# Risk Assessment Work Group

UKOPA Technical Seminar

Report from RAWG Dent Workshop 1
May 2009

UKOPA/09/00xx

# UKOPA Work – Integrity Assessment of Dents

Background

- MFL tools have been identifying dent features for a number of years (10)
- Existing recognised assessment methods identify dents as features which require investigation and assessment
- A limited number of failures due to dents have been reported
- The majority of dents are likely to result from construction /installation

UKOPA initiated work to identify industry best practice –

Stage 1 - Integrity Assessment of Construction Dents Subject to Fatigue Loading

# Integrity Assessment of Construction Dents Subject to Fatigue Loading

## Report Prepared for UKOPA

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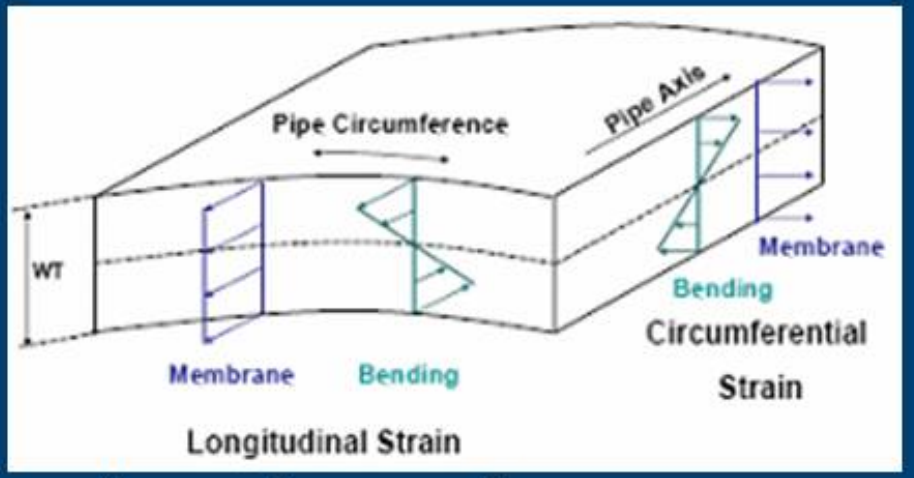
# Integrity Assessment of Dents in Fatigue

## Proposed Scope of Work Phase 1: Feasibility Study

- Develop an understanding of the scale of the problem
  - Review pipeline dent failures
  - Review research being conducted by operators and regulators, particularly in the USA
- Critically review current published research findings and the feasibility of these approaches to enable operators to develop dent management strategies
- Advise UKOPA of the benefits of conducting specific additional work.
- If appropriate, develop a workscope for Phase 2.

# Strain Based Assessments

- Methodology detailed in ASME B31.8 (2003)
- Have to consider:
  - Longitudinal bending strain
  - Circumferential bending strain
  - Longitudinal membrane strain
  - Circumferential membrane strain




- Calculate strain in each direction (based on radius of curvature)
  - Literature divided on best method for calculation
- Compare against code limit of 6% strain
- Requires measurement of dent profile

# Static Assessment Methods
# Depth Based

| | Plain Dents | |
|---|---|---|
| | **Constrained** | **Unconstrained** |
| ASME B31.8 | Upto 6%OD | |
| ASME B31.4 | Upto 6% OD in pipe diameters > NPS 4<br>Upto 6mm in pipe diameters < NPS 4 | |
| API 1156 | Upto 6%OD<br>>2% OD requires a fatigue assessment | |
| EPRG | ≤7%OD at a hoop stress of 72%SMYS | |
| PDAM | Upto 10%OD | Up to 7%OD |
| Z662 | Upto 6mm for ≤ 101.6mm OD or<br><6%OD for >101.6mm | |

# Static Assessment Methods
# Depth Based

| | Dents at welds | Dents with cracks or gouges | Dents with corrosion |
|---|---|---|---|
| ASME B31.8 | Not allowed | Not allowed | Analyse separately |
| ASME B31.4 | Not allowed | Not allowed | Not allowed |
| API 1156 | Upto 2% OD | Not allowed | Not considered |
| EPRG | Not allowed | Not allowed | Not allowed |
| Z662 | Not allowed | Not allowed | Not allowed |

# Static Assessment Methods - Depth Based

## In gas pipelines:

- Due to re-rounding effects dents >2%OD are likely to be constrained
- Dents on the bottom of the pipe (particularly deep dents) assumed to be plain rock dents

## In liquid pipelines:

- Unconstrained dents >5%OD extremely unlikely
- Acceptability of unconstrained dents >2% should be based on a dynamic assessment

# Dent Measurement & Detection

| Dent Attribute | Geometry Tool | High Resolution Geometry Tool | Metal Loss Tool | Crack Detection Tool |
|---|---|---|---|---|
| Location along pipeline | ✓ | ✓ | ✓ | ✓ |
| Orientation | ✓ | ✓ | ✓ | ✓ |
| Size (%OD) | ✓ | ✓ | | |
| Size and shape of dent | | ✓ | | |
| Detects dents on welds | ✓ | ✓ | ✓ | ✓ |
| Detects metal loss in dent | | | ✓ | |
| Detects cracks in dents | | | | ✓ |
| Detects rock dents | | | | |

