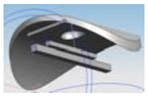
Operations Technology Development

Yield Strength Determination Through Sub-Size Samples



The objective of this multi-phase project is to develop, validate, and obtain regulatory acceptance for a method to establish pipeline yield strength that allows for a less expensive sampling procedure that does not require the line to be taken out of service.

Project Description

In this project, research is being conducted to develop a method where six-inch hot-tap coupons can be removed from a pipeline without interrupting service, and subsequently sent for machining and laboratory testing to determine yield strength values.

The objective is to demonstrate that sub-size samples provide the same yield strength values as traditional full-size samples.

In Phase 1, researchers evaluated three techniques for establishing yield-strength values – a partial-wall, sub-size sample and two surface micro-indentation (stress-strain probe) methods. Results indicated that material variability through the pipe wall was too great for surface techniques to be used effectively.

Phase 2 focused on validating that a full-wall, longitudinal, sub-size sample can produce results that are equivalent to – or more conservative than – a standard full-size sample.

The objective of the current Phase 3 effort is to develop a methodology for statistical sampling and field verification to determine yield-strength properties for undocumented pipe.

Deliverables

The deliverables for this project include a set of research findings demonstrating that full-wall, longitudinal, sub-size samples are equivalent to full-size samples for determining yield strength.

Benefits

Utilities and their customers will benefit from the ability to determine yield-strength values in a less expensive and more efficient method than currently allowed.

Many natural gas utilities operate pipeline segments that do not have historical documentation to validate the pipe's Specified Minimum Yield Strength (SMYS). In these situations, operators must either: 1) Assume a low SMYS of 24,000 psi (per 49 CFR 192), which results in many pipe segments being categorized as a transmission line vs. a distribution line and, therefore, must be operated and maintained accordingly; or 2) Establish the SMYS with laboratory testing, which is currently time consuming, expensive, and inconvenient as the requirements for specimen size necessitates a complete shutdown and removal of circumferential pipe samples for laboratory testing.

Research was conducted to determine if small pipe specimens can provide the same testing results as larger samples that are more costly to extract and test.

Technical Concept & Approach

In Phase 1, a variety of tests (e.g., carbon segregation tests and carbon profiling) were performed and researchers addressed a number of issues, including:

- The possible lack of uniformity of both the steel microstructure and the chemistry of the pipes
- The possibility that a centerline specimen may be unrepresentative (through segregation) of the full-section properties
- The need for greater precision in machining and testing smaller specimens.

Phase 2 included the following tasks:

- The design of a longitudinal, full-wall specimen that can be extracted from a standard hot-tap coupon.
- Using 20 pipe segments from Phase 1, a total of 100 tensile specimens (20 pipes x 5 per pipe) were extracted, machined, prepared, and tested.
- The original micrographs from Phase 1 were reanalyzed for oriented grain size (longitudinal and transverse). Phase 1 full-size transverse and Phase 2 longitudinal tensile test data were compared.
- Research results were presented to appropriate industry organizations.

For Phase 3, a comprehensive series of synthetic pipeline segments were developed. The sets form "pipeline populations" to perform yield strength sampling and analysis.

Sampling activities are using four technical approaches:

1. The current federal code requirements will be used for samples from the synthetic segments. This will include all the variations allowed by the federal code based on segment length (number of joints that make up the pipeline segment). Computerized sampling methods will be used to randomly sample tens of thousands of times from each pipeline segment.
2. A series of random samples will be drawn from each of the pipeline segments. Nonparametric statistical analysis will be used to calculate the estimated average and likely minimum yield strengths of the segment.
3. Probabilistic analysis (Bayesian) analysis will be used to calculate the proportions (categories or buckets) of yield strengths.
4. Adaptive sampling will draw an initial *smaller* sample set, completely at random, and will analyze the results before additional sampling is conducted.

Results

Results from Phase 1 indicated that no partial-wall technique can accurately determine a pipe's yield strength without correction factors to account for material variability. The research team subsequently developed a Phase 2 plan to develop and test full-wall sub-size samples that would not require correction factors.

In 2010, researchers completed the testing of the full-wall, longitudinal, sub-size samples. Results indicate that the new testing methodology can effectively be used to determine yield strength values. The mini, full-wall specimens were found to be superior to the currently specified full-size tensile specimens. On average, the sub-size sample method produces a -8.5% lower (conservative) value for yield strength when compared to the full-size test method. A sample set from the pipeline population would result in an average yield strength between -13.2% and -3.8% for the full-size method with a 95% confidence.

Status

In 2011, the research team presented the project results to the American Petroleum Institute 5L committee, the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration, and the ASTM A370 committee. The research team subsequently initiated a request with ASTM to make minor modifications to A370 to include sub-size specimens.

In 2011, Phase 3 of this project was initiated. Six pipeline segment categories were established. These synthetic segments will be used to carry out sampling experiments that use the currently approved (federal code) method for sampling and SMYS calculation, as well as several statistically and probabilistically based sampling methods.

For more information:

Maureen Droessler
Program Administrator
Operations Technology Development, NFP
Phone: 847/768-0608
maureen.droessler@otd-co.org