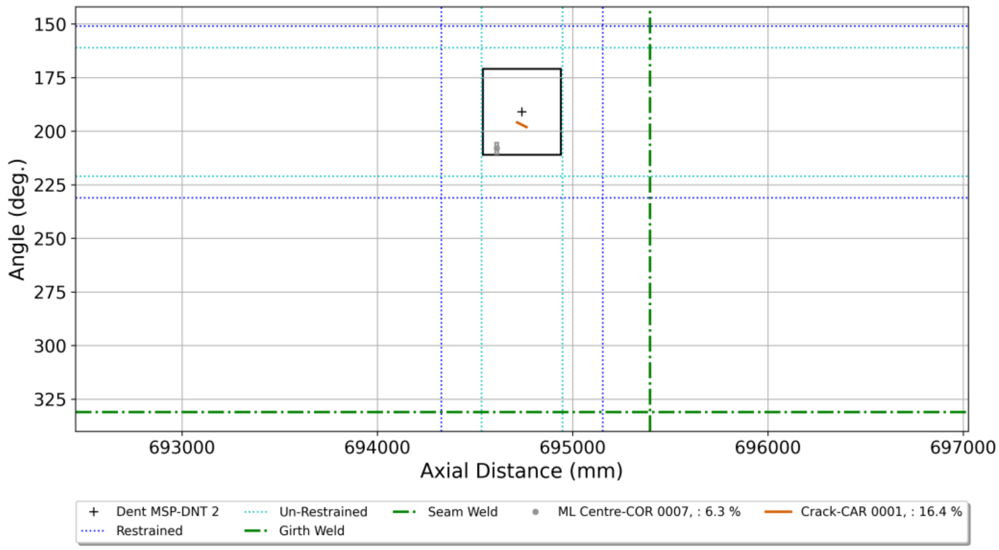

Figure 13: Interacting features

Weld Interaction Assessment:
- The feature does not interact with the long seam weld.
- The feature does not interact with the girth weld.
- The feature does not interact with a weld as per API 1183 guidelines.
- The feature does not interact with a weld based on the feature attributes provided in the assessment input.

Conclusion:
The feature is assessed as NOT interacting with any weld.

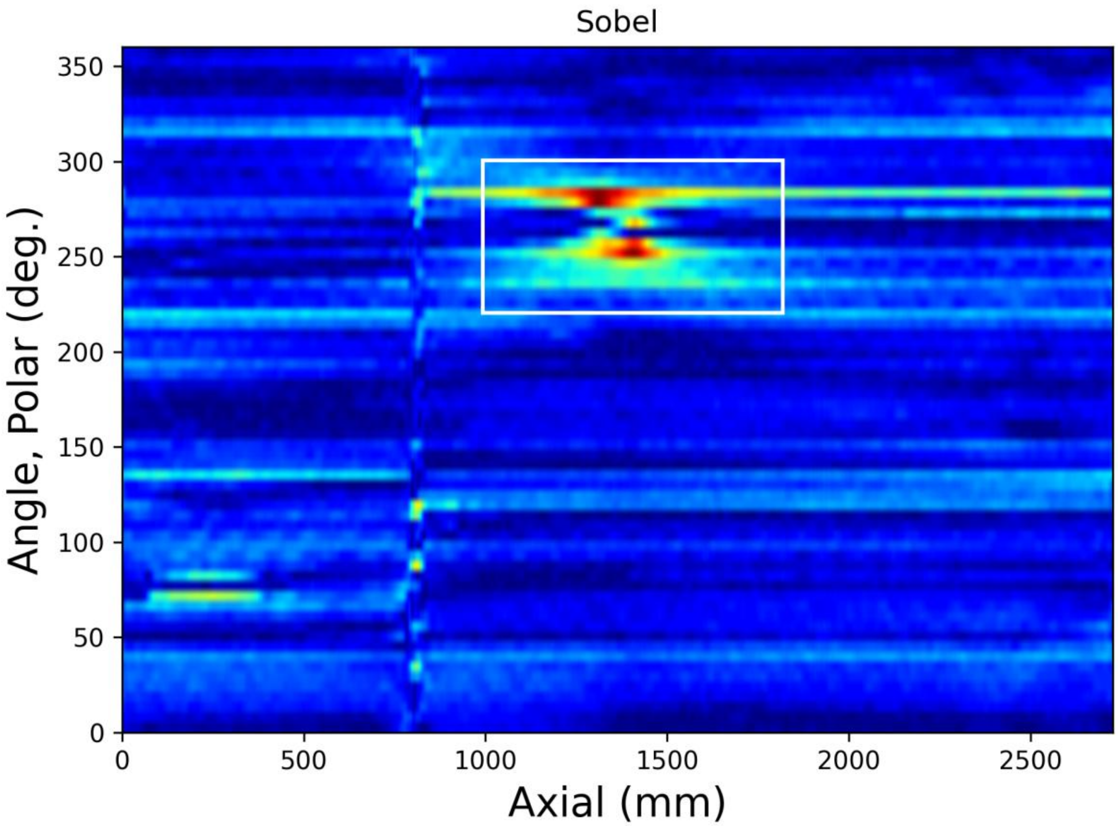

Figure 14: Sobel plot to identify weld interaction

5 OPERATIONAL PRESSURE DATA

The operational pressure data is scaled to the location of the feature using the methodology outlined in API 1176. The scaling process considers upstream discharge pressure, downstream suction pressure, the hydraulic distance of the feature, and elevation information.

- Scaled maximum pressure at the feature location: **5.17 MPa.**

- Scaled Minimum Pressure at the feature location: **0.00 MPa.**

- Retrieved pressure data duration: **14.25 years.**

The scaled pressure data is processed using rainflow counting to quantify the pressure cycles. The resulting rainflow data is then used to calculate the Spectrum Severity Indicator (SSI). A reference stress of **90 MPa** is used to determine the number of equivalent cycles that would cause the same level of fatigue damage as represented by the rainflow data. The calculated SSI value is **689.0 cycles.**

The detailed rainflow counting results are saved in:
"L00XX_AB-CD_AB_1275_Rainflow.xlsx".

6 IMU DATA REVIEW

Figure 15 depicts the global shape of the pipe derived from the IMU data. The red line represents the best-fit straight line, and the deviation of the pipe from this line is quantified using the root mean square error (RMSE). The straight line deviation is 13.03 mm.

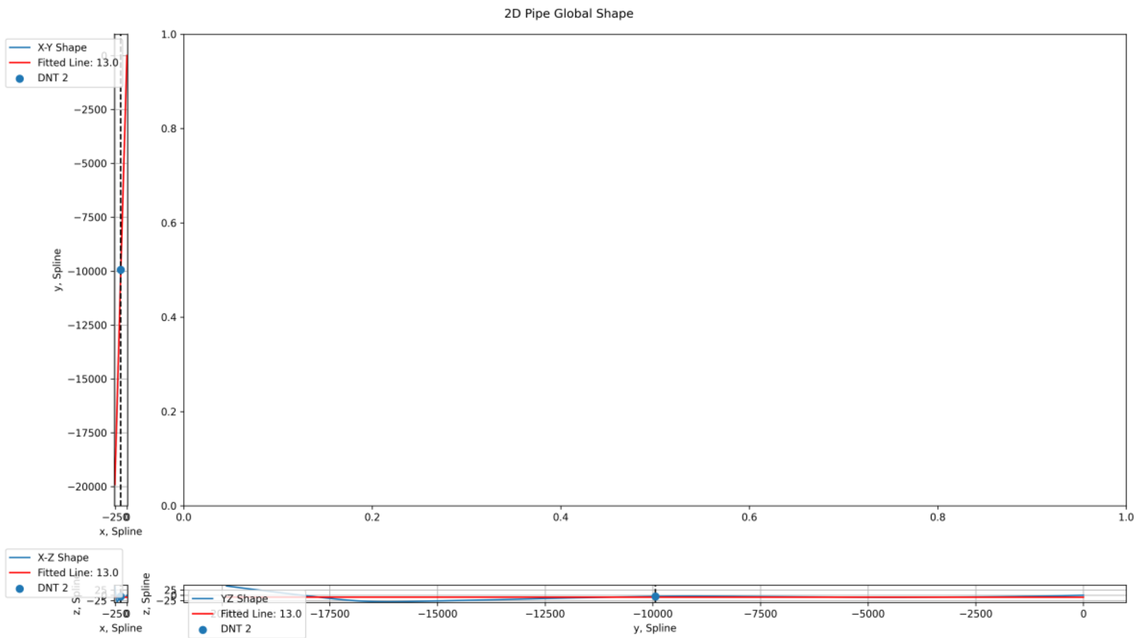

Figure 15: Global pipe shape

7 BURST PRESSURE, CORROSION (ASME 31G)

The corrosion burst pressure is calculated using the ASME B31G Level 1 method. When multiple corrosion features are present, they are assumed to be non-interacting. It is recommended to manually validate this assumption for the specific features being assessed.

Table 14 – Corrosion Burst Pressure

Corrosion Feature	Corrosion Depth	Corrosion Length	Corrosion Width, deg	Failure Stress	Failure Pressure	Safety Factor (Operating Pressure)	Safe Pressure	Modified 31G
COR 0007	0.50	16.30	5.29	395.70	8.24	1.54	5.90	True

8 STRAIN CALCULATION

8.1 CURVATURE

The axial curvature at the deepest point of the dent feature is 218.46 mm.
A curve-fitting equation was applied to the ILI profile data to calculate this curvature, achieving a fitting error of 0.01.

