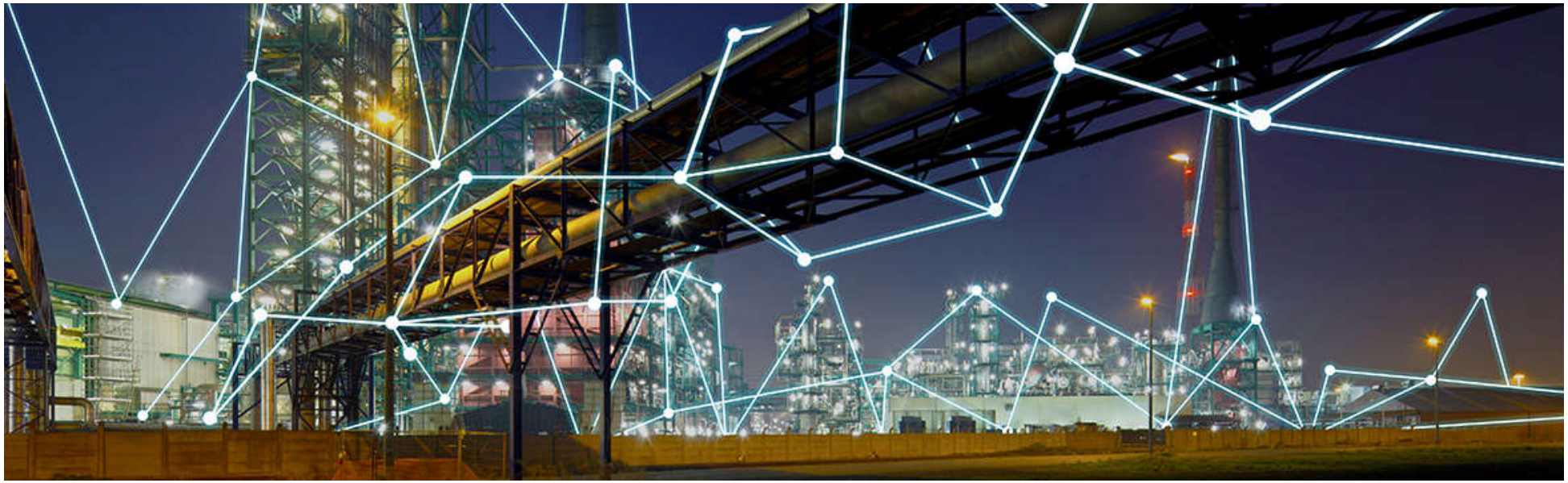


ASSESSMENT OF COMBINED DEFECTS

A Roadmap to Zero Incidents · Paul Bailes · © ROSEN Group · Paris – France - 28 November-2019

ROSEN
empowered by technology

CONTENTS

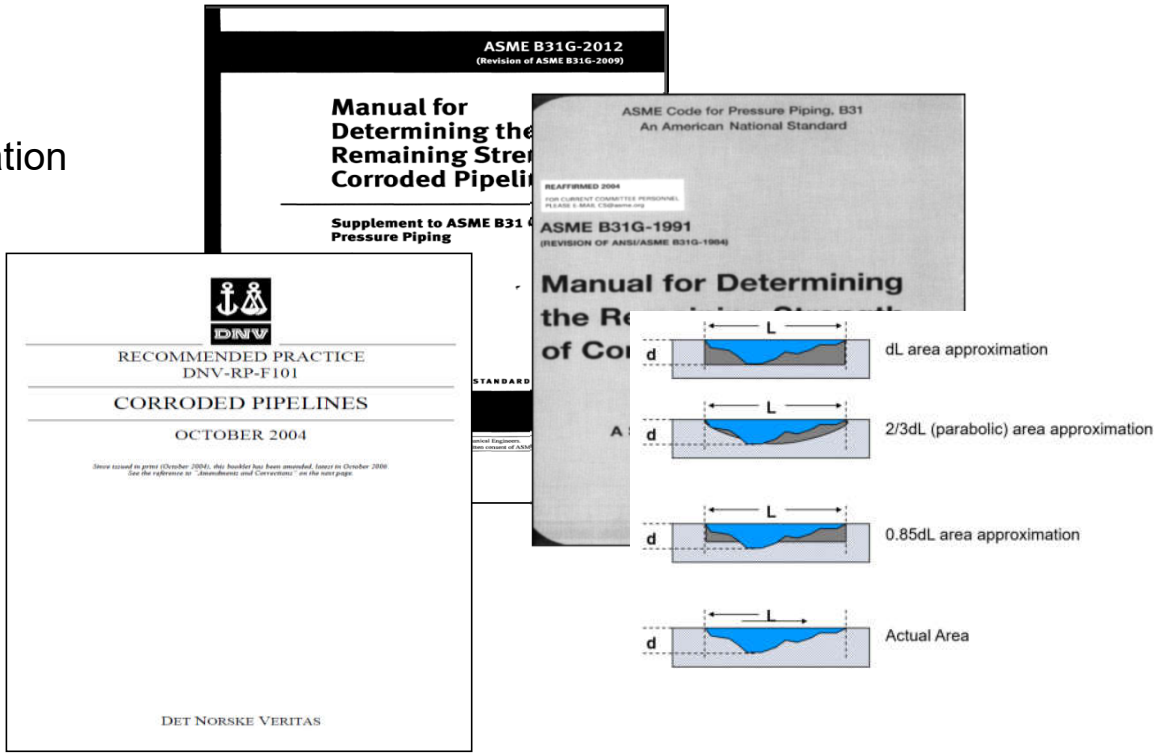
- Codified Assessment Methods
- Combined Inspection Technologies
- Combined Defects
- Key Considerations for Assessment of Combined Defects
- Case Study 1 – Dent Combined With Internal Cracks
- Case Study 2 – Dent Combined With External Gouge
- Case Study 3 – Remaining Life Assessment, Subsea Pipeline With 10% Dent

