CAAP Quarterly Report

Date of Report: April 2, 2020

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

Contract Number: 693JK31850006CAAP

Project Title: Predicting Remaining Fatigue Life of a Dent with Corrosion Using Advanced Measurements and Modeling

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For quarterly period ending: March 31, 2020

Business and Activity Section

(a) Contract Activity

Impact of COVID-19 on the Contract: Georgia Tech closed campus and stopped all laboratory work on March 19, 2020. As a result, all laboratory ultrasonic measurements and the mechanical testing of samples has stopped. The investigators have subsequently pivoted to the modelling and simulation portions of the project, focusing on interpretation of the previous results of Tasks 2 and 5. In addition, we are developing a quantitative understanding of the interaction of nonlinear Rayleigh waves and material microstructure.

Both year one summary papers submitted last quarter (Q5) were accepted and are in print:

- Pfeifer, D., Kim, Jin-Yeon, and Jacobs, L.J., "Nonlinear Rayleigh waves to evaluate plasticity damage in X52 pipeline material," *Mechanical Systems and Signal Processing*, Vol. 143 (2020) 106794.
- Fahse, D.N., Levy, K.M.S., Kim, Jin-Yeon, and Jacobs, L.J., "Comparison of changes in nonclassical and classical acoustic nonlinear parameters due to thermal aging of 9Cr-1Mo ferritic martensitic steel," *NDT&E International*, Vol. 110 (2020) 102226.

(b) Status Update of Past Quarter Activities (Fifth Quarter Activities)

The primary activities in the sixth quarter were on Task 1, baseline measurements on virgin specimens from all four different pipe grades received from Fleet Technology (C30532 Grade X60, C30285A Grade X45, C30621 Grade X52, C30221 Grade X70) to quantify the effect of material variability on the measured NLU parameter β.

The legacy materials were manufactured decades ago and have been in service since the 1960's, and there is an inconsistency in their properties. This work developed baseline measurements on different positions in one specimen to quantify the influence of uneven material variations on the measured

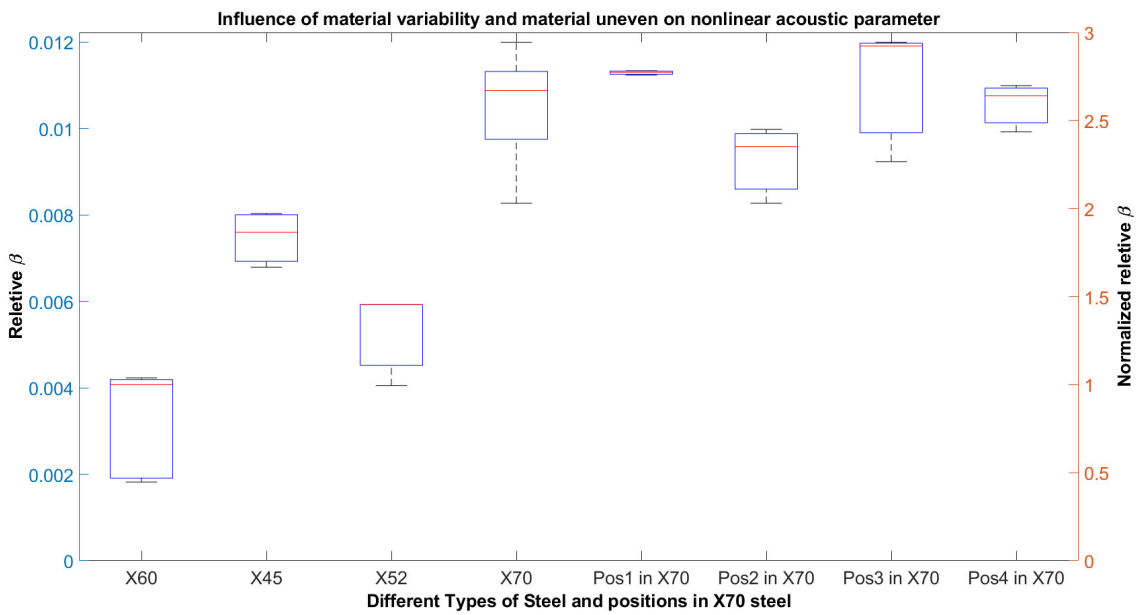
nonlinear acoustic parameter, β.

(c) Cost share activity

No cost share expenses this quarter. Held in-depth technical virtual meeting with Fleet Technology and Colonial Pipe on March 26, 2020. Personnel services support/expenses from Georgia Tech: support for PI Laurence Jacobs, Dr. Jin-Yeon Kim (doctoral level Research Scientist) and Hengyu Yang (PhD student) with an approximate cost of 10% total.

(d) Task 1: Baseline NLU measurements on virgin specimens from three different pipe grades

Measured the classical NLU parameter β in X70 steel sample 4f on four different positions to investigate the material inner uneven. The results are shown in the figure below. The results indicate there exists a 20% measurement variation in β at different positions on the same specimen. This variation can not to be ignored, and further measurements will be done at the same point in one specimen to minimize unnecessary measurement error. The baseline measurements of all four types of undamaged legacy materials provided by Fleet Technology are shown below. The measurements indicate a significant level of variability in the undamaged material, with changes on the order of 20% within individual materials.



1. Background and Objectives in the 6th Quarter

1.1 Background

Ongoing research activities focused on: quantifying the variability of the measured nonlinearity parameter in four different samples of the legacy pipeline material; training of new PhD student on the project, Mr. Hengyu Yang developing skills to measure acoustic nonlinearity parameter, β in a repeatable and consistent fashion.

1.2 Objectives in the 6th Quarter

These results continue to show that the variability in the measured β is much larger than that present in more modern material systems, which will require the implementation of extremely accurate measurement procedures for in-service monitoring. It is critical to understand if changes in the measