UKOPA

United Kingdom Onshore Pipeline Operators' Association

UKOPA Dent Management Strategy

Update February 2014

UKOPA/14/012

UKOPA Dent Management Strategy - Overview

❑ Stage 1 of the UKOPA Dent Management Strategy involved the development of dent prioritisation algorithms, simple assessment rules using published information and UKOPA best practice

❑ Stage 2 involves the development of assessment rules:-

  i) assess dents in conjunction with corrosion damage in order to define an acceptable limit for corrosion which does not impact on the static assessment and which can be accounted for in a fatigue assessment,

  ii) develop dent SCF equations and assess the application of standard SN fatigue rules for the assessment of dent, and

  iii) review the dent depth and toughness limits for the acceptability of dents associated with welds.

UKOPA Dent Management Strategy

- ❑ Assessment of dents in conjunction with corrosion – Study carried out by GLND – complete

- ❑ Development of dent SCF equations and SN fatigue rules – Study carried out by GLND – complete

- ❑ Review of dent depth and toughness limits for the acceptability of dents associated with welds – being carried out by Penspen Integrity - in progress
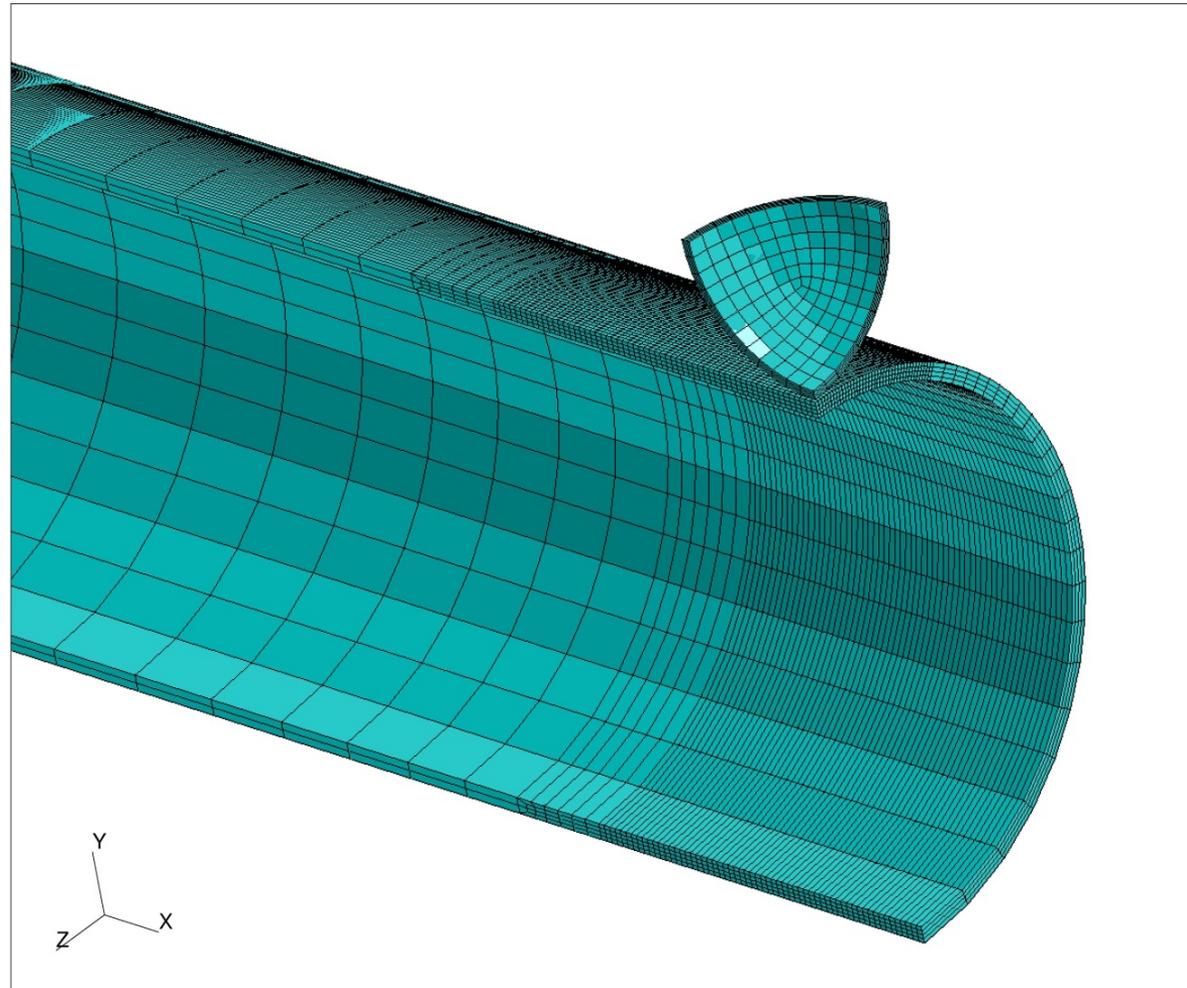
Dent + Corrosion, Dent Fatigue

GLND Report 11631 –

Study to Investigate the Acceptability of 20% Corrosion Metal Loss Associated with a Plain Dent in a Pipeline
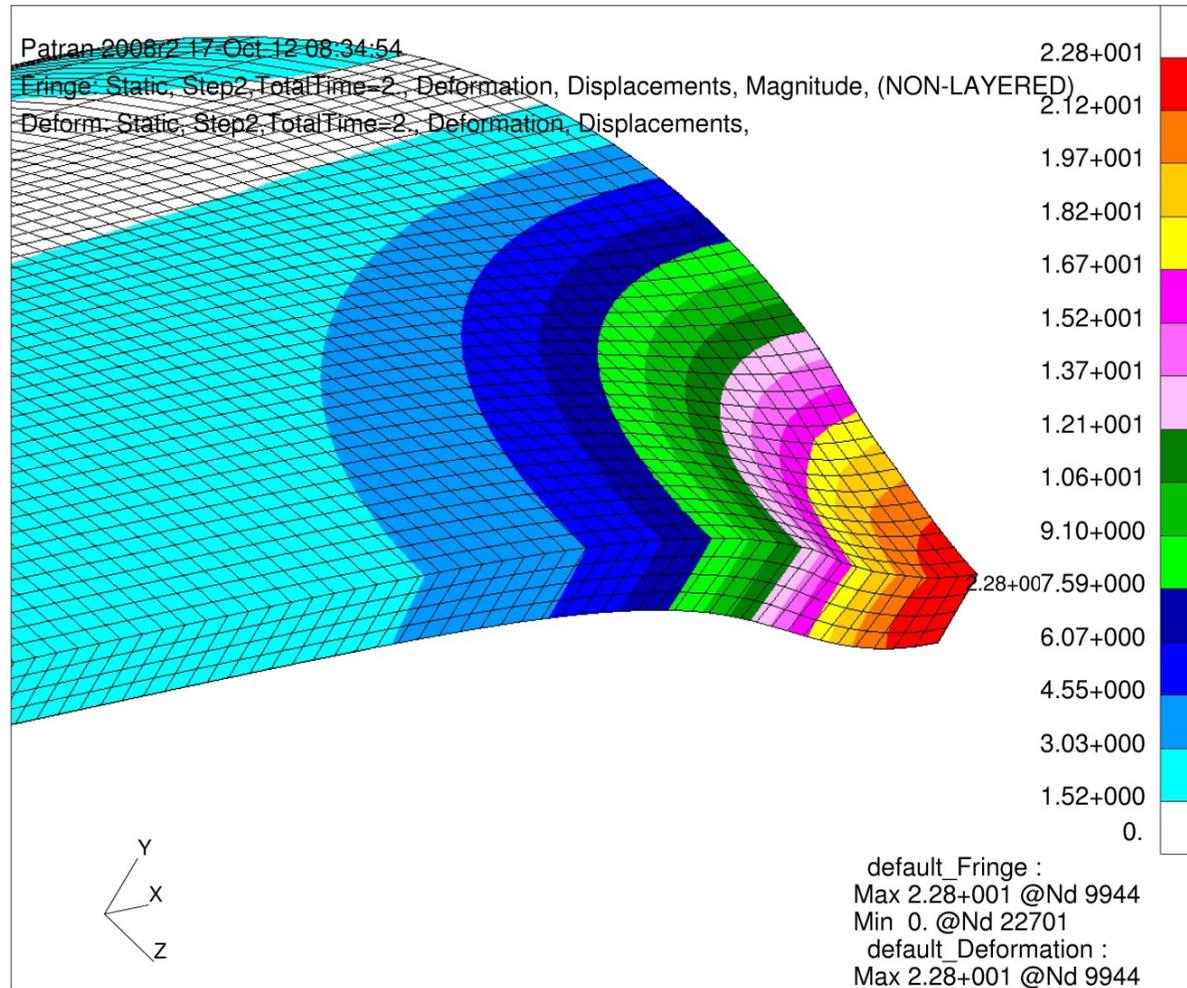
GLND Report 12505 –

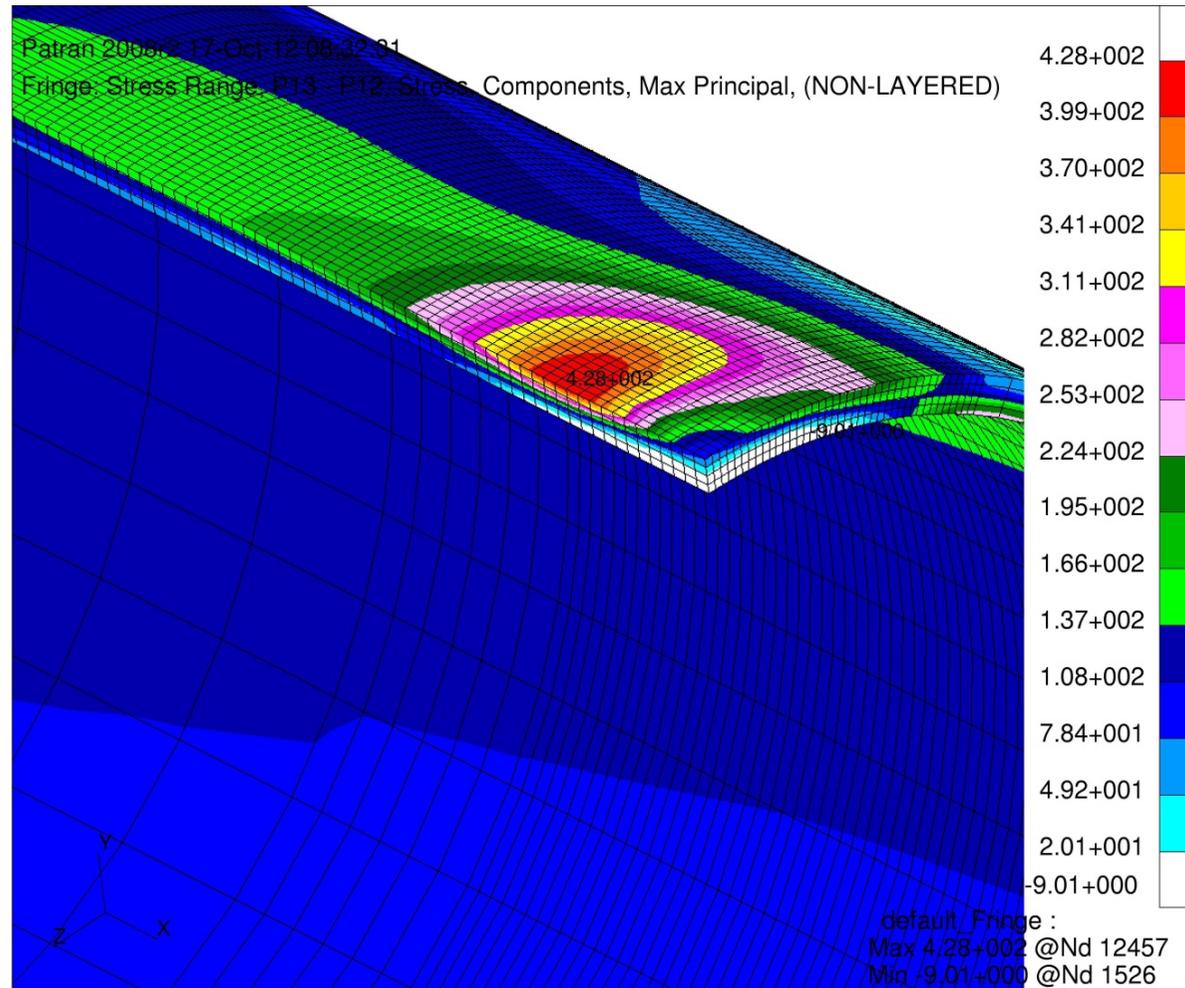Feasibility Study: Fatigue Assessment of Plain Dent Damage