CONTENTS

- Codified Assessment Methods
- Combined Inspection Technologies
- Combined Defects
- Key Considerations for Assessment of Combined Defects
- Case Study 1 – Dent Combined With Internal Cracks
- Case Study 2 – Dent Combined With External Gouge
- Case Study 3 – Remaining Life Assessment, Subsea Pipeline With 10% Dent

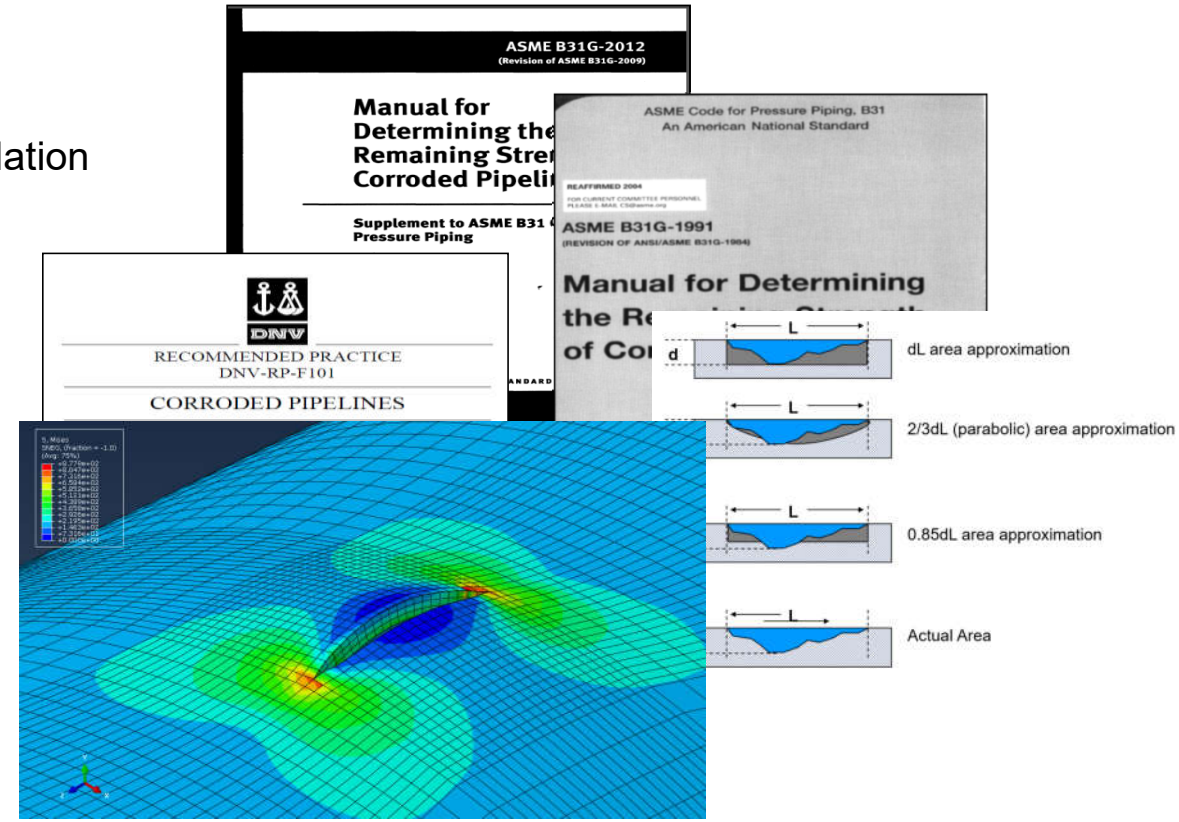
CODIFIED METHODS

- Predominantly for assessing features in isolation
- Widely used for many years



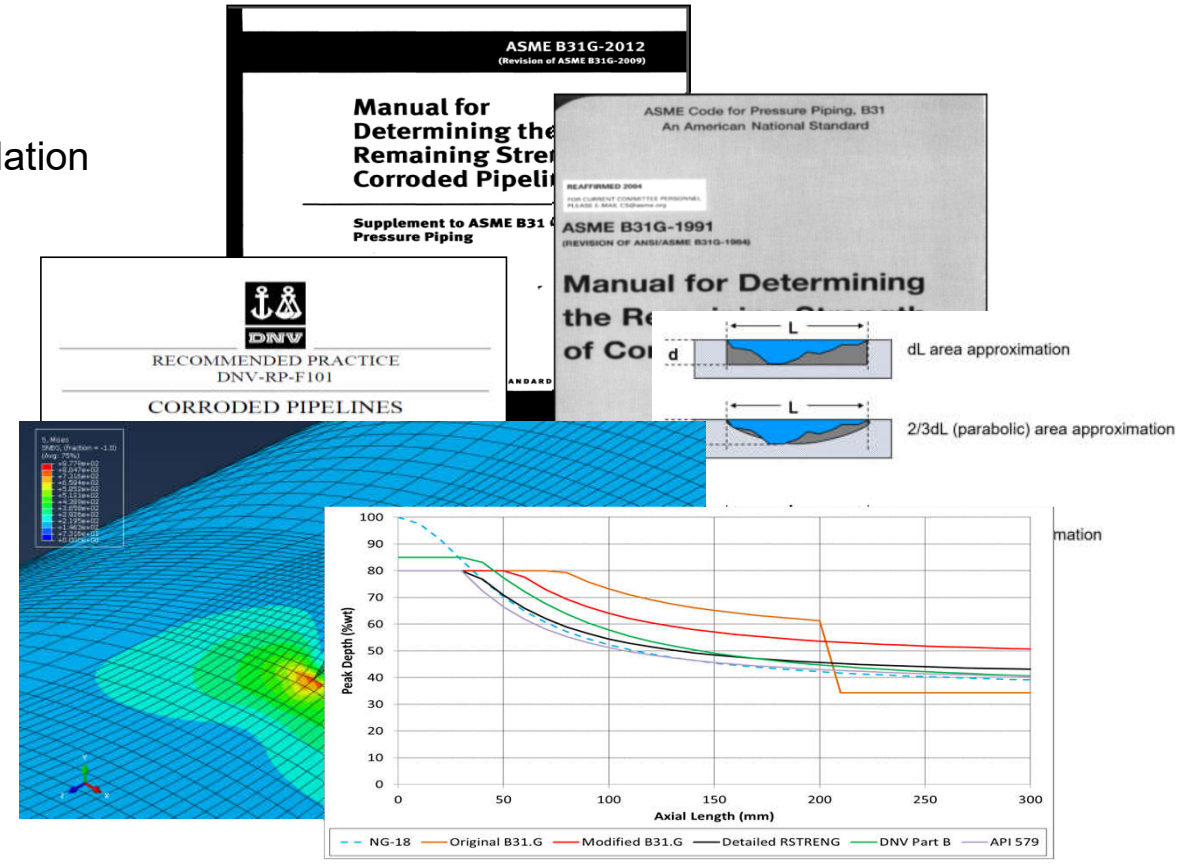
CODIFIED METHODS

- Predominantly for assessing features in isolation
- Widely used for many years
- Validated through Finite Element Analysis



CODIFIED METHODS

- Predominantly for assessing features in isolation
- Widely used for many years
- Validated through Finite Element Analysis
- Conservatisms built into assessments
- Can consider multiple loads (axial, bending etc.)



CONTENTS

- Codified Assessment Methods
- Combined Inspection Technologies
- Combined Defects
- Key Considerations for Assessment of Combined Defects
- Case Study 1 – Dent Combined With Internal Cracks
- Case Study 2 – Dent Combined With External Gouge
- Case Study 3 – Remaining Life Assessment, Subsea Pipeline With 10% Dent

COMBINED INSPECTION TECHNOLOGIES

EMAT + AFD

UT-C / UT-A + AFD

UT + CDP

UT/UT-C/UT-A/AFD/CDP + XGP

COMBINED INSPECTION TECHNOLOGIES

EMAT + AFD

Cracks and corrosion/milling

UT-C / UT-A + AFD

Cracks and corrosion/milling

UT + CDP

Corrosion and laminations

UT/UT-C/UT-A/AFD/CDP + XGP

Laminations/Cracks/Corrosion/

Milling and Dents

CONTENTS

- Codified Assessment Methods
- Combined Inspection Technologies
- Combined Defects
- Key Considerations for Assessment of Combined Defects
- Case Study 1 – Dent Combined With Internal Cracks
- Case Study 2 – Dent Combined With External Gouge
- Case Study 3 – Remaining Life Assessment, Subsea Pipeline With 10% Dent