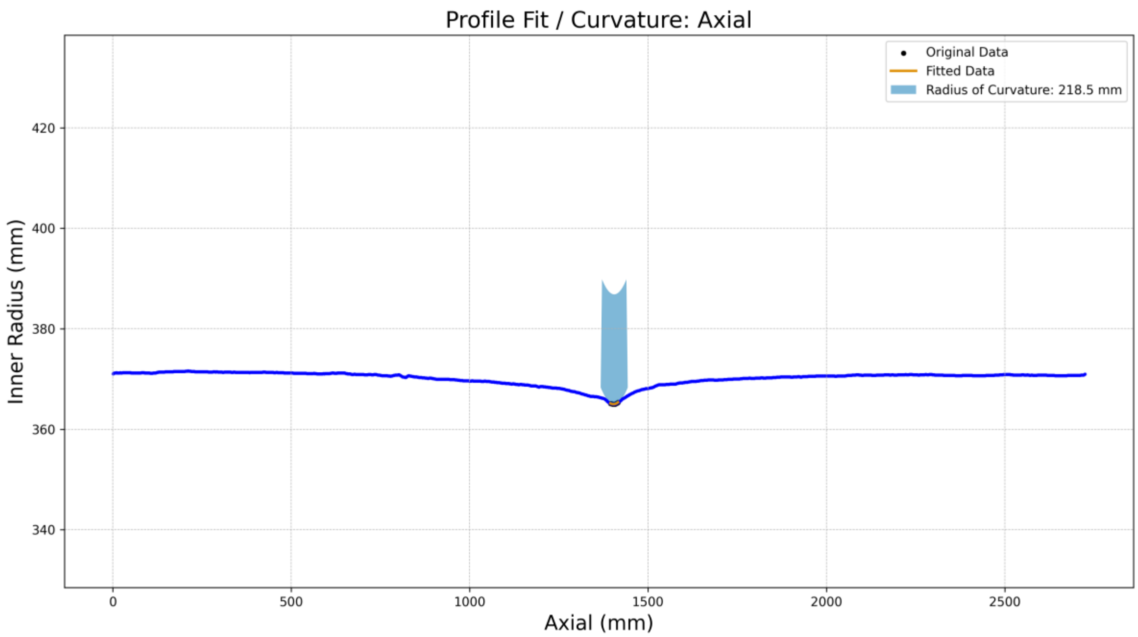

Figure 16: Axial curvature at the deepest point of the dent

The transverse curvature at the deepest point of the dent feature is -3729.82 mm.
A curve-fitting equation was applied to the ILI profile data to calculate this curvature, achieving a fitting error of 0.00

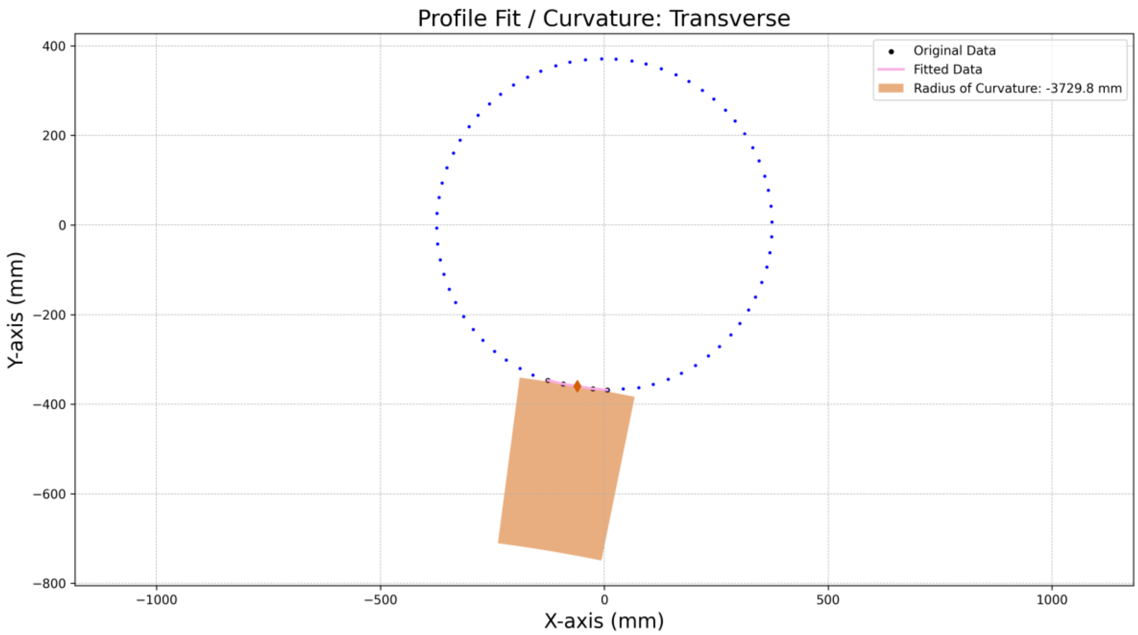

Figure 17: Transverse curvature at the deepest point of the dent

8.2 Deterministic Strain Assessment

The assessment of dent formation strain and the potential for crack formation during indentation is based on the strain model **"ASME B31.8".**

The analysis is performed using the mean profile of the dent feature, with the dent length measured at **85 % dent depth.**

Key strain results:
- Bending strain in circumferential direction: **1.82 %**
- Bending strain in longitudinal direction: **1.17 %**
- Extensional strain in longitudinal direction: **1.16 %**
- Equivalent strain on the inside surface of the pipe: **4.27 %**
- Equivalent strain on the outside surface of the pipe: **1.85 %**

The highest strain is observed on the **inside surface** of the pipe, with a maximum value of **4.27 %**

8.3 Probabilistic Strain Assessment

This section presents the probabilistic strain assessment results, which provide a more accurate estimate of dent formation strain and evaluate the potential for crack formation during indentation.

To account for uncertainties in the ILI tool's recorded profile, the recorded profile was used as the basis for generating random 3D profiles within the specified ILI tool tolerance. These simulated profiles were used to perform strain assessments and estimate the strain demand. The strain demand was then compared to the material's strain capacity to calculate the probability of exceedance (PoF). This probabilistic approach incorporates the inherent uncertainties of the ILI tool and material properties, enhancing the reliability of the assessment.

To account for uncertainties in the strain assessment, 10000 Monte Carlo simulations were carried out.

Simulated axial profile plot is not available.

Simulated transverse profile plot is not available.

Figure 18 shows strain demand and capacity distributions.