# API Field Guide for Dent Assessment

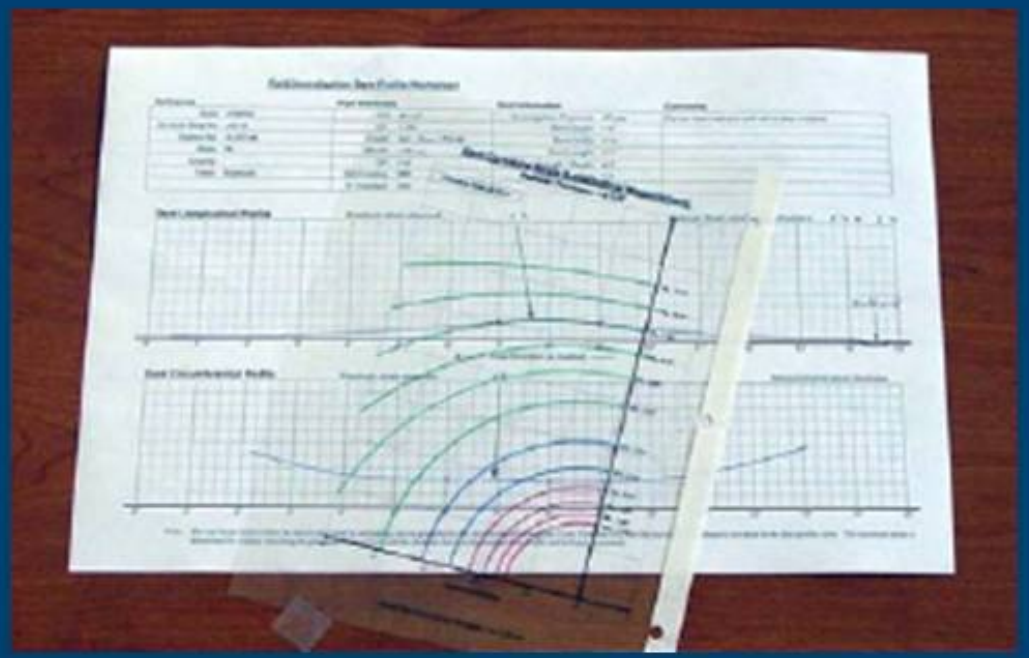
- Gives a risk-ranking methodology for dent severity

$$P = (P_m + P_i)\frac{d}{D} = (A + B + C + W + M + R)\frac{d}{D}$$

- $P_m$ represents the pipe properties and operational characteristics which depend on:
  - A = geometry (D/t) ratio
  - B = relative risk of brittle fracture
  - C = relative operational risk – pressure cycling factor
- $P_i$ represents ILI data
  - W = presence of welds & severity of welds
  - M = corrosion caused metal loss
  - R = dent location

# Duke Energy (DEGT) Dent Strategy

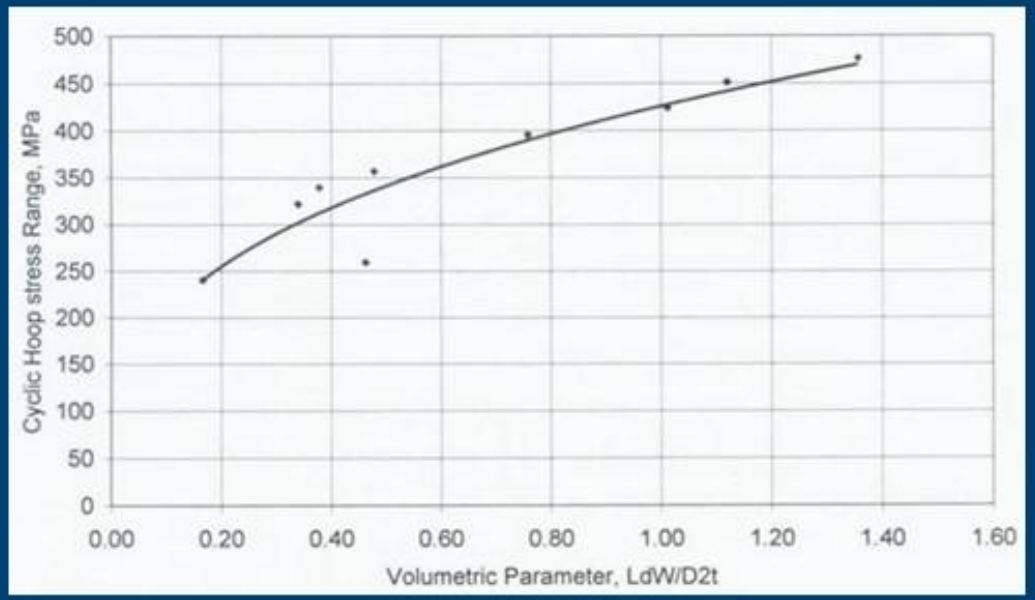
- Uses dent strain and dent depth as governing criteria
- Dents are initially characterised based on HR-MFL data
- HR caliper inspection run if there are a number of high risk dents
- Strain measured using radius of curvature templates
- Compared to 6% strain criterion but could be unconservative
- Only conducted on dents that fail depth criterion