COMBINED DEFECTS

	Corrosion	Milling	Cracks	Dents	Laminations
Corrosion					
Milling	Cluster				
Cracks	SCC indicator	Misclassified Corrosion?			
Dents	Codified Guidance	Stress Concentration Factor (SCF)	Pressure dependant		
Lamination	Increase Corroded Surface Area	Increase Metal Loss Surface Area	HIC?	NA	

COMBINED DEFECTS

	Corrosion	Milling	Cracks	Dents	Laminations
Corrosion					
Milling	Cluster				
Cracks	SCC indicator	Misclassified Corrosion?			
Dents	Codified Guidance	Stress Concentration Factor (SCF)	Pressure dependant		
Laminations	Increase Corroded Surface Area	Increase Metal Loss Surface Area	HIC?	NA	

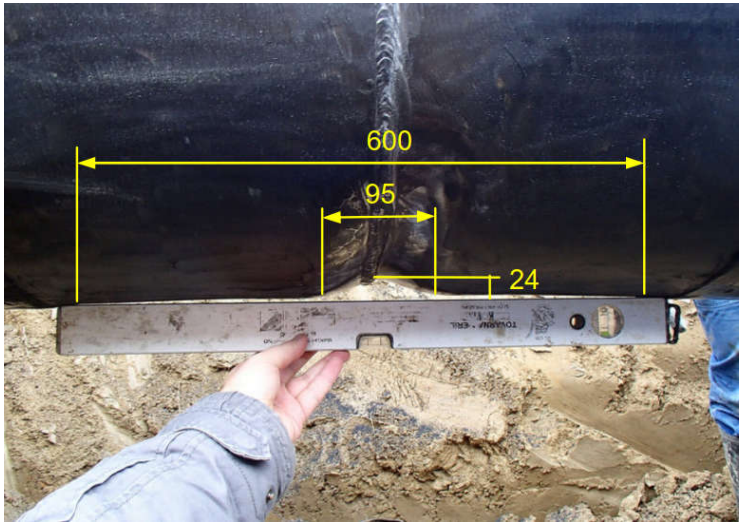
	Axial Stresses				
	Bending Strain - Construction	Bending Strain - Geo-hazards	Seismic Loading	Thermal Cycling	Freespans
Corrosion	Increased Complexity				
Milling					
Cracks					
Dents					
Laminations					

Must also consider possibility of additional axial loading

COMBINED DEFECTS

Dent Defect Combinations

- Limited Codified Guidance
  - Dent with Metal Loss
  - Dent on Weld
- Level 2 Guidance (e.g. API 579) conservative
- Options before detailed FEA?:
  - More detailed inputs (material certificates etc.)
  - Model geometry in (simple) FEA to obtain Stress Concentration Factor (SCF), and use in fracture/fatigue assessments
- Pending API Guidance API RP 1183
- Not prescriptive



CONTENTS

- Codified Assessment Methods
- Combined Inspection Technologies
- Combined Defects
- Key Considerations for Assessment of Combined Defects
- Case Study 1 – Dent Combined With Internal Cracks
- Case Study 2 – Dent Combined With External Gouge
- Case Study 3 – Remaining Life Assessment, Subsea Pipeline With 10% Dent

ASSESSMENT OF COMBINED DEFECTS

ROSEN
empowered by technology

Key Considerations

Prescriptive guidance often not available – case by case

We have to understand the origin of the features, to develop the appropriate assessment

- Are the features interacting in terms of failure mechanism?
- Were the cracks caused by the dent? Or pre-existing (manufacture)

Note: Cracks initiated by indentation at locations which challenge the best ILI technologies

- Is there a mechanism for crack growth?
- Purpose of the assessment – deterministic or to prove a threat to be low?
- What is the location of the feature (internal or external crack)?
- Are there any other external loads present?

