DEFECT ASSESSMENT METHODS
PRCI Project No. PR-218-05404

U.S DOT R&D FORUM

New Orleans

February 7-8 2007

Presented by: Bob Francini (KAI)

John Kiefner (KAI)

Keith Leewis (P-PIC)

Kiefner & Associates incorporated

DEFECTS THAT COULD AFFECT PIPELINE INTEGRITY

- Corrosion-caused metal loss
- Longitudinally-oriented cracks
- Circumferentially-oriented corrosion
- Circumferentially-oriented cracks
- Dents
- Dents with reduced wall & damage

Kiefner & Associates incorporated

METHODS USED TO EVALUATE FLAWS IN PIPELINES

Corrosion-Caused Metal Loss

ASME B31G	Modified B31G
RSTRENG	KAPA
PCORR	COR-LAS™
PAFFC	API RP 579
DNV RP F-101	

Cracks (axial)

SURFFLAW	KAPA
COR-LAS™	PAFFC
API RP 579	BS 7910

Cracks and Blunt Flaws (circumferential)

API STD. 1104, Appendix A
CSA Z662, Appendix K
API RP 579
BS 7910

Kiefner & Associates incorporated

METHODS USED TO EVALUATE FLAWS IN PIPELINES

Plane Dents

API Publication 1156
B31.8
API 579
PRCI PR-218-9405 Fatigue Rating Shallow Unrestrained Dents
PRCI PR-218-9822 Guidelines for the Assessment of Dents on Welds

Dents with Gouges

API 579
Dent-Gouge Fracture Model (EPRG)
Patch to Ductile Flaw Growth Model (PRCI-Battelle)
Empirical Q-factor Model (PRCI)

Kiefner & Associates incorporated

STATUS OF MODELS FOR EVALUATING CORROSION-CAUSE METAL LOSS

- Mature technology
- Most of the models are based on Maxey's Surface Flaw Equation
- Comparisons show that the models give similar predictions and all have been validated against PRCI's Database of Corroded Pipe Tests
  - Any of the models can be used with confidence, but ASME B31G tends to give excessively conservative predictions
- Further research is being carried out to better address multiple defect interaction and varying axial stress
- Little or no need to pursue this in the future

Kiefner & Associates incorporated

STATUS OF MODELS FOR EVALUATING AXIAL CRACKS

- Log-secant equation (a.k.a. NG-18 surface flaw equation) is empirically based
  - Can be used without the need for special software and utilizes Charpy energy (upper shelf) to represent material toughness.
- PAFFC and CorLas™ are based on J-integral and tearing modulus theory.
  - Can use Charpy energy correlations for toughness.
  - Are implement in software packages.
- API RP 579 Level II and BS 7910 methodologies are based on the FAD methodology.
  - Can be used without special software and can accommodate toughness based on Charpy energy.

Kiefner & Associates incorporated

STATUS OF MODELS FOR EVALUATING AXIAL CRACKS CONTINUED

- These models have been validated against PRCI full-scale test results and other data.
- Comparisons show that the models give similar predictions.
  - Log-sec equation tends to give excessively conservative predictions for flaws with depth/thickness ratios less than 0.3.
- Further research is being carried out to develop a “new” model for axial cracks.
- The weak link in fracture mechanics based models are fracture toughness correlations.
- The existing methods work well, so further effort beyond the on-going work on a new model is probably not necessary.

Kiefner & Associates incorporated

STATUS OF MODELS FOR EVALUATING ROCK DENTS AND PLAIN DENTS

- API 579 has dent radius criteria
  - requires radius > 15 x remaining wall
- B31.8
  - Maximum strain <6% (4% in ductile welds) calculated from curvature
- Calculation based on caliper or in the ditch readings
  - Kiefner methodology – trace & compare
- Need to better understand the effect of length and membrane strain on fatigue life

Kiefner & Associates incorporated

STATUS OF MODELS FOR EVALUATING DENTS WITH METAL LOSS OR CRACKS

- ASME B31.8 –
  - Evaluate dent and metal loss independently
  - Grind out cracks
  - Not ideal, needs validation
- Dent & Gouge Fracture Model
  - Conservative
  - Requires high toughness
  - Curvature limited to >5t
  - Length not included
- API 579 Level 2
  - Uses Q factor
  - Limits cyclic stresses
- Q Factor – not recommended
- R&D overlaps mechanical damage (dents with gouges)

Kiefner & Associates incorporated

STATUS OF MODELS FOR EVALUATING DENTS WITH GOUGES

- The current dent-gouge fracture model results in better predictions if the depth of cracking from re-rounding of the dent is added to the gouge depth in the model.
- Patch to ductile flaw growth model has not been codified or fully validated.
- The empirical Q-factor model is not recommended.