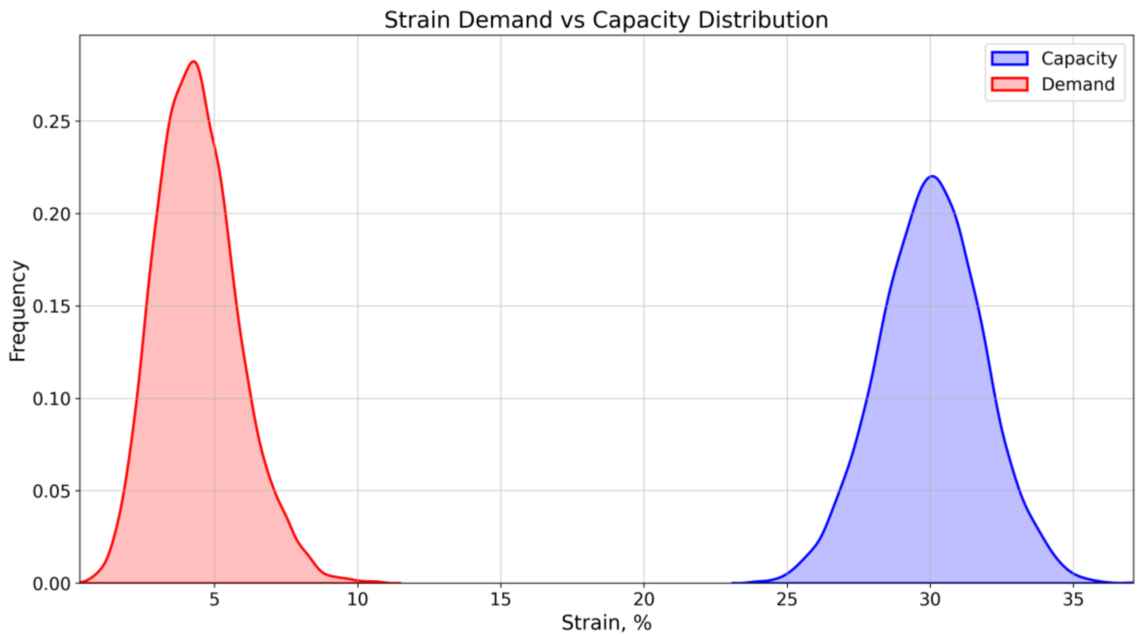

Figure 18: Strain demand and capacity distribution.

Strain Simulation Summary:
- Simulated Strain Mean: **4.41 %**
- Simulated Strain Standard Deviation: **1.44 %**
- Simulated Strain Maximum: **10.81 %**
- Simulated Strain Minimum: **0.29 %**

Material Strain Capacity

Material strain capacity follows a normal distribution and is adjusted (derated) based on

feature attributes such as whether the dent is topside, associated with welds, or associated with corrosion.
- Material Capacity Mean: **30.00 %**
- Material Capacity Standard Deviation: **1.80 %**

Key Strain Simulation Results
The strain safety factor is calculated as the ratio of the 95th percentile strain demand to the 5th percentile strain capacity.
- Strain Demand (95th Percentile): **6.99 %**
- Strain Capacity (5th Percentile): **27.00 %**
- Strain Safety Factor: **3.86**
- Probability of Failure (PoF): **8.65E-29**

Conclusions:

The calculated **strain safety factor of 3.86** exceeds the minimum required safety factor of 1.25 indicating that the feature meets the strain safety requirements.

The feature satisfies the strain safety factor criteria.

The feature's strain probability of failure (PoF) is **8.65E-29,** which is below the required target of **1.00E-03.**

The feature satisfies the strain probability of failure criteria.

9 FATIGUE CALCULATION

9.1 API 1183 FATIGUE ASSESSMENT

This section presents the fatigue assessment results based on API 1183 guidelines. The assessment assumes the feature is classified as a plain dent, without interactions with welds, corrosion, or cracks.

Key Feature Characteristics for Fatigue Assessment:

- The feature is classified as a restrained dent with a depth of 1.1 % OD.
- Based on the depth, the feature is categorized as a shallow restrained dent.
- The pipe's year of manufacture is 1953, and the dent feature is assumed to be 72.0 years old.
- The feature is classified as a single-peak dent.

Feature Interaction Considerations:
- The feature is interacting with corrosion. The interaction with corrosion reduces the feature's fatigue life by a maximum factor of **1.22.**

Table 15 – Corrosion Fatigue Life Reduction

Corrosion Feature	Fatigue Reduction
COR 0007	1.22

The interaction with a crack renders the API 1183 fatigue assessment results not valid. A Level 3 assessment is required to evaluate the feature's fatigue life accurately.

Conclusion:
- Dent Feature Fatigue Life: **8.11 years.**
- Dent Feature Remaining Fatigue Life: **0.00 years.**
- Dent Feature Corrosion Fatigue Life: **6.67 years.**
- Dent Feature Remaining Corrosion Fatigue Life: **0.00 years.**

The remaining fatigue life of the dent feature, including the effects of all interactions is 0.00 years.

9.1.1 Fatigue Life Dent Screening

The fatigue life of the dent, calculated using the screening model, is 7.46 years.

9.1.2 EPRG/API 579

The dent feature's acceptable number of pressure cycles is 267.7. The feature has experienced an annual rate of 33.0 pressure cycles, calculated from the rainflow data. Calculated fatigue life of the dent is 8.11 years.

9.1.3 PRCI (Shape Parameter)

The fatigue life assessment results using the PRCI Shape Parameter model are currently not available.

9.2 Finite Element Analysis (FEA) Stress and Fatigue Assessment

9.2.1 FEA Assessment

The ILI-reported profile data is used to generate a detailed FEA model utilizing 3D solid 8-node linear brick elements. This model provides an accurate representation of the dented region for further assessment.The axial and transverse nodal locations are shown in Figure 19 and Figure 20 respectively. The pipe wall is meshed with 4 elements through the thickness to ensure adequate stress resolution. The entire pipe model consists of 68808 solid elements. Geometric non-linearity is considered in the model. The pipe material is modeled as elastic-plastic, incorporating non-linear material behavior.