CONTENTS

- Codified Assessment Methods
- Combined Inspection Technologies
- Combined Defects
- Key Considerations for Assessment of Combined Defects
- Case Study 1 – Dent Combined With Internal Cracks
- Case Study 2 – Dent Combined With External Gouge
- Case Study 3 – Remaining Life Assessment, Subsea Pipeline With 10% Dent

COMBINED DEFECTS – CASE STUDIES

ROSEN
empowered by technology

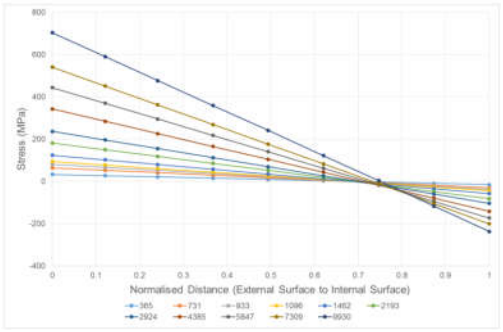
Case Study 1

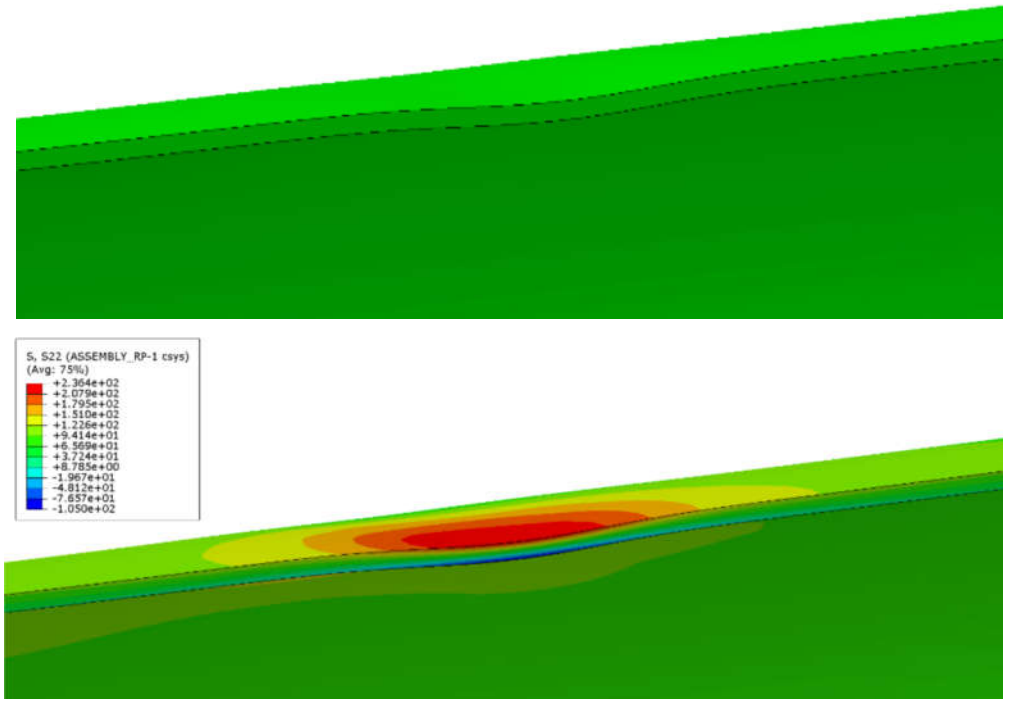
- Dent on 10 inch oil pipeline
- Verified in-field, small axial crack indications (<1 mm) reported on internal surface
- Time limitations on repair work – 18 months (internal approval required for Type B sleeve)
- Two fatigue assessments performed
  - Fracture mechanics – internal crack fatigue growth
  - S-N curve – crack initiation and growth on external surface

COMBINED DEFECTS – CASE STUDIES

Case Study 1

- Dent was modelled using in-field laser scan data
- Significant tensile stresses on external surface
- Compressive stress on internal surface

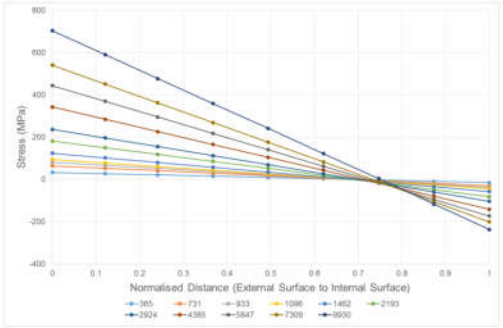




COMBINED DEFECTS – CASE STUDIES

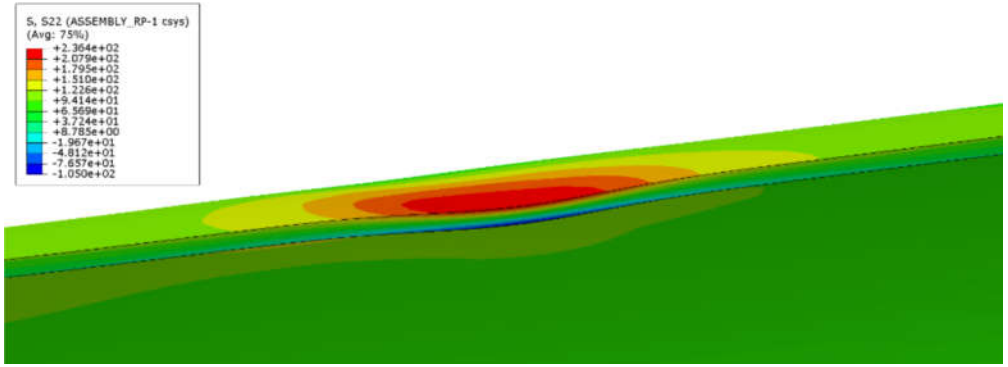
Case Study 1

- Dent was modelled using in-field laser scan data
- Significant tensile stresses on external surface
- Compressive stress on internal surface