# GE Energy Dent Strategy

- Applies longitudinal dent strain criterion to rank dents in lines not heavily pressurised
- Applies fatigue risk assessment to pressure cycled pipelines

$$\text{Fatigue Life} \propto \frac{1}{\frac{LdW}{D^2t}}$$




- Correlation between dent volume parameter and cyclic hoop stress range and therefore fatigue life

# Code Dent Assessment Criteria 1

| | Plain Dents | |
|---|---|---|
| | Constrained | Unconstrained |
| ASME B31.4 | ≤ 6% OD | |
| ASME B31.4 | Dia > 100 mm - ≤ 6% OD<br>Dia ≤ 100 mm - ≤ 6mm | |
| API 1156 | ≤ 6% OD<br>> 2% - fatigue assessment | |
| EPRG | ≤ 7% @ $\sigma_h$ = 72% SMYS | |
| PDAM | ≤ 10% OD | ≤ 7% OD |
| Z662 | Dia > 100 mm - ≤ 6% OD<br>Dia ≤ 100 mm - ≤ 6mm | |
| P11 | ≤ 12% OD<br>> 2% - fatigue assessment | |

# Code Dent Assessment Criteria 2

| | Dents at welds | Dents with corrosion | Dents with gouges/ cracks |
|---|---|---|---|
| ASME B31.8 | Up to 2% OD or 4% strain on ductile welds<br>Not allowed on brittle welds | Assess individually | Not allowed |
| ASME B31.4 | Not allowed | Not allowed | Not allowed |
| API 1156 | Up to 2% OD on ductile welds<br>Not allowed on brittle welds | Not considered | Not allowed |
| EPRG | Not allowed | Not allowed | Not allowed |
| PDAM | Not allowed | Not allowed | Not allowed |
| Z662 | Not allowed | Not allowed | Not allowed |
| P11 | Not Allowed | Not allowed | Not allowed |

# Advantica Work for NG & Gas Networks – High Level Dent Assessment from ILI

- Considers plain, smooth and kinked dents
- Applies the gas industry pipeline defect assessment procedure - P11
- Reviews ILI tools for dent identification, location and measurement
- Presents current understanding of the effect of dents on pipeline integrity
- Presents a high level dent assessment algorithm

# Pipeline Failures due to Dents

- US - external interference most significant cause of pipeline failures
- US - of external interference failures, only a small proportion are related to dents

  (<2% - liquid pipelines, < 1% gas pipelines)
- Dents below code limits have failed when SCC is present
- UK/Europe – external interference 2nd mots significant cause of pipeline failures
- CONCAWE - 6 failures of construction dents occurred between 1971 - 2004 (1.6% of spillages from liquid pipelines)

# UKOPA Dent Management Strategy

- Develop initial dent screening guidance based on work by Newcastle University and Advantica
- Workshop 1 –
  - Assess guidance using dent inspection data provided by UKOPA members
  - Identify gaps
  - Propose additional work

# RAWG Dent Workshop 1 Purpose

To develop a dent screening algorithm, apply the algorithm to assessment of real dents, assess its potential value/usefulness to pipeline operators, assess gaps and any areas of further work and draft recommendations for UKOPA approval

Recommend assessment criteria based on operator experience

Minimise the need for expert assessment at first stage

# Workshop Output

- Dent screening algorithms –
  - MFL/UT
  - Geometric
  - MFL/UT + Geometric
  - Definitions & simple assessment rules
  - Dent assessment algorithm
  - Proposals for further work
  - Agenda for 2nd workshop

