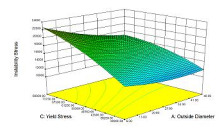
Leak-Rupture Boundary Calculator

The objective of this project was to develop a tool that allows operators to determine the leak-rupture boundary for a pipe segment based on properties such as the diameter, toughness, and yield strength. Operators can use the calculator for risk modeling and consequence analysis.



Project Description

Transmission pipes operating at pressures greater than 20% Specific Minimum Yield Strength (SMYS) in High-Consequence Areas (HCAs) are required to comply with the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration's Subpart O Integrity Management regulations.

For pipelines operators to ensure that their limited assessment resources are focused on the highest-risk segments, a technical basis is needed to understand which segments could possibly fail by leak versus rupture, and regulators need the technical justification that forms the basis of integrity-management regulations.

Two studies on the topic have been conducted in recent years. These studies (*Leak vs. Rupture Considerations for Steel, Low-Stress Natural Gas Transmission Pipelines* and *Criteria for Reinspection Intervals for Low-Stress Steel Pipelines)* indicate that failure by rupture may occur at a pressure that produces a hoop stress above 30% of the pipeline's SMYS. While these reports provide valuable information, the industry could benefit through further validation.

In this project, research involved an international incident review and mathematical modeling to develop a calculator to determine the leak-rupture boundary (LRB) for specific pipe segments.

Deliverable

The deliverable for this project includes a closed-form solution that allows the calculation of the LRB as a percentage of SMYS with a confidence that 97.5% of pipelines with the selected attributes of yield strength, toughness, diameter, and wall thickness would fail by leak instead of rupture. A user-friendly calculator was created to allow operators to perform analysis for specific pipe segments.

Benefits

Research performed in this project provides operators and regulators with a new body of knowledge regarding the boundary between failure by leak and failure by rupture. Results provide an enhanced understanding of the parameters influencing failure modes to allow integrity-management programs to consider the proximity of a pipe segment's operating pressure in relation to the leak-rupture boundary. The information could also be used by regulators to update integrity management regulations to reflect the risk associated with different pipe materials.

Technical Concept & Approach

The project involved an international incident review and mathematical modeling to determine the LRB for different material types. The review included an expanded data set of 10 additional years of incidents not accounted for in the earlier research. as well as pertinent international incident data. The deliverable of this task was a report summarizing the past and recent U.S. and international incidents and a lower boundary for the transition in failure modes.

Mathematical models to determine the appropriate boundary for failure by rupture vs. failure by leak were identified, reviewed, selected, modified if necessary, and validated. The mathematical models considered both corrosion and mechanical damage defects.

Results

The incident review was initially conducted to provide an analysis of incident and testing data to identify trends in ruptures across different pipe attributes.

A total of 18,813 incidents were reviewed from more than 10 countries. A total of 1,014 full-size tests were reviewed from more than 10 sources.

The 20,095 reported failures were filtered to a conclusive failure-by-rupture set with supporting pipeline feature data. The final conclusive rupture data set included 638 confirmed ruptures with supporting data. The four-coefficient, full-factor regression model was then overlaid with the incident and full-size-test rupture data set. When these 638 confirmed ruptures were overlaid on the regression model failure surfaces, a total of 14 confirmed ruptures fell below the lower confidence limit surface. This equates to 2.19% of the population that is in line with the 2.5% confidence level of the model and validates the accuracy of the model.

Toward this goal, investigators developed a list of pipeline attributes and categories that define a failure stress range within a certain probability (e.g., 80% or 90%).

A sensitivity study was conducted on input parameters to decide which had the greatest influence on the LRB. The most sensitive parameters (in order from most sensitive to least sensitive) were: defect length, yield strength and toughness, diameter, and wall thickness. No statistically validated correlation could be made between pipeline vintage and LRB values.

Multiple models were reviewed. The most reliable and easiest to use were the Maxey/Folias and Maxey Arrest Stress models, and they defined the same LRB with the same inputs. Model predictions were compared and validated to 268 leak/rupture full-scale pressurized-pipe experiments. The practical use of the models is problematic due to the assumptions and limitations. The most limiting characteristic of the models in their current form is that they do not take into account the probability of error for the model, standard error of the solution, or provide confidence levels for the LRB.

The uncertainty and variability of actual measurements for diameter, thickness, toughness, and yield strength were factored into the solution and the standard errors of the models were calculated. This information was used to calculate a closed-form solution. The 95% confidence interval-solution surfaces for both the lower and upper confidence limits were calculated and plotted to capture 95% of confirmed ruptures.

The results of the study found that the yield strength, toughness, wall thickness, and diameter of a pipe segment can be used to predict the LRB. The research indicated that the boundary could range from slightly below 20% SMYS for rare pipe materials to well over 30% SMYS for many others.

Status

This project is complete.

A Final Report titled *Leak-Rupture Boundary Determination Project* was issued in May 2011. The LRB Calculator is now available through OTD.

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