Kiefner & Associates incorporated

STATUS OF MODELS FOR EVALUATING DENTS WITH GOUGES CONTINUED

- This area is the focus of much current research:
  - Dent and Gouge Fracture Model (FAD) approach is being extended by AF&A with KAI (improved burst test prediction) and Advantica (time dependent model)
  - Patch to the Ductile Flaw Growth Model will be extended by Battelle (time dependent model)

Kiefner & Associates incorporated

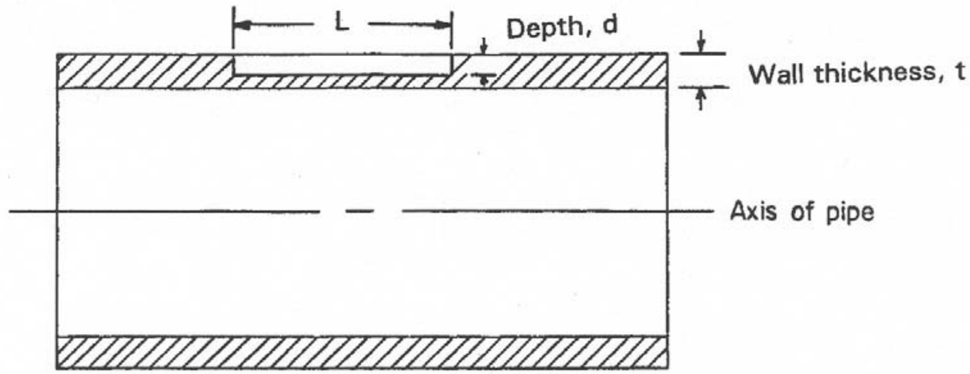
STATUS OF MODELS FOR EVALUATING DENTS AND DENTS WITH GOUGES CONT.

- Further FEM & full scale testing research is being carried out to validate a range of models for fabricated gouges and dents.
  - Most existing test data on gouge and dent defects may not simulate the behavior of real gouges and dents.
  - Are a starting point for dents with gouge damage, but there is still a need for more realistic mechanical damage.
- Consideration should be given to developing a *realistic* mechanical damage test method to validate new and existing models.

Kiefner & Associates incorporated

Questions?