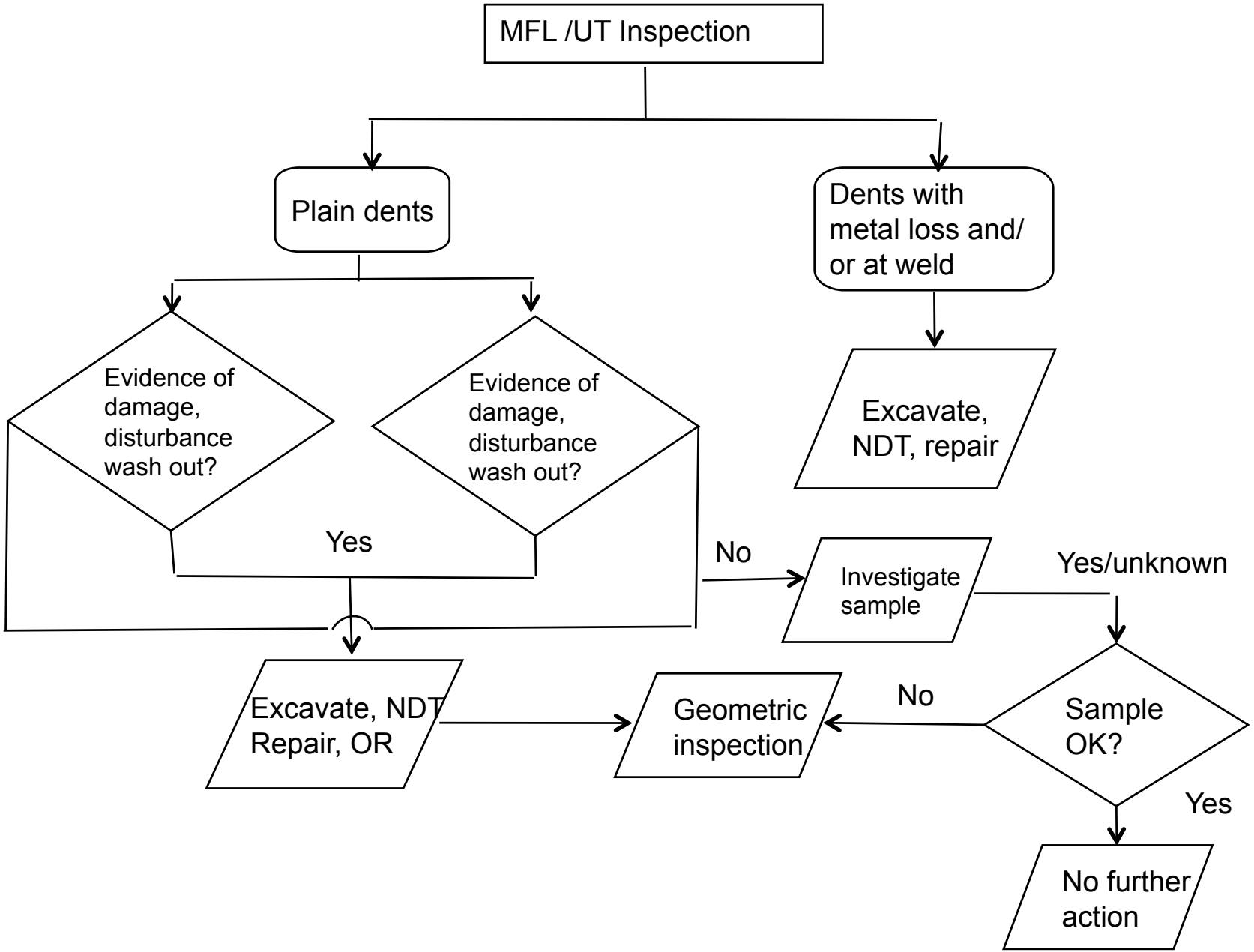
# Definitions

- Plain (or smooth) dent – distortion of pipe geometry causing depression on external surface, no metal loss, no change of curvature at any adjacent seam or girth weld
- Dent associated with weld – dent changes curvature at seam or girth weld
- Kinked dent - rapid changes in contour
- Constrained dent - will not move or re-round during pressurisation
- Position - Top of pipe - 8'o clock to 4 o' clock