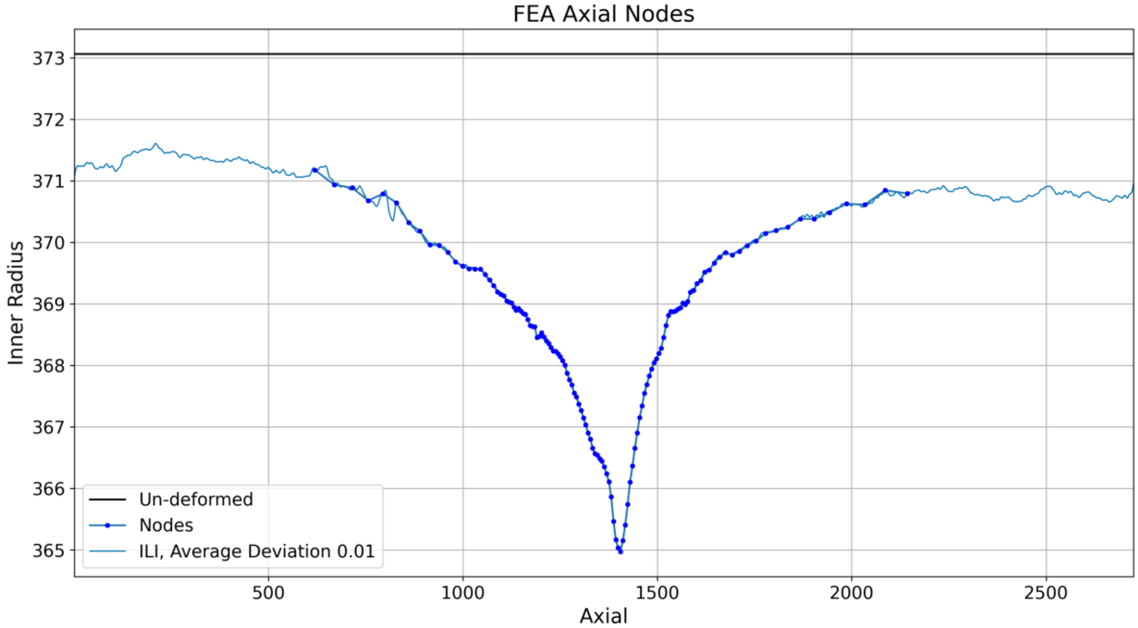

Figure 19: Axial nodal coordinate locations.

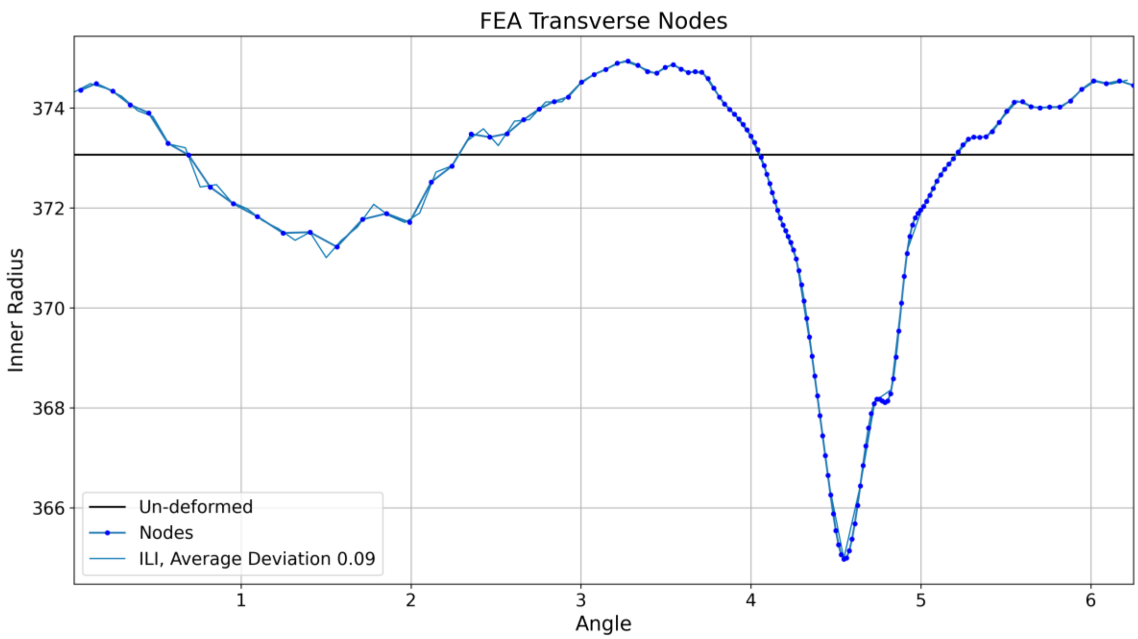

Figure 20: Transverse nodal coordinate locations.

Figure 21 shows dent mask, the maximum stress with in this region is used for fatigue assessment.

