CAAP Quarterly Report

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Prepared for: *U.S. DOT Pipeline and Hazardous Materials Safety Administration*

Contract Number: 693JK32050006CAAP

Project Title: Nondestructive Diagnosis and Probabilistic Prognosis of Aging Plastic Pipe

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For quarterly period ending: 2/28/2021

Business and Activity Section

(a) Contract Activity

Nothing to report.

(b) Status Update of Past Quarter Activities

One PhD graduate student (Bibo Zhong) has been assigned to develop the nonlinear ultrasonic test method for pipe degradation evaluation. The main activities in Q1 includes literature review and preliminary tests on PVC samples.
The second PhD graduate student was recruited in January 2021. He will perform plastic aging test (task 1) and material characterization (task 2).

(c) Cost share activity

No charge to the project in this Quarter. The graduate students have been supported by UNL internal grants during last semester.

(d) Task1：Accelerated aging of PE pipe samples in lab
Task 3: Develop Ultrasonic NDE technology

We followed the procedures presented in reference [1] to create artificial defects that may induce slow crack growth in PE pipes. These samples were then tested using ultrasonic measurements. These preliminary tests help us better understand the effects of stress, temperature, and time on mechanical properties of PE materials. We will use the preliminary results to design a detailed PE aging test plan in next quarter.

1. Background and Objectives in the 2nd Quarter

1.1 Background

Aging of plastic materials (PE, PVC etc.) often cause significant decrease of ductility, i.e. embrittlement. The objective of this research is to develop an ultrasonic NDT test method to evaluate the aging deterioration of in-situ PE pipes.

1.2 Objectives in the 2nd Quarter

In the 2nd quarter, we performed preliminary tests to obtain better understanding of the key factors that may induce slow crack growth (SCG). These preliminary results will help us design a detailed PE aging test plan.

2. Experimental Program in the 2nd Quarter

2.1 Experimental design

Four 3/4 inch diameter (nominal) HDPE pipe specimens were used for testing. Each test piece is 4 inches long. The specimens were subjected to a 30% squeeze-off and/or high temperature at 110 °C. For proof-of-concept purpose, test parameters in the preliminary tests are larger than the values used the typical aging tests.

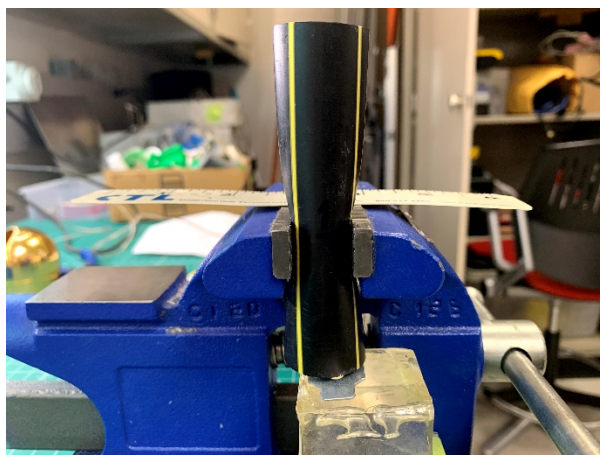

Figure 1 Setup for Squeeze-off

The setup for squeeze-off test is shown in Figure 1. A clamp was used to compress the outer diameter of the specimens from 1.05 inch to 11/16 inch for 2 hours. It was noticed that the squeeze-off had only a temporary effect on the shape of specimens, and the deformation recovered within a few hours. For the heating treatment, the specimens were put in an oven at 110 °C for 48 hours. Table 1 summarizes all tests experienced by the four specimens.

Table 1 Treatments for 4 PVC specimens

Specimen #	1	2	3	4 (reference)
Treatment #1	Squeezed for 2 hours	Squeezed for 2 hours	N/A	N/A
Treatment #2	N/A	Heating at 110 °C for 48 hours	Heating at 110 °C for 48 hours	N/A

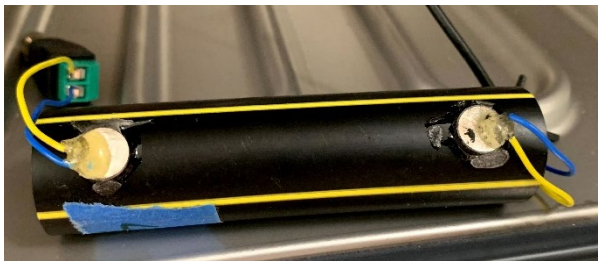

Figure 2 Ultrasonic test setup

After the squeeze-off and heating tests, a pair of PZT discs were attached to each specimen for ultrasonic thermal modulation test, as shown in Figure 2. In the thermal modulation test, all four specimens were subject to a thermal cycle from 22 ℃ - 34 ℃ - 22 ℃. The ultrasonic wave velocity changes (*dv/v*) were measured during the thermal cycle.

2.2 Experimental results

Figure 3 shows the experimental results from the ultrasonic thermal modulation test on all specimens. Specimen 2 (squeeze-off and heating) shows the highest sensitivity to temperature change, followed by specimen 1 (squeeze-off only). These test results indicate that the combination of stress and high temperature is able to generate significant effect on mechanical properties of HDPE material. Specimens 3 (heating only) does not show sufficient different from the reference specimens, which indicates that a short period of high temperature without excess stress (110 ℃ for 48 hours at zero stress) is not an effective aging method.

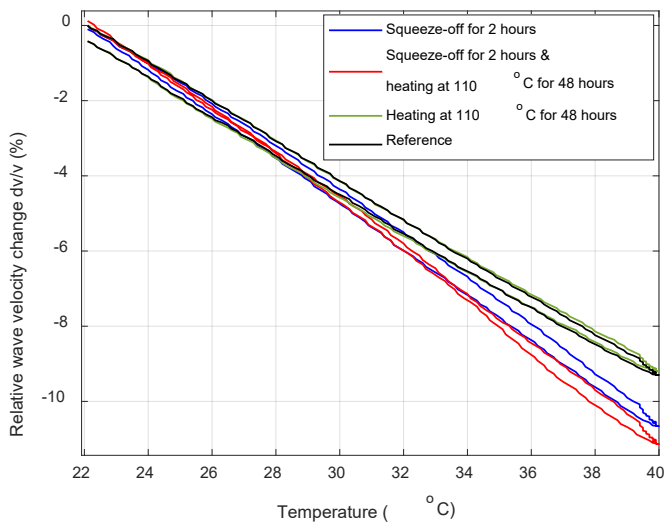

Figure 3 Experimental results from ultrasonic thermal modulation test on specimens

3. Results and Discussions

The preliminary test results show feasibility of using the ultrasonic thermal modulation test method to characterize aging/damage in PE pipes. Combination of stress and high temperature is effective to generate aging in PE.

4. Future work

In Q3, we will design aging test protocols based on RPM model and literature data. Samples aged to different degrees will be characterized.

Reference

Maupin, J. and Mamoun, M., 2009. Plastic Pipe Failure, Risk, and Threat Analysis (No. GTI Project No. 20385). Gas Technology Institute.