  Bottom of pipe – 4 o' clock to 8 o' clock

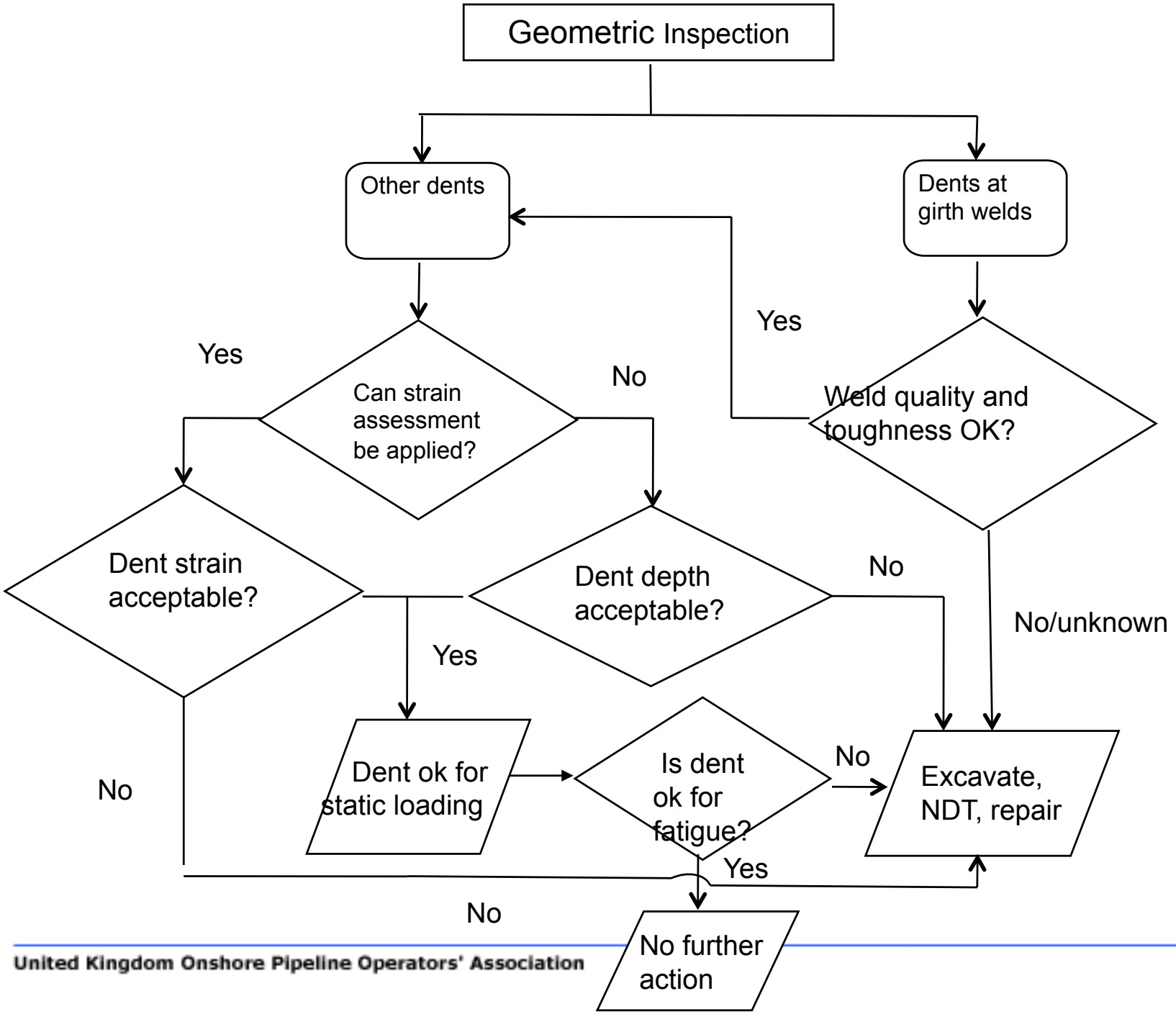
# Simple Assessment Dent Rules

- Kinked dents (eg wrinkles) – repair
- Static assessment of dents – depth/strain limits
- If pipeline is pressure cycled – assess dent location for damage:-
  - TOL – coating damage (DCVG/Pearson)
  - BOL – disturbance, washout etc
  - BOL dents in rocky locations should be monitored not excavated
  - Dents associated with welds ≤ 2% dia - acceptable if weld toughness & quality are acceptable
  - New dent features identified between MFL/UT inspections - investigate


MFL /UT Inspection
Plain dents
Dents with metal loss and/ or at weld
Evidence of damage, disturbance wash out?
Evidence of damage, disturbance wash out?
Excavate, NDT, repair
Yes
No
Investigate sample
Yes/unknown
Excavate, NDT Repair, OR
Geometric inspection
No
Sample OK?
Yes
No further action

