Ultrasonic Measurement of Plastic Strain in Pipelines
Progress Report

FWP-42623

A progress report submitted to the Natural Gas infrastructure reliability program managed by the National Energy Technology Laboratory

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Introduction

The goal of this project is to help to maintain the integrity of nation's natural gas transmission infrastructure. We are pursuing this goal utilizing ultrasonic measurements to characterize the damage in natural gas pipelines. The objective of this project is to develop nondestructive ultrasonic measurement methodologies to characterize natural gas pipelines suffering exterior mechanical damage, as a means of determining the likelihood of eventual failure. Technically, this requires a measurement of the plastic strain and residual stress in the damage area, whether the pipe has been dented due to third party contact, or bent due to earth movement.

FY 04 objectives and accomplishments to date

The main task this FY is the field test in September on damaged pipelines. Accomplishments have included the design and fabrication of a simple cart to place our sensors in the inside of the pipe. The cart is shown in Figure 1. In addition, a pipe with calibrated dents has been designed and obtained in collaboration with Battelle. A picture of the 24 inch diameter pipe is shown on Figure 2 with and the layout and dent time are shown in Figure 2b. The 1st number in the dent identification is the length of the indenter, with the second being the depth of indentation as a percentage of the pipe diameter. In preparation for the field test, Finite element modeling of the dents has been performed with results included in Figure 3. The strain are seen to be localized in the dent region, with stresses extending well beyond the dent region.