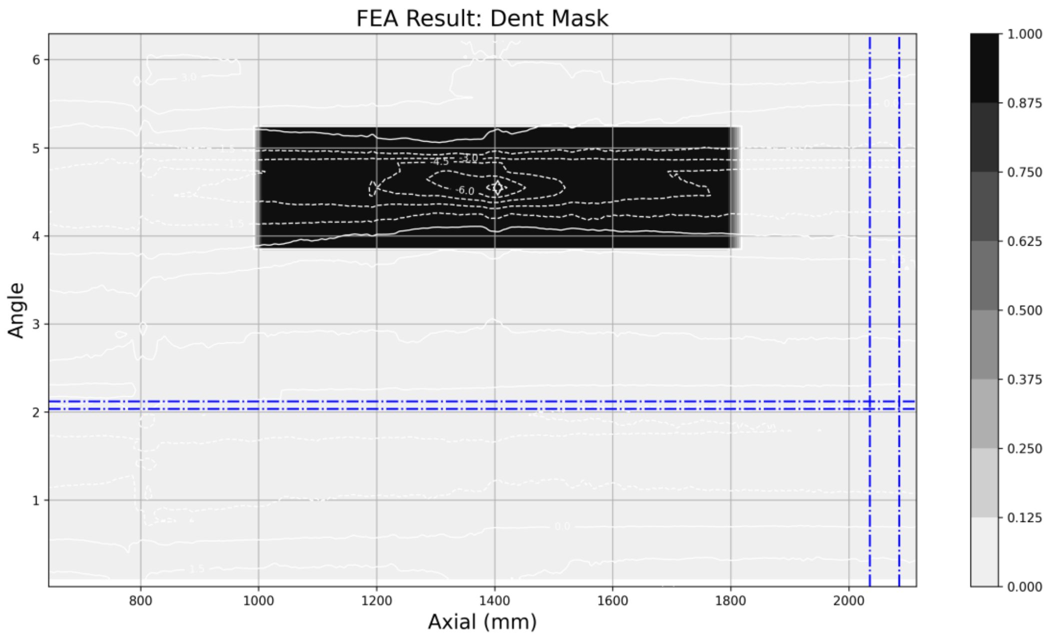

Figure 21: Dent Mask, used to extract maximum stress.

Figure 22 shows the corrosion mask, the maximum stress with in this region is used for corrosion fatigue assessment.

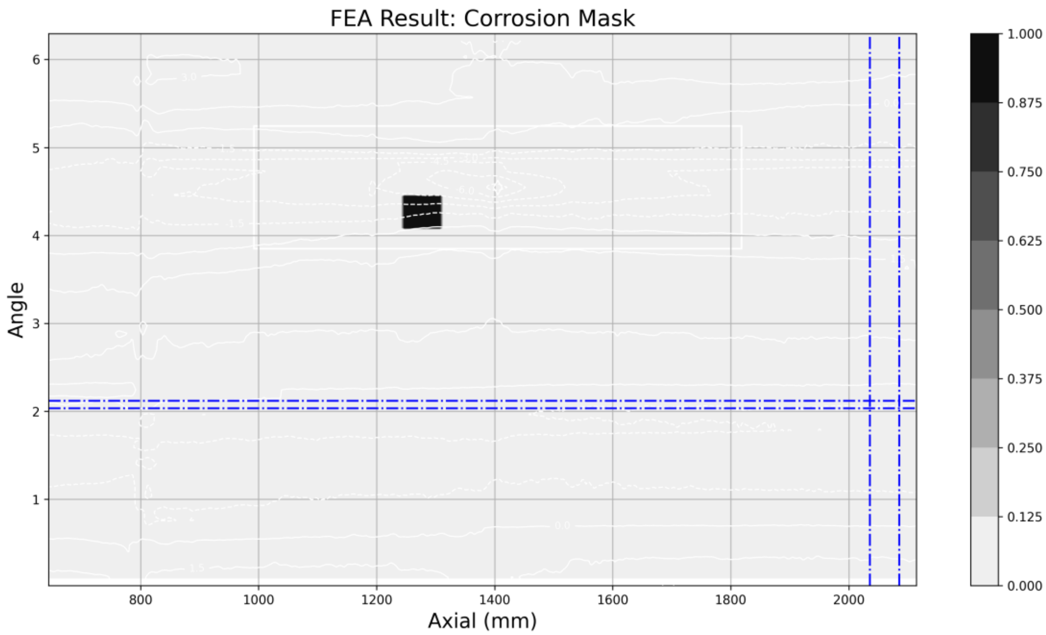

Figure 22: Corrosion Mask, used to extract corrosion stress.

Figure 23 presents the FEA maximum principal stress. The stress contour plot includes dent deformation contour lines overlaid on the maximum envelope stress through the pipe thickness. The extracted stress values at key locations are summarized below:

Table 16 – Extracted FEA Stress Values

Location	Stress Value (MPa)
Maximum	422.29
Corrosion	335.43

To account for strain hardening due to dent formation strain, the FEA stress values are multiplied by a factor of 1.15