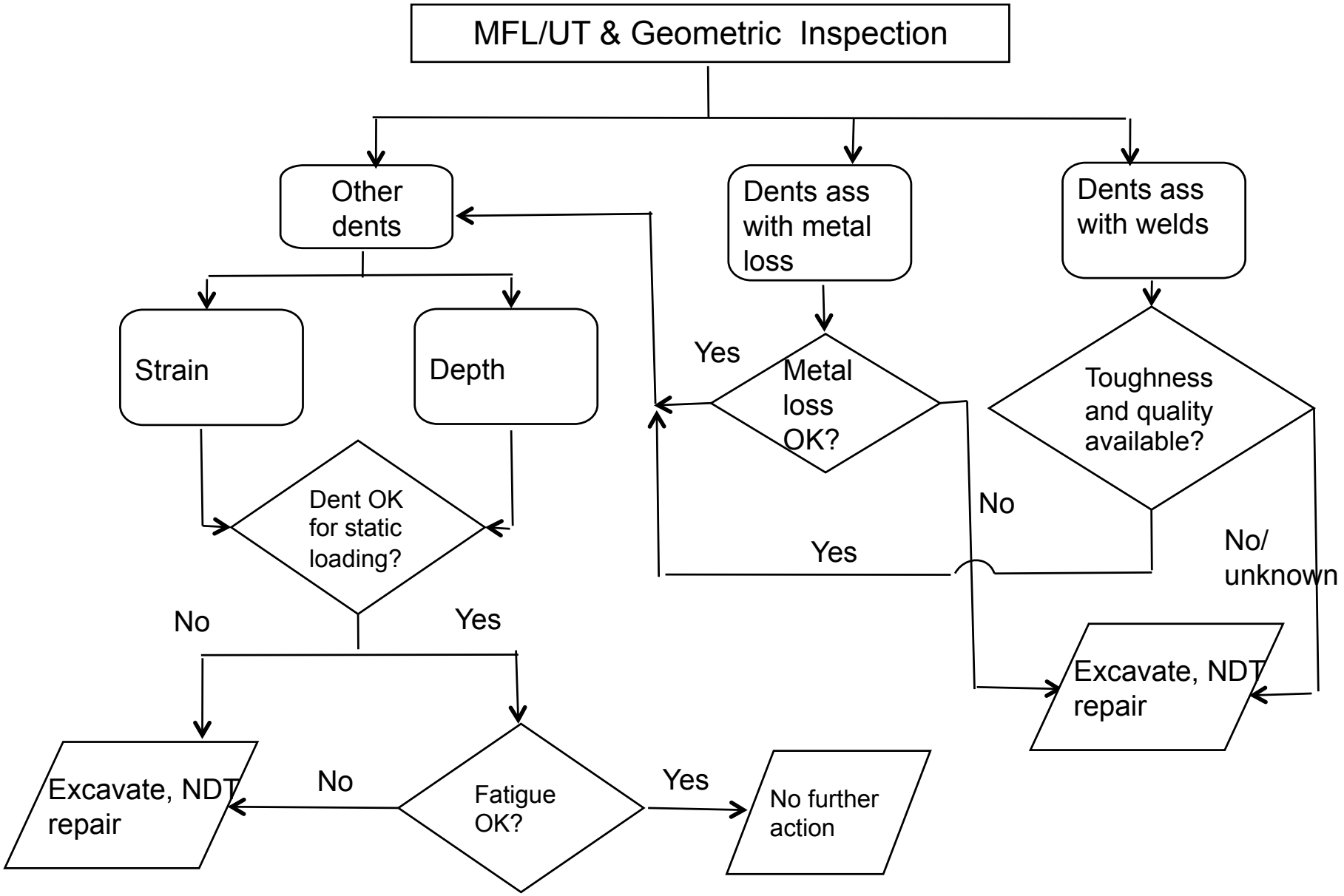
# Case Study – MFL Only

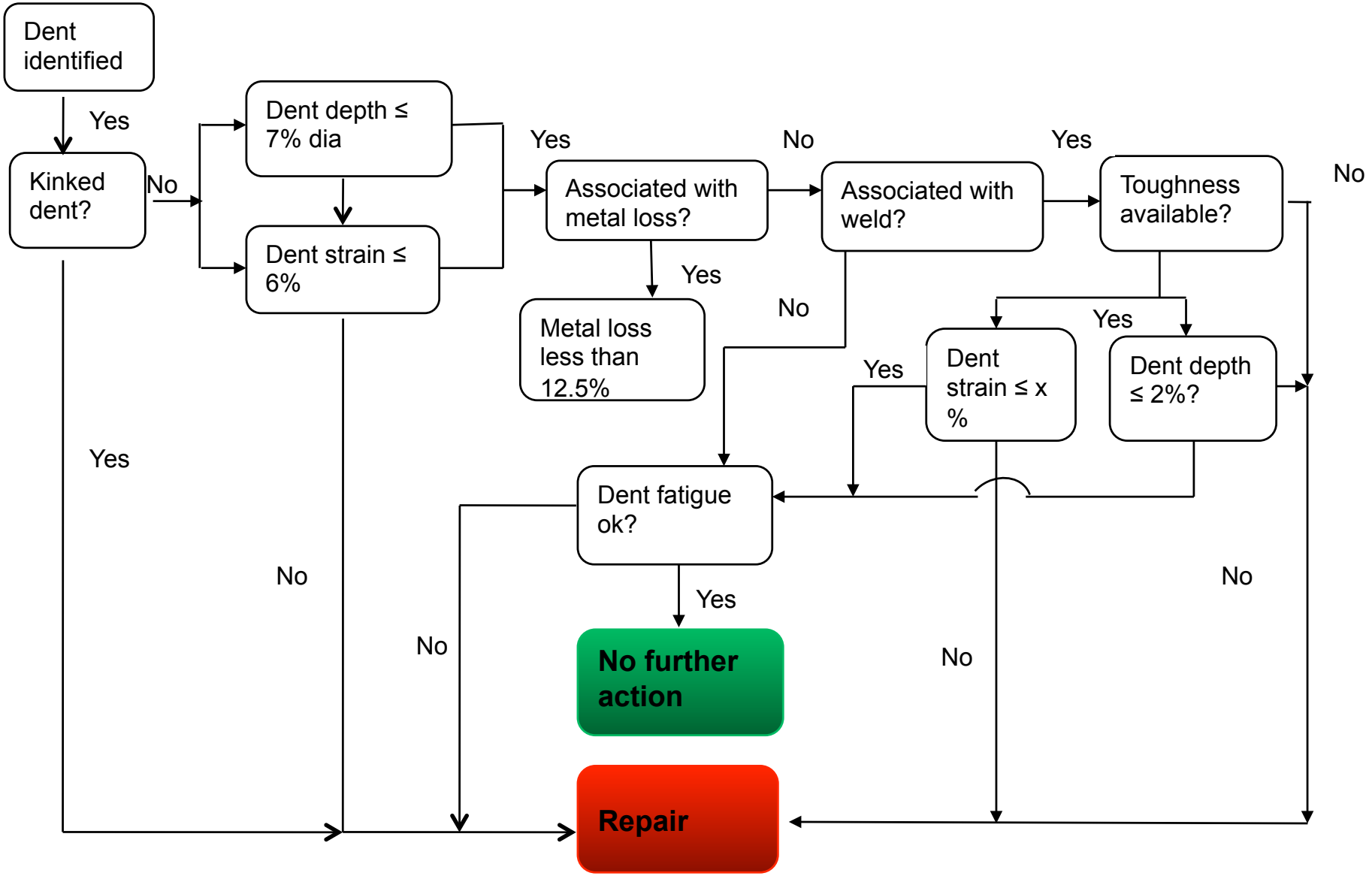
- 270mm dia, 6.4/5.6 mm wt, 230km
- 55 dents
- 2 dents associated with seam + metal loss, - excavated
- 1 dent associated with metal loss – excavated
- 22 dents – seam weld not identified, 12 of these between 8 & 4 o'clock
- 30 plain dents, approx 50% between 8 & 4 o'clock
- 12 dents seam weld not clear to be excavated, sample of plain dents to be excavated
- Dig costs high, so caliper