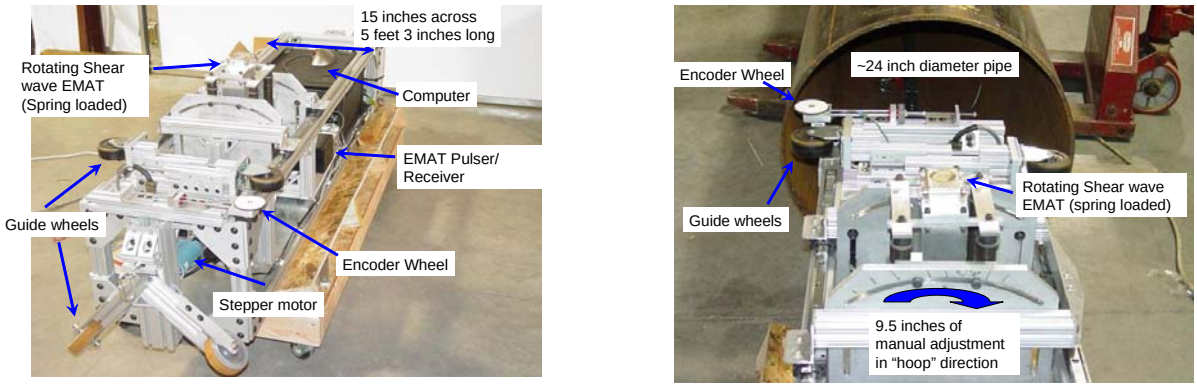

Figure 1. Wheeled cart for transporting sensors into 24 inch diameter pipe

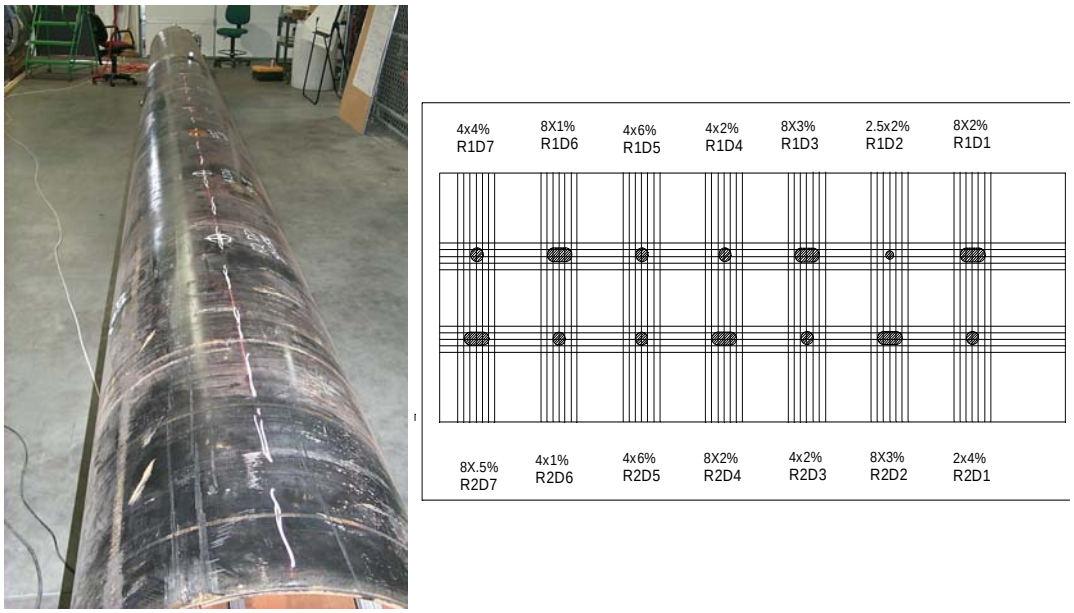

Figure 2. Pipe with calibrated dents and dent layout.

Accomplishments

- Designed and built a simple test rig to enable data to be acquired inside a pipeline while moving
- Designed and acquired a 24 inch diameter gas pipe with calibrated dents
- Performed Finite Element modeling of dents in calibrated pipe
- Performed measurements on dented pipe with sensors on cart.

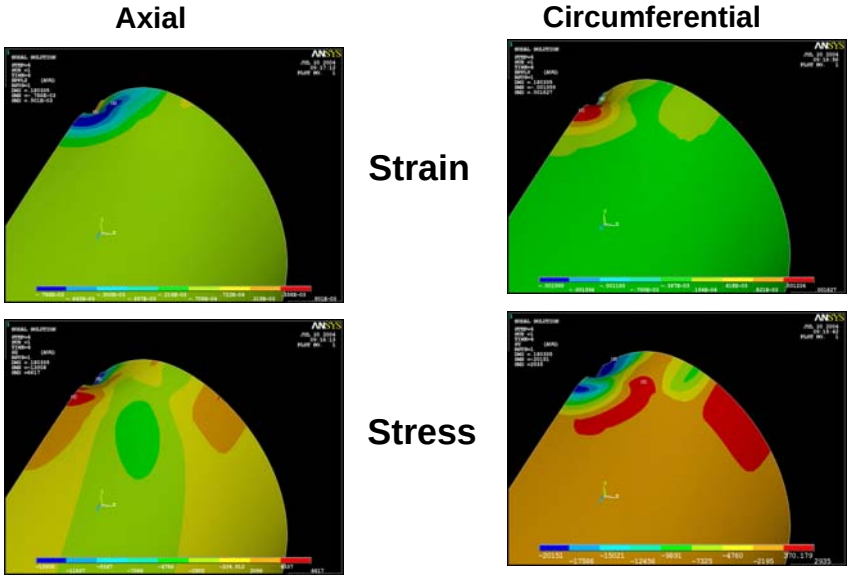

Figure 3. Finite element results of stresses and strain around 8X2% dent.