Fatigue Life (internal crack) > 18 months

Fatigue life (external crack) >50 years



CONTENTS

- Codified Assessment Methods
- Combined Inspection Technologies
- Combined Defects
- Key Considerations for Assessment of Combined Defects
- Case Study 1 – Dent Combined With Internal Cracks
- Case Study 2 – Dent Combined With External Gouge
- Case Study 3 – Remaining Life Assessment, Subsea Pipeline With 10% Dent

COMBINED DEFECTS – CASE STUDIES

Case Study 2

Dent Gouge FEA

- 24” Oil pipeline operating at 100 bar
- In-field investigation identified dent gouge combination

Unable to weld onto live pipeline – next shut-down opportunity > 6 month

Can the pipeline be operated until shut-down opportunity?

COMBINED DEFECTS – CASE STUDIES

Case Study 2

Dent Gouge FEA

- No Caliper ILI
- Depth based measurements to model dent and gouge
- Account for grinding of gouge (up to 0.7 mm) to remove linear indications

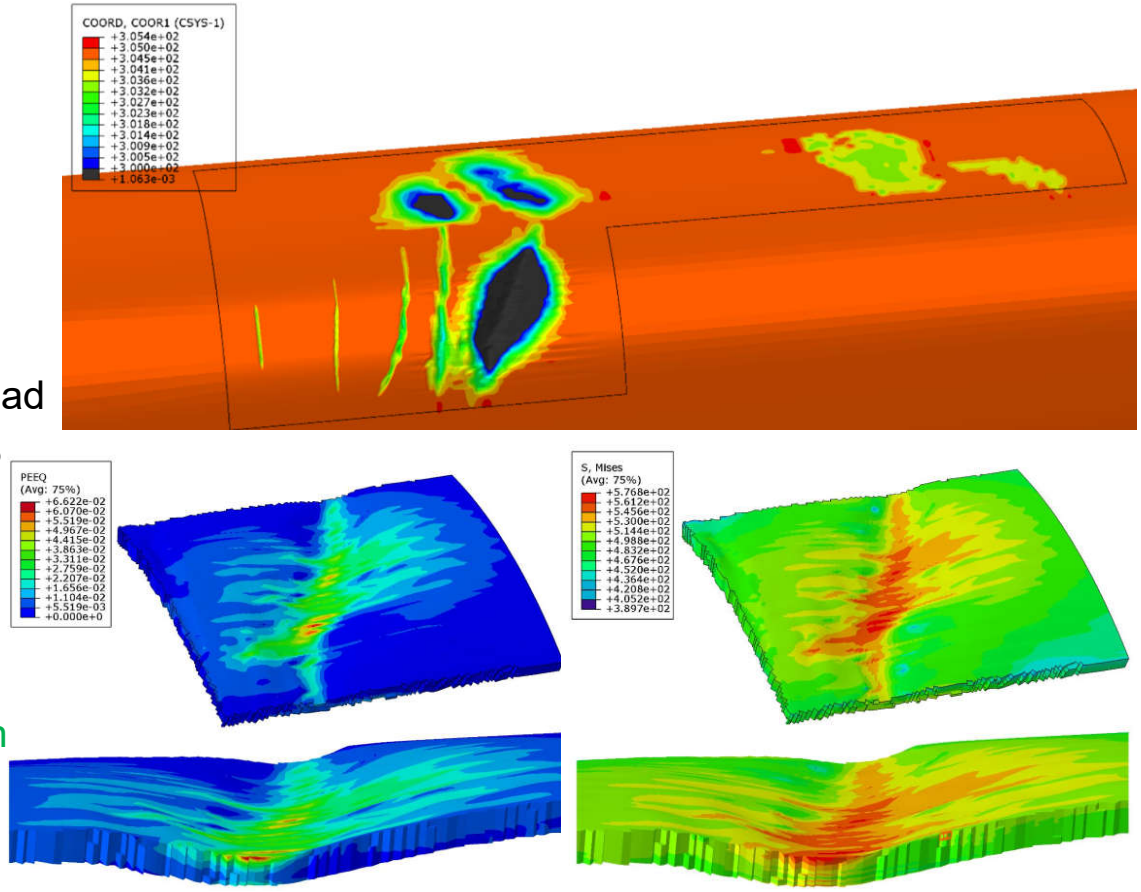
COMBINED DEFECTS – CASE STUDIES

empowered by technology

Case Study 2

Dent Gouge FEA

- Dent and gouge modelled in FEA
- Static strength acceptable when considering load Safety factor recommended by API 579 of 1.53
- Fatigue life in excess of 50yrs from 2008 construction
- Defect re-coated and backfilled until shut-down was feasible