Geometric Inspection
Other dents
Dents at girth welds
Yes
Can strain assessment be applied?
No
Yes
Weld quality and toughness OK?
Dent strain acceptable?
Dent depth acceptable?
No
No/unknown
Yes
Dent ok for static loading
Is dent ok for fatigue?
No
Excavate, NDT, repair
No
Yes
No
No further action

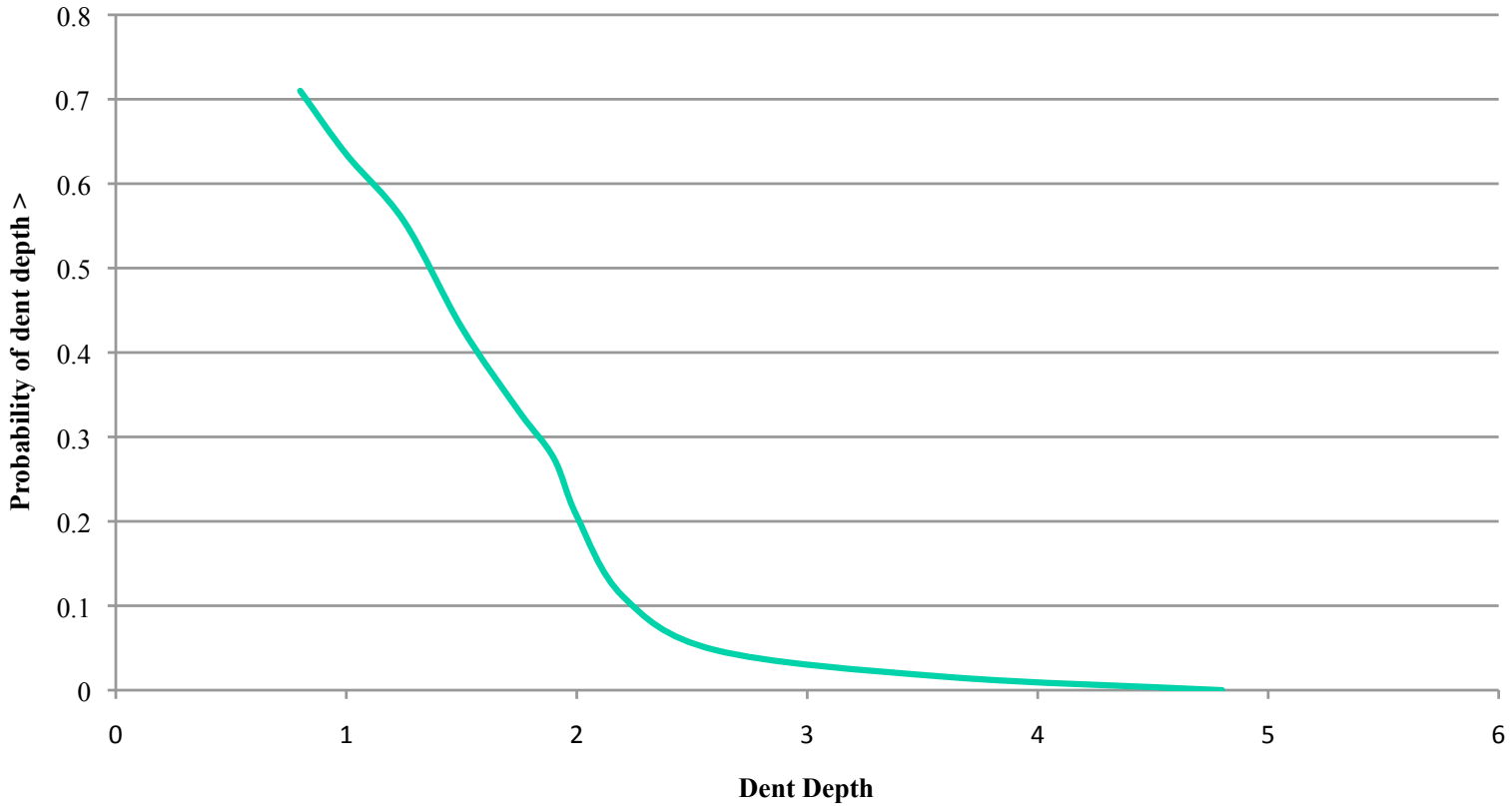
# Case Study – Caliper Only

- 760mm dia, 12.7 mm wt,
- 63 dents
- 2 dents associated with girth weld, 1.5% & 3.5%
- 1 dent 4.8%
- 60 dents – between 4 & 8 o'clock
- 3 dents to be excavated


MFL/UT & Geometric Inspection
Other dents
Dents ass with metal loss
Dents ass with welds
Strain
Depth
Yes
Metal loss OK?
Toughness and quality available?
No
Yes
No/ unknown
Dent OK for static loading?
No
Yes
Excavate, NDT repair
Excavate, NDT repair
No
Fatigue OK?
Yes
No further action