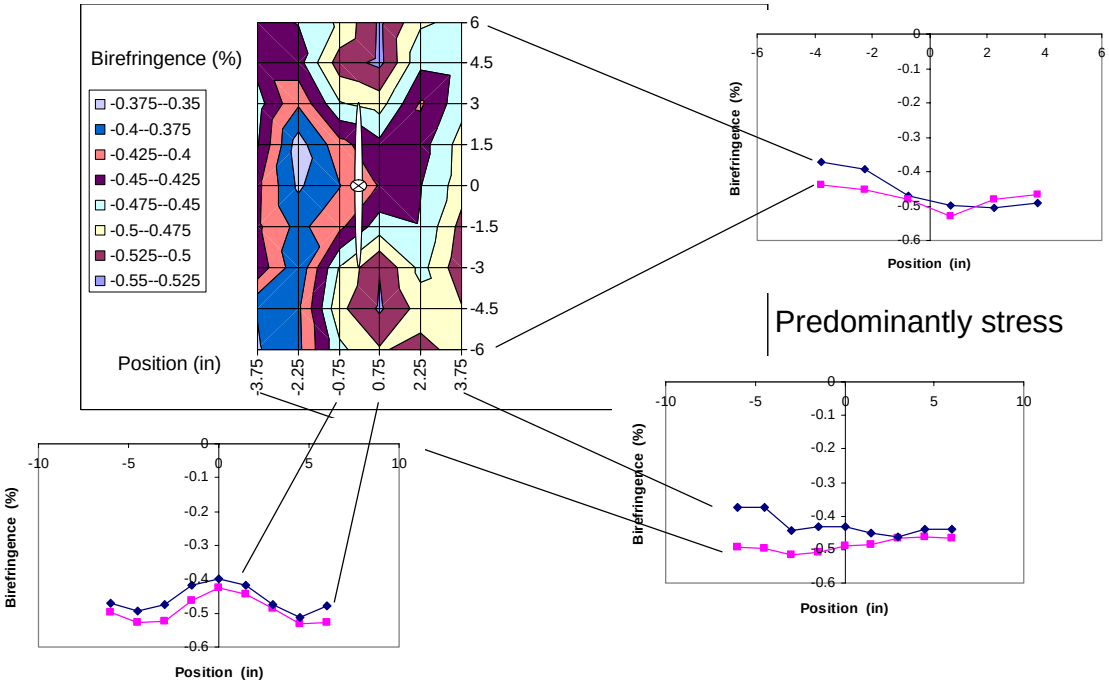

Figure 4. Ultrasonic results around dent created with 8 inch indenter pressed to a depth of 2% of the pipe diameter

Results from ultrasonic measurements of the dents are shown in Figure 4, where the Shear wave birefringence as a function of position is plotted around the dent created with the 8 inch long indenter pressed into the pipe to a depth of 2% of the pipe diameter. The ultrasonic measurements are strongly affected by this small dent with a maximum of the birefringence occurring nearest to the dent. Comparisons with the finite element modeling are shown in Figure 5 where the stress is plotted as a function of position along with the ultrasonic birefringence.

The ultrasonic measurements are in good agreement with finite element prediction, with the ultrasonic measurements indicating ~ 4000 psi of stress, and the finite element predicts 6000 psi of stress.

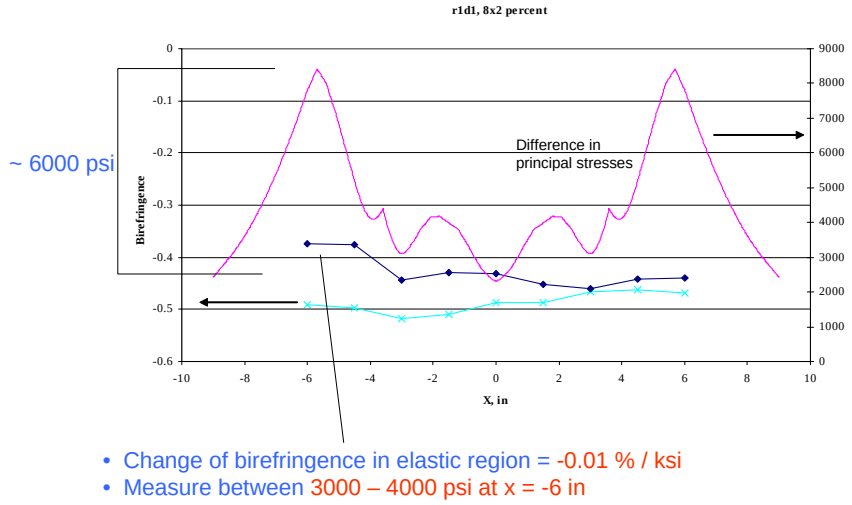

Figure 5. Comparison between finite element predictions and ultrasonic measurements

Presentation

This project resulted in 2 presentations at the domestic conferences of SPIE

- 9th SPIE Annual International Symposium Nondestructive Evaluation for Health Monitoring and Diagnostics

- Annual Review of progress in Quantitative NDE meeting

Path forward

We are continuing to characterize the pipe with calibrated dents and are in the final stages of preparing for the field test and meetings with robotics platforms for commercialization.