A Pipeliner's Perspective on Longwall Mining

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Introduction

• There are over 300,000 miles of gas transmission and 175,000 miles of liquid transmission pipelines in the United States
  – Historically, many of these pipelines run from the Gulf Coast to the Northeast
  – A significant number of these pipelines run through the eastern coalfields with their associated longwall mining
  – Interstate pipelines are regulated by the DOT
What Could Possibly Happen?
Overview

• KAI approach for mitigating the effects of longwall mining on high-pressure pipelines:
  – Perform an integrity analysis of pipeline
  – Perform a longitudinal stress analysis to determine the existing stress on pipeline
  – Estimate stress from subsidence
  – Develop a formal mitigation plan
Integrity Analysis

• This is the Single Most Important Step
• A Pipeline is Not Just A Pipeline
  – They vary in age:
    • Nearly 15,000 miles were built before 1940
    • 185,000 miles were built between 1940 and 1970
  – Pipe fabrication and construction practices have seen considerable change over this period
Something You Don’t See Anymore—Wrinkle Bends
Integrity Analysis-Why do It?

• Subsidence increases the longitudinal stress on the pipeline
  – This stress increase can result in the failure of defects that would not be of concern under normal operating conditions
  – Examples
    • Circumferential corrosion and stress corrosion cracking (SCC)
    • Pre API 1104 girth welds
    • Coating can be damaged
Integrity Analysis Process

• Includes
  – A review of the history of the pipeline,
  – Review of in-line inspection reports (if available), and
  – Review of girth weld inspection reports (if available)
    • A girth weld is the weld used to join individual lengths (aka joints) of pipe.
Existing Stress

- Hoop stress due to pressure
  \[\sigma_{H\text{-pressure}} = \frac{P \cdot D}{2t}\]

- Longitudinal stress due to pressure
  \[\sigma_{L\text{-pressure}} = v \cdot \sigma_{H\text{-pressure}}\]

- Longitudinal stress due to temperature
  \[\sigma_{L\text{-thermal}} = E \cdot \alpha \left( T_{\text{installed}} - T_{\text{operating}} \right)\]
Additional Existing Stress

• There can be other sources of existing stress but they can be very difficult to determine
  – For example bending stresses from construction
  – Usually increase estimate to account for these stresses
Subsidence Stress

• Steps:
  – Estimate subsidence
    • Depending on analysis also need curvature and horizontal displacement of the soil and soil strains
  – Use subsidence estimate to determine stress
    • Simple hand calculations
    • Soil-pipe interaction finite element analysis
Calculate Subsidence

• Use standard estimation programs such as Comprehensive and Integrated Subsidence Prediction (CISPM) and Surface Deformation Prediction System (SDPS)
  – Depending on the analysis need to know subsidence, horizontal soil displacement, soil strain and curvature
Subsidence Calculation

Example

Subsidence

Soil strain
Subsidence Stress

• An initial estimation of the bending strain can be obtained from the curvature
  – Works for buried or exposed pipe but doesn’t account for terrain
Finite Element Modeling

- A better estimate of stress can be obtained using finite element modeling
  - The pipe soil interaction is modeled as nonlinear springs
  - Exposed pipe is modeled using contact elements for the ground contact

![Diagram of finite element modeling](image-url)

a) Actual Three-dimensional Soil Restraint on Pipeline

b) Idealized Representation of Soil with Discrete Springs
A Case Study-The Problem
A Case Study - Subsidence

Subsidence and Horizontal Displacement with Buried Segment
A Case Study-FEA Model
A Case Study-Results

Longitudinal and equivalent stress compared with code limits
Determining Allowable Stress

• In most cases the allowable stress can be determined from design codes
  – ASME B31.4 for hazardous liquids
  – ASME B31.8 for gas

• In some cases additional analysis of pre-existing defects is required to set allowable stress levels
Mitigation Plan

- The recommended steps to take prior to the subsidence
- A multi-level monitoring criterion with appropriate responses for each level
- Inspection procedure required for the monitoring criterion
- Recommendations for post-subsidence mitigation if required
Design for Subsidence

• The Pipeline Research Council International (PRCI) report entitled “Guidelines for Constructing Natural Gas and Liquid Hydrocarbon Pipelines through Areas Prone to Landslide and Subsidence Hazards” gives a summary of state-of-the-art subsidence design
Some Design Strategies

• Increase the pipeline capacity to resist ground movement
• Reduce the soil loads on the pipe
• Modifying the pipe alignment
Bad
Good

Save your questions for later