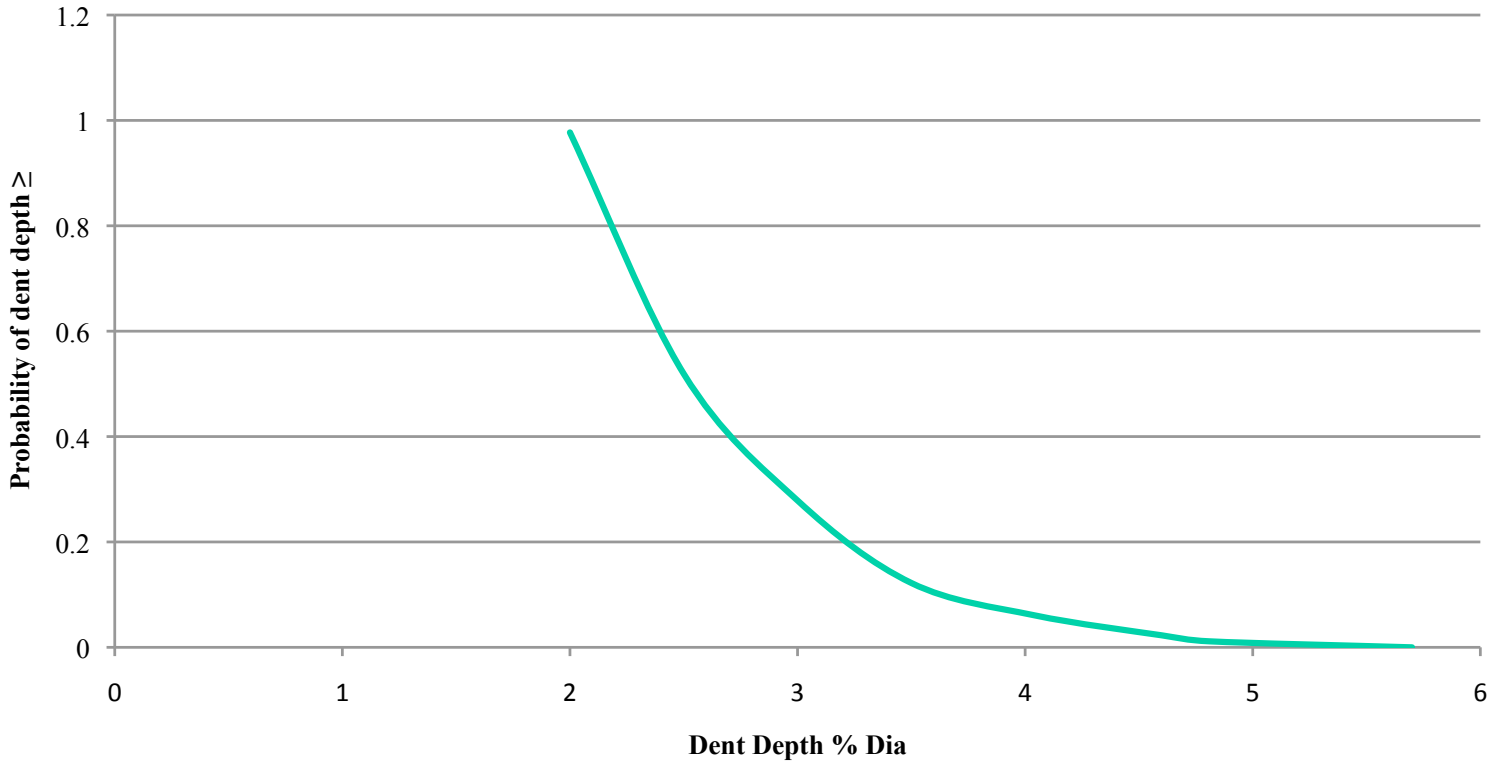

Dent identified
Yes
Kinked dent?
No
Dent depth ≤ 7% dia
Dent strain ≤ 6%
Yes
Associated with metal loss?
Yes
Metal loss less than 12.5%
No
Associated with weld?
Yes
Toughness available?
No
Yes
Dent strain ≤ x %
Yes
Dent depth ≤ 2%?
Yes
No
Dent fatigue ok?
Yes
No
No
No
No further action
Repair

# Example 2 – 769 mm dia, 12.7 mm wt




80% dents less than 2% dia depth

# Dia 914mm, wt 9.52mm




Only dents ≥ 2% dia reported

Of these dents, 80% are less than 3.25% dia

# Issues/Rules

- Assumptions on location and constraint
- Causes – external interference vs construction
- Criteria – external interference vs construction
- Depth criteria/strain criteria
- Interpretation of depth/strain (re-rounding)
- Dents associated with i) seam welds ii) girth welds

# UKOPA Best Practice

- MFL + Geometric inspection to assess dents
- Record physical examination results in fault database
- Transparent rules for screening and assessment for use by operators

# UKOPA Dent Management Strategy

Actions:-

- Collate UKOPA member dent data into database
- Develop weighting model to supplement screening algorithms
- Improve first stage assessment:-
  - Develop worst case stress & strain concentration factors for dents
  - Define fatigue criteria - develop fatigue SN curve for dented pipelines
  - Establish best practice for detailed assessment based on UKOPA member experience