FEA Model

323.9x9.5mm - Displacement Predictions

323.9x9.5mm – Stress Range

Dent + Corrosion

GLND Report 11631 –

Study to Investigate the Acceptability of 20% Corrosion Metal Loss Associated with a Plain Dent in a Pipeline

The dent plus corrosion acceptance limits specified in the Dent Management Strategy of 6%OD dent depth and 20% wt corrosion depth are greater than those specified in pipeline codes, currently used by some UKOPA member companies.

The study undertaken by GLND reviewed the most recent industry guidance and research work undertaken on combined dent plus corrosion work, with supporting finite element (FE) analyses to justify the UKOPA limits.

Conclusions and Recommendations

❑ A review of a limited number of full-scale tests found in the literature support the UKOPA limits of 6%OD dents with corrosion up to 20%t in depth in pipelines operating up to 72% SMYS.

❑ FEA of dents + 20% depth corrosion showed failure pressures were in excess of those for corrosion only.

❑ A model has been developed for predicting the remaining life of a dent plus corrosion feature, based on the EPRG dent model and a closed form equation developed for the GL Noble Denton corrosion model.

❑ It is recommended that the UKOPA dent management strategy is updated to take account of the results of this study.

Dent Fatigue Assessment

GLND Report 12505 –

Feasibility Study: Fatigue Assessment of Plain Dent Damage

The UKOPA Dent Management Strategy recommends use of the EPRG methodology for assessing dent fatigue life, this methodology is conservative, an alternative is required.

Preferred approach - Use dent SCF + standard fatigue SN curves in a generic fatigue life calculation procedure

The study undertaken by GLND reviewed published dent SCF equations, compiled and compared SCFs calculated using FEA, and carried out fatigue calculations.

Conclusions and Recommendations

❑ A number of published dent fatigue methodologies have been reviewed and compared. The review confirms that the EPRG dent fatigue methodology is conservative, and predicts low fatigue lives in comparisons with other methodologies.

❑ The GLND dent fatigue methodology gives predictions which compare best with a full scale fatigue test.

❑ It is recommended that the UKOPA dent management strategy is updated to use the GLND dent fatigue methodology, and that additional fatigue calculations for UKOPA member pipelines are carried out using the GLND methodology and included in the dent management strategy.

Dent Damage Data - Summary

❑ The results indicate that ILI measurements overestimate depth and underestimate width and length

❑ ILI measurements are recorded under operational pressure, whereas field measurements are recorded at reduced pressure, so field measurements would be expected to be greater

❑ The accuracy of dent size inspection data impacts on establishing the maximum acceptable dent parameters

❑ The majority of dent depths are ≤ 5% OD

❗ A significant proportion of top of line dents had associated metal loss damage (gouges)

Dent Damage Data – Current Database

Field Measurements Only

Product	Dents
Natural Gas	277
Ethylene	27
Spiked Crude	9
NGL	1
CO	1
	315

Cause of Dent	Number	%
External Interference	109	34.6%
Original Construction Damage	108	34.3%
External Corrosion	10	3.2%
Girth Weld Defect	13	4.1%
Ground Movement	12	3.8%
Pipe Mill Damage	8	2.5%
Pipe Defect	3	1.0%
Other / Unknown	52	16.5%
TOTAL	315	100.0%

Depth / Diameter Ratio	Number
Greater than 10%	19
Greater than 5%	42
Greater than 1%	134
Greater than 0.5%	187

Dent depth and toughness limits for dents associated with welds

Study undertaken by Penspen Integrity

Task 1 – Literature Review Report 13131-RPT-001 Rev B

Review of recent international work covering dents on welds, in particular welds of unknown quality (analytical studies, testing and failures)