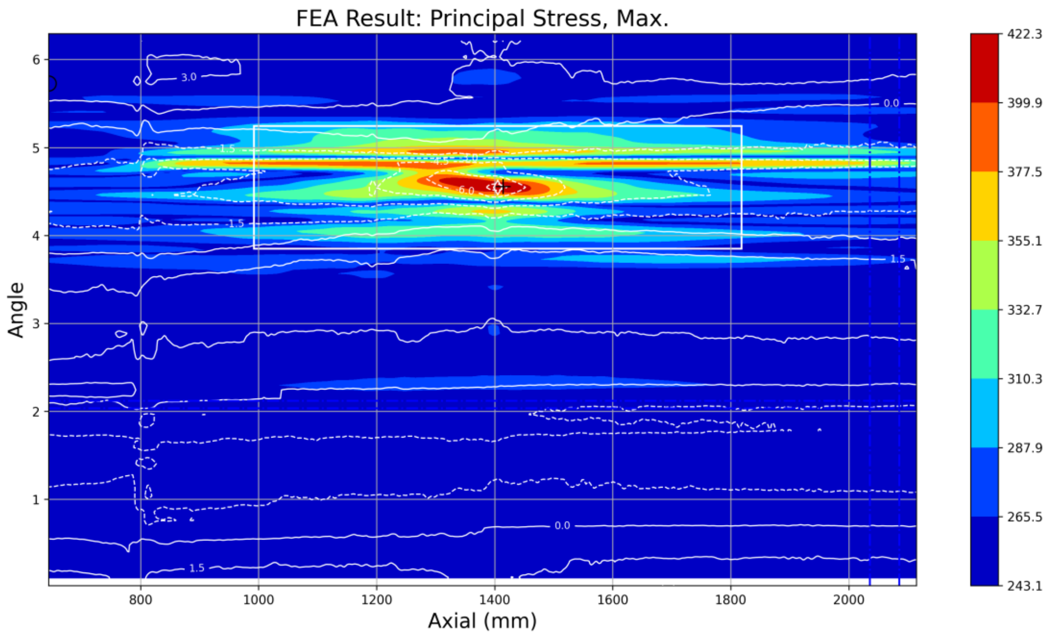

Figure 23: FEA Maximum Principal Stress.

Figure 24 shows the normalized stress plot, which represents the ratio of the maximum principal stress to the corresponding nominal hoop stress.

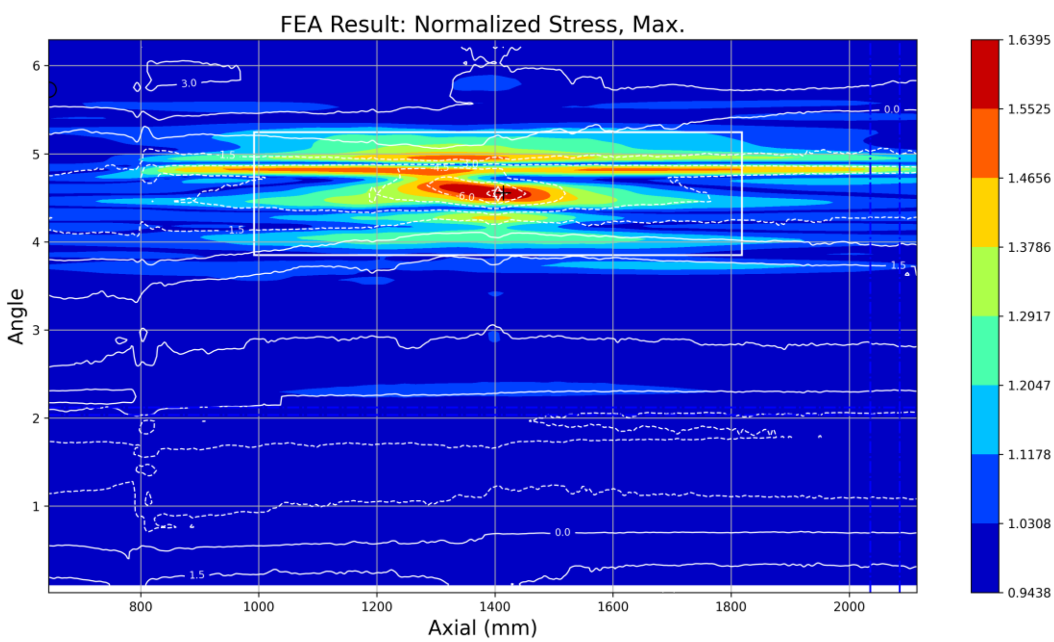

Figure 24: FEA Normalised Stress.

9.2.2 FEA Fatigue Assessment

The stress estimated from the FEA model was used to perform a probabilistic fatigue assessment. The assessment was conducted at the current dent age and projected for 1 reinspection interval (with an ILI reinspection interval of 5.0 years). To account for uncertainty in the estimated stress, the stress is assumed to follow a normal distribution, with the spread in estimated stress defined by a coefficient of variation of 10.0 %. The fatigue assessment was performed using 487.1 MPa stress, assuming no interactions. The fatigue assessment was performed using 386.9 MPa stress considering corrosion interaction. Corrosion interaction reduces fatigue life by a factor of 1.22. The highest probability of fatigue damage exceedance is at the "Maximum" location. Probabilistic fatigue assessment results are given in table below:

Table 17 – Probability of Exceedance Fatigue Damage

Dent Age	Fatigue Stress	Fatigue, Demand	Fatigue, Capacity	Fatigue, Safety Factor	Fatigue, PoF	Fatigue, Remaining Damage	Location
72.00	487.12	0.15	0.61	3.95	4.87E-06	0.45	Maximum
77.00	487.12	0.16	0.61	3.70	7.98E-06	0.44	Maximum
72.00	386.92	0.09	0.62	6.59	8.90E-08	0.52	Corrosion
77.00	386.92	0.10	0.62	6.17	1.59E-07	0.52	Corrosion
72.00	487.12	0.15	0.61	3.95	4.87E-06	0.45	Feature
77.00	487.12	0.16	0.61	3.70	7.98E-06	0.44	Feature

A deterministic fatigue assessment was conducted using conservative assumptions to evaluate the fatigue life of the dent feature. The stress used for the assessment is calculated as: Mean + 1.5 × Standard Deviation (Std.). The S-N curve intercept is adjusted to Mean - 1.0 × Std. Assessment results are summarized in table below:

Table 18 – Fatigue Deterministic Results

Deterministic Stress	SN Parameter, log a	Fatigue, Deterministic Damage	Fatigue, Deterministic Dent Life	Fatigue, Deterministic Remaining Life	Fatigue, Deterministic Factor of Safety	Location
560.19	12.39	0.15	428.91	356.91	71.38	Maximum
444.96	12.31	0.09	704.08	632.08	126.42	Corrosion
560.19	12.39	0.15	428.91	356.91	71.38	Feature

The following figures illustrate the fatigue damage demand and capacity distributions for a dent age of 77.0 years.