CONTENTS

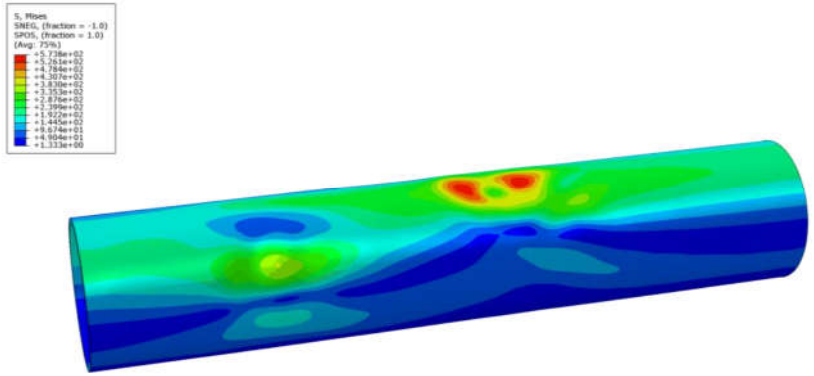
- Codified Assessment Methods
- Combined Inspection Technologies
- Combined Defects
- Key Considerations for Assessment of Combined Defects
- Case Study 1 – Dent Combined With Internal Cracks
- Case Study 2 – Dent Combined With External Gouge
- Case Study 3 – Remaining Life Assessment, Subsea Pipeline With 10% Dent

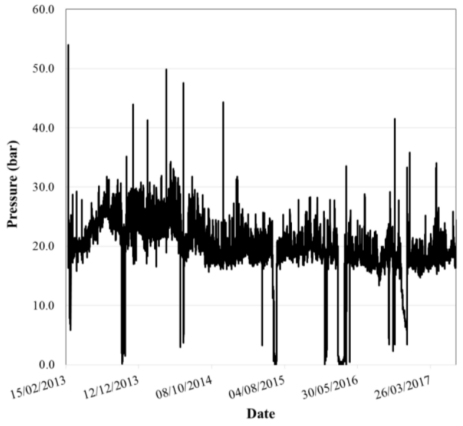
COMBINED DEFECTS – CASE STUDIES

Case Study 3

Remaining Life Assessment of 10.2% OD Dent on Subsea Pipeline

- Unacceptable to conventional fatigue assessment
- Pipeline scheduled for decommissioning in 3 years….
- Pressure history indicated a large spike to 54 bar following detection of the dent
- Required bespoke pseudo-hydrotest type assessment





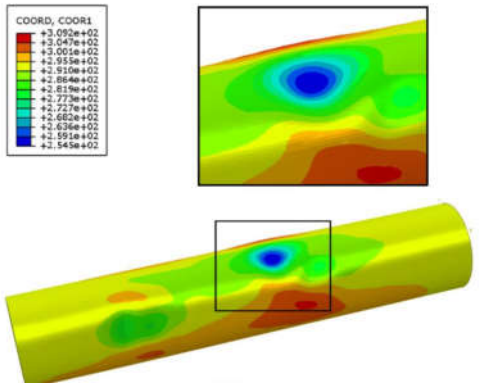
COMBINED DEFECTS – CASE STUDIES

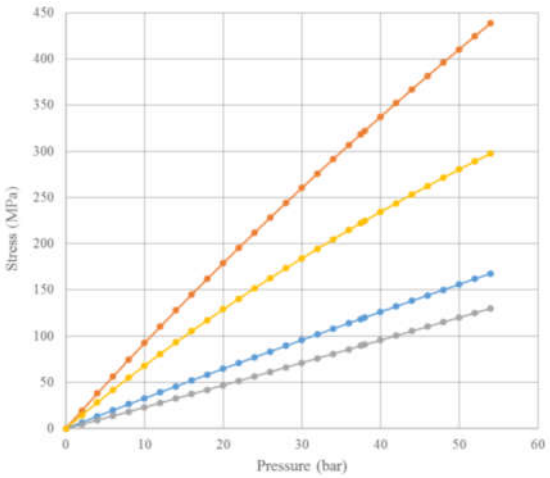
Case Study 3

Remaining Life Assessment of 10.2% OD Dent on Subsea Pipeline

- Dent modelled in FEA to review relationship between internal pressure and the axial and circumferential stresses