Complete, comments have been returned

Task 2 – Draft additional guidance – draft complete, to be released for comment

Task 3 – Test Cases – in progress, analysis of the Essar failure is complete

Work to be complete in March 2014

Task 1 -Conclusions

- Existing guidance is conservative

- Existing best practice is given in PDAM (requires weld quality and toughness)

- There is no assessment method for dents on welds of poor quality

- Future assessment methods are likely to be based on FEA

Task 2 – Key findings for Additional Guidance

- Dents associated with welds have shorter fatigue lives

- The acceptable depth for a dent associated with a weld is less than a dent in plain pipe

- There is no evidence for changing the current depth acceptability limit of 2% OD for dents associated with welds

- Pipelines transporting liquids are more susceptible to fatigue at dents

- There is no assessment method for dents on welds of poor quality

- Future assessment methods are likely to be based on FEA

- The dent shape has a significant affect on SCF

Task 2 – Key findings for Additional Guidance

From Kiefner and Leewis for PRCI:

❑ There is no single equation or expression currently available that is capable of predicting the safe operating pressure or time to failure of a dent or mechanical damage which is a) simple and b) accurate

❑ Simple models tend to be inaccurate and conservative as a result of excessive simplification of a complex problem

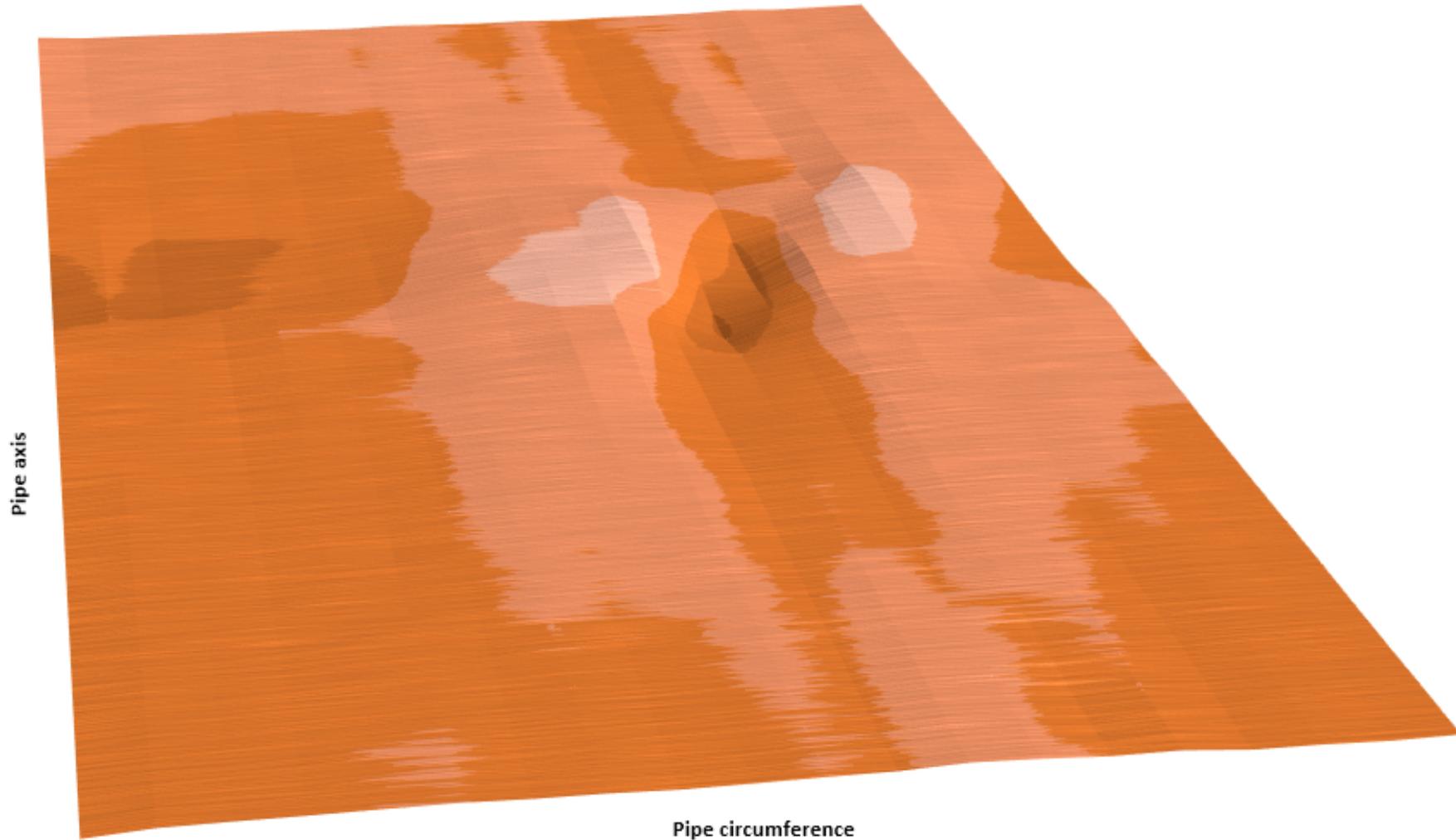❑ Complex procedural approaches combining FEA and fracture mechanics will continue to evolve