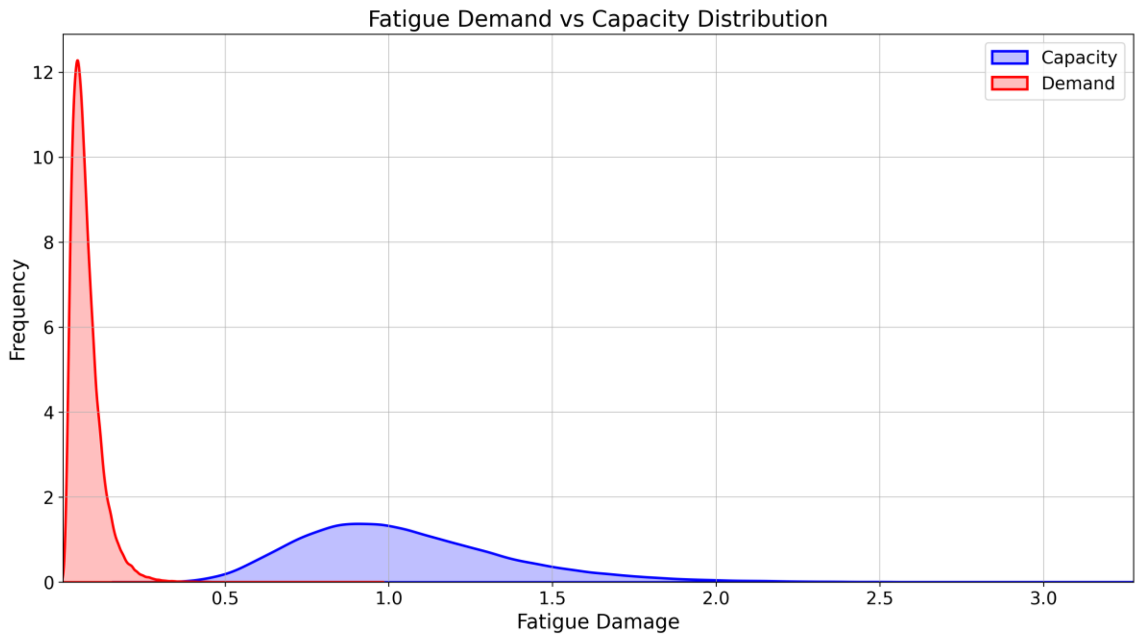

Figure 25: Fatigue damage demand and capacity distribution (Maximum).

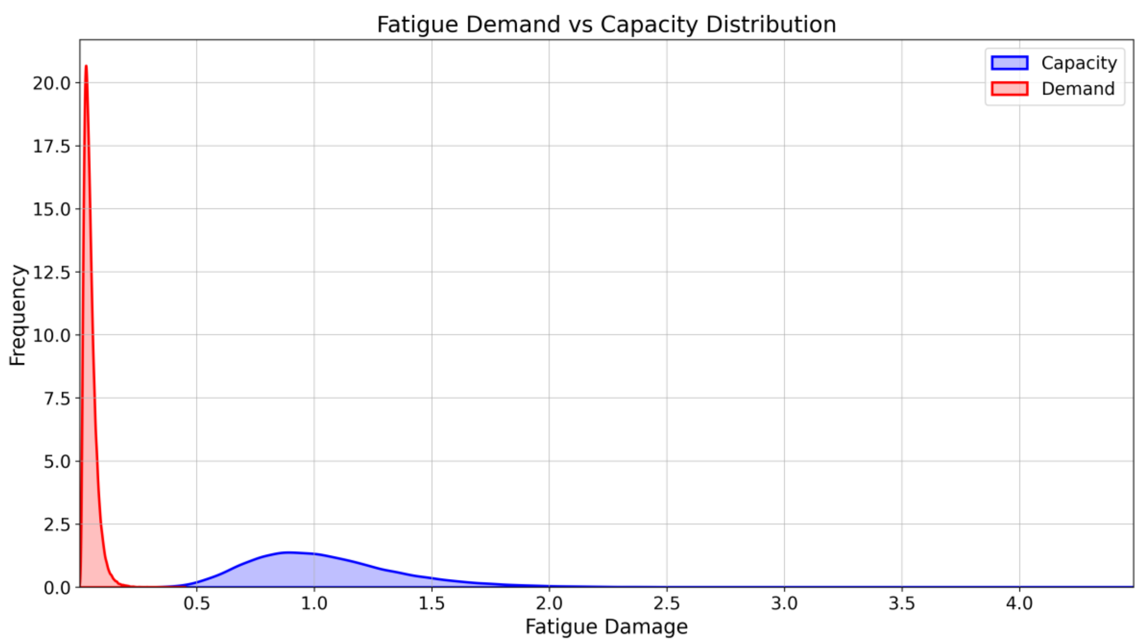

Figure 26: Fatigue damage demand and capacity distribution (Corrosion).

10 SUMMARY

Level 3 assessment is recommended for the feature.

Why assessment is recommended?

Feature is interacting with crack feature.