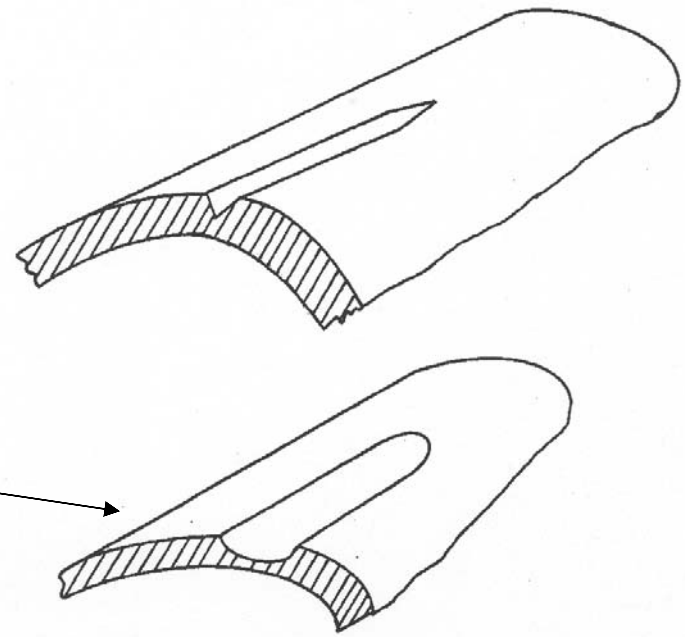
Kiefner & Associates incorporated

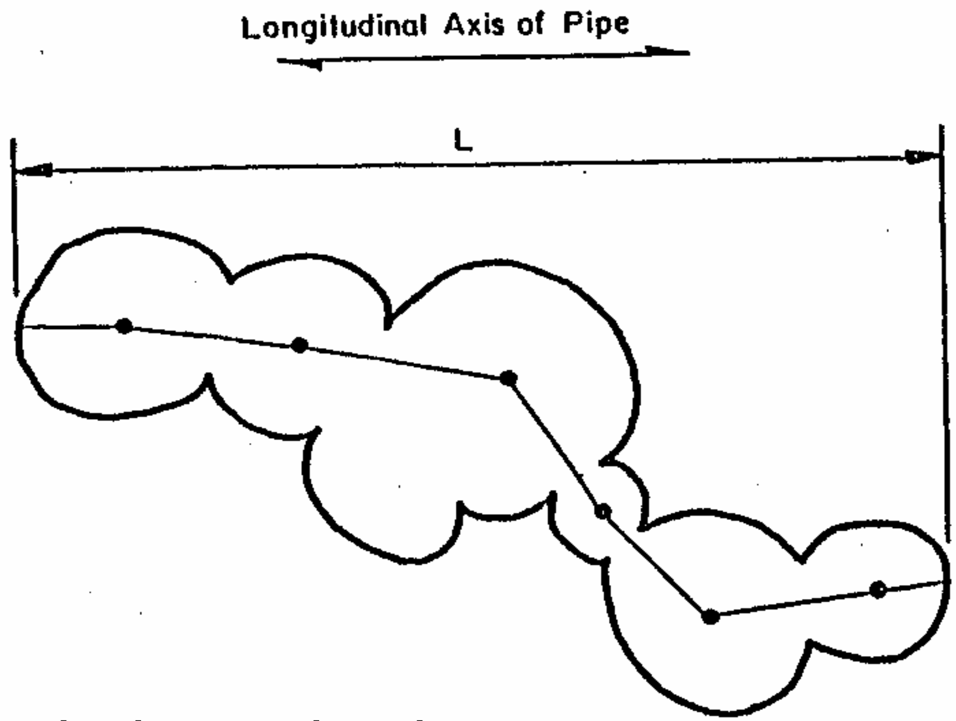


SURFACE FLAW

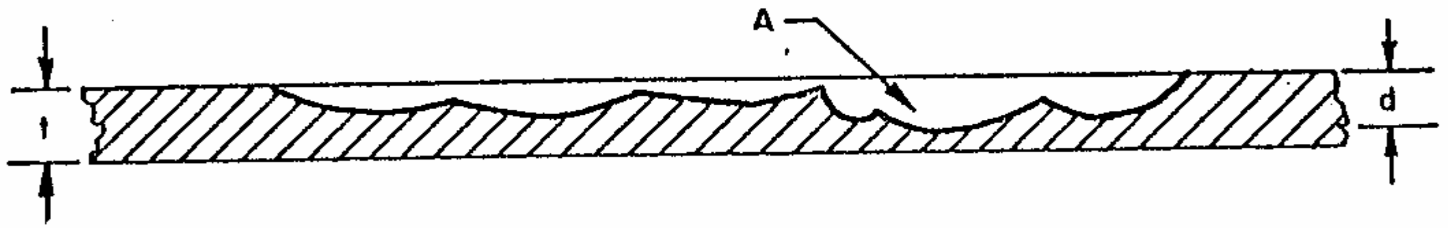
Sharp Flaw

Blunt Flaw





Length and depth determination



Kiefner & Associates incorporated

Maxey's Surface Flaw Equation

$$S = S_o \left[\frac{1 - A/A_O}{1 - (A/A_O)(1/M)} \right]$$

$$A = Ld \quad \text{(for a rectangular defect)}$$

$$A_O = Lt$$

$$M = \sqrt{1 + \frac{0.8L^2}{Dt}}$$

Kiefner & Associates incorporated

API RP 579 Level II Assessment
Failure Assessment Diagram Approach