Task 3 – Test Cases

- ❑ Essar dent failure

- ❑ Exxon data

FEA model
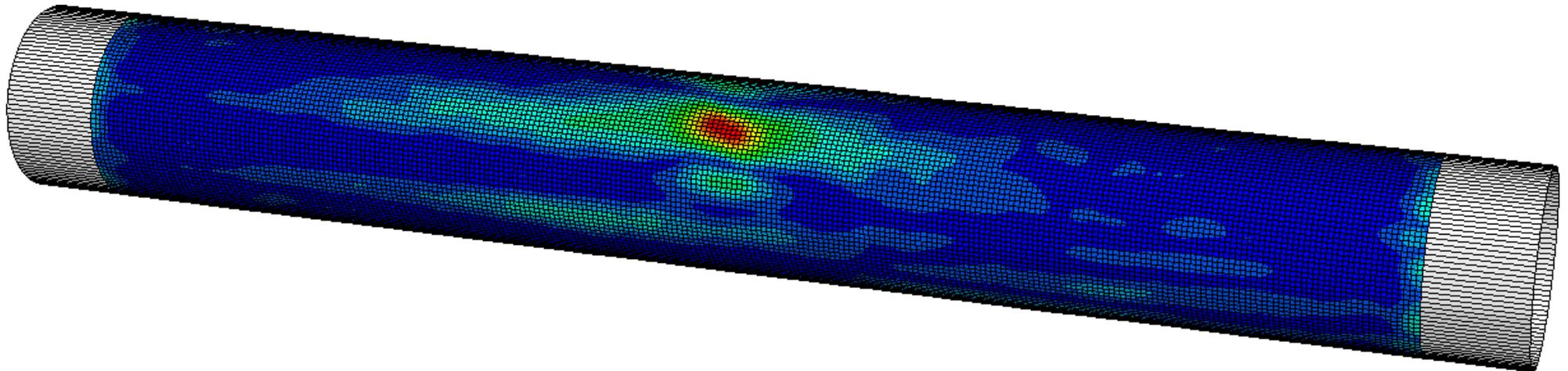
FEA geometry model – Essar dent

Pipe axis

Pipe circumference

Analysis of Essar Dent

❑ Dent assumed to be unconstrained

❑ MAOP 50 bar results in a maximum elastic stress of 944 MPa

❑ Dent fails the fatigue assessment

❑ Similar dent depths are recorded on Exxon pipelines, one which failed and one which did not are being considered in the current study

Further Studies

- Further consideration of weld quality issues:
    - Very poor quality welds – no dents allowed
    - Low uncertain quality welds – dents allowed with reduced strain limit + fatigue assessment
    - Good quality welds – dents allowed with increased strain limit + fatigue assessment

- Screening of dents reported in UKOPA liquid pipelines:
    - Determine pressure cycle regime
    - Process and smooth 3D dent geometry data and rank geometric parameters according to significance to pipeline integrity
    - Calculate peak strain and stress range (FEA)
    - Carry out fatigue analysis to determine remaining life for a selected sample of dents based on SCF, rank dents based on predicted remaining life