Innovative Methods for Assessing Pipeline Integrity Presented at the 2016 International Pipeline Conference

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Introduction

The 11th International Pipeline Conference (IPC 2016) and Exhibition was held in Calgary, Alberta, Canada September 26-30, 2016. Organized by volunteers representing oil and gas companies, energy and pipeline associations, and governmental regulatory agencies, the biannual IPC has become internationally known as the world's premier pipeline conference. IPC 2016 attracted a large number of pipeline industry delegates from more than 30 countries. By serving on the IPC Technical Committee, EWI helped organize the technical aspects of the conference and aided in the selection of high-quality technical papers and presentations related to materials, welding, and fracture control.

The conference proceedings included two presentations detailing EWI's recent research focused on assessing transmission pipeline integrity. Corresponding papers were included in the conference proceedings and are available upon request.

Numerical Simulation of Mechanical Damage Severity

It is well known that mechanical damage (also referred to as "third-party damage") is one of the most significant threats to the integrity of both oil and gas transmission pipelines. This damage includes mechanical dents, dents with gouges or cracks, dents with metal-loss defects, and dents that interface with welds. In addition, the shape, size, location, and orientation of the damage are important factors, as are the pipe's geometry and grade, the force of the impact, the level of residual stresses present, and pressure fluctuations. Although significant research has been conducted on this topic, quantifying the severity of mechanical damage remains a significant challenge due to the complexity of its effects. As a result, researchers are still working to better understand the failure mechanisms, and to develop a means to screen and characterize the severity of mechanical damage via in-line inspection.

EWI's presentation "Finite Element Modeling and Quantification of Mechanical Damage Severity in Pipelines" discussed the development and validation of an elastic-plastic finite element analysis (FEA) model capable of simulating mechanical dents in pipelines under different conditions. This FEA model has been used to effectively quantify the effects of damage through a broad parametric study. It can determine whether three-dimensional FEA modeling (Figure 1) is required and considers the effects of FEA element types, soil constraint conditions, indenter types, pipeline grades, and internal pressure on the dent response. The model was also used to assess the minimum wall thickness for which a dent has an insignificant effect on pipeline integrity. The application of the proposed FEA model was illustrated by successfully predicting the failure behavior of a dent in a full-scale fatigue test involving a modern pipeline steel.

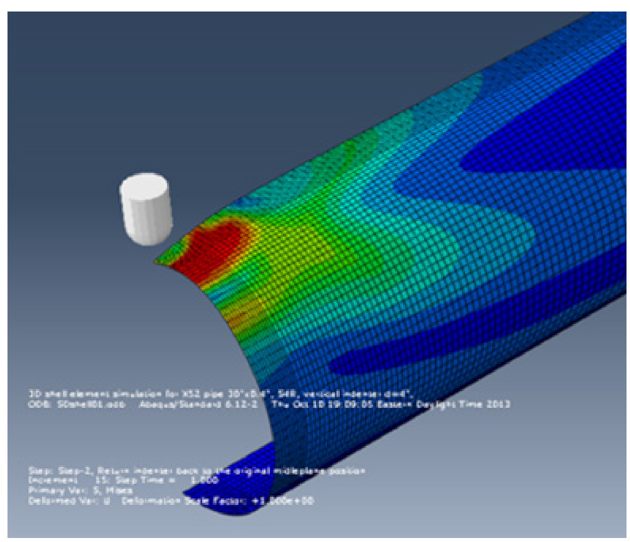

Figure 1: A dome dent simulated by a one-quarter FEA model

Improved Technology for Running Fracture Control

Fracture-control technology is an essential requirement for designing large-diameter, high-pressure gas transmission pipelines. The Battelle two-curve (BTC) model developed in the early 1970s has been used extensively by the gas transmission pipeline industry to determine arrest toughness in terms of the Charpy impact energy. Because of its semi-empirical nature and calibration with test data limited to grades X65 and below, the BTC model is not applicable to higher-grade pipeline steels. Simple correction methods were thus utilized to extend the BTC model to grades X70 and X80, but this extended model is not applicable to higher grades. Moreover, while the BTC model can predict the minimum arrest toughness, it cannot predict fracture arrest distance.

As discussed in the presentation "Modified Two-curve Model for Predicting Fracture Arrest Toughness and Arrest Distance of Full-size Burst Tests," EWI has developed a modern fracture mechanics model and a novel fracture arrest distance model capable of determining the minimum Charpy energy for a running fracture occurring in a modern gas pipeline. When coupled with an arrest distance algorithm, this modified two-curve (MTC) model can effectively predict fracture arrest toughness, running fracture velocity, and fracture arrest distance in one simulation for a single pipe or a set of multiple pipes with given toughness. This innovative model fills the technical gaps in current running fracture control techniques, and thus resulted in extensive discussions by many experts at IPC 2016.

A typical, full-scale burst test for high-strength, high-toughness X80 pipeline steel was used to validate the proposed model. Figure 2 provides results from a MTC simulation of the X80 full-scale burst test. The MTC predictions were consistent with the full-scale test data on arrest toughness, fracture velocity, and arrest distance.

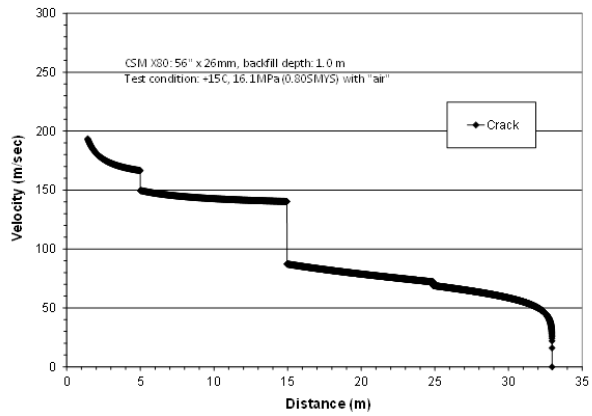

Figure 2: MTC simulation results for X80 fracture velocity and arrest distance

The MTC model was then used to optimize the design of pipe segment arrangements for a mockup full-scale burst test using high-strength pipeline steel. The MTC simulation results confirmed the experimental observation that different pipe arrangements result in different arrest toughness and arrest distance for pipes of the same grade. As a result, the MTC model can be used for running fracture control in modern pipeline design and vintage pipeline integrity assessment.

How EWI Can Help

EWI's oil and gas experts provide leading-edge consulting services on pipeline integrity assessment and management. Our full suite of simulation software and extensive testing capabilities allow us to develop new and improved pipeline integrity assessment techniques using analytical, experimental, and numerical simulation methods.

Xian-Kui Zhu *is a Principal Engineer in EWI's Structural Integrity and Modeling Group. He is also an ASME fellow, and an internationally recognized expert in the areas of mechanical testing and evaluation, solid mechanics, fracture mechanics, and computational mechanics. He applies this expertise to structural integrity and fitness-for-service assessments, material performance evaluations, engineering critical analysis, fatigue and damage evaluations, weld analysis, and strain-based design for oil and gas pipelines.*