- Fracture assessments to determine maximum allowable crack sizes that could have survive 54 bar spike:
  - Semi-elliptical
  - Coincident with highest stress locations
  - Axial and circumferential cracks
  - Aspect ratios



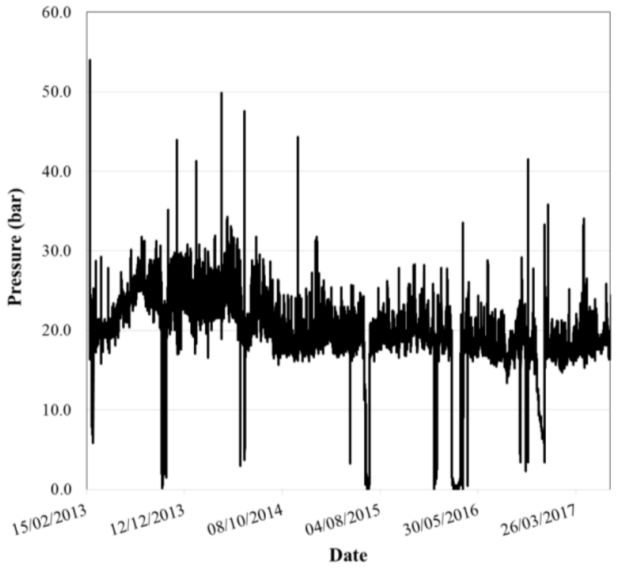


COMBINED DEFECTS – CASE STUDIES

Case Study 3

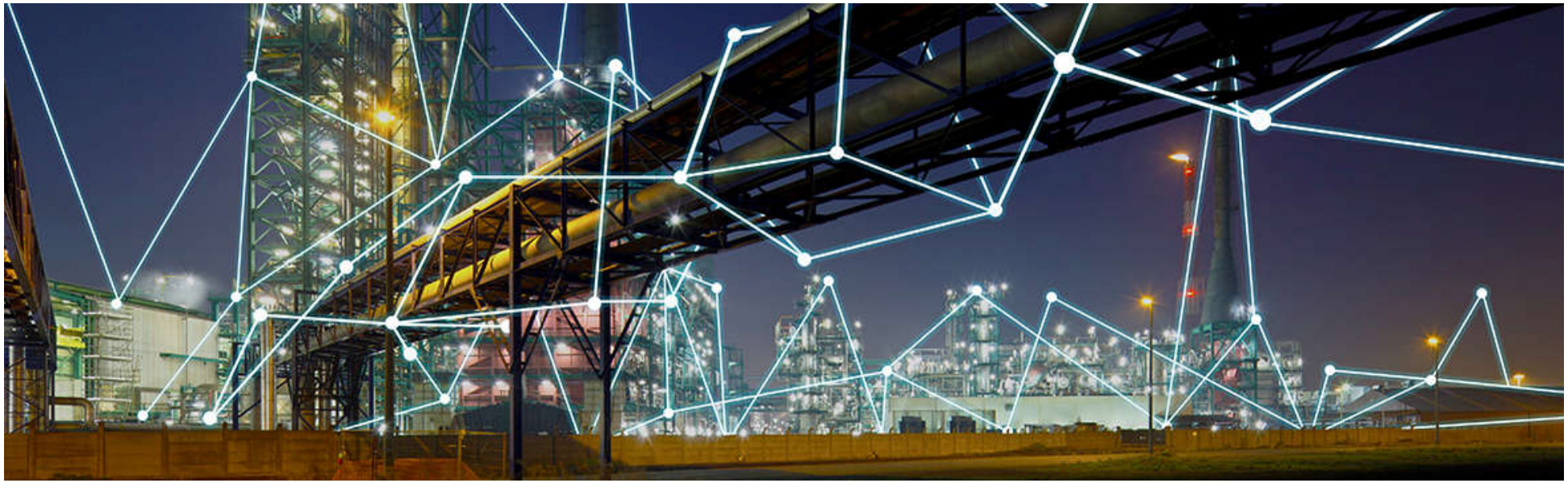
Remaining Life Assessment of 10.2% OD Dent on Subsea Pipeline

- Pressure data converted to stress cycles to grow the allowable cracks that could have survived pressure spike
  - 54 bar pressure spike → decommissioning date
- Fracture assessments performed at fully grown dimensions – lowest failure pressure defines new Maximum Operating Pressure



Low risk of fracture due to fatigue growth if operating pressure <48 bar

New Maximum Operating Pressure acceptable to operator



THANK YOU FOR JOINING THIS PRESENTATION.

ROSEN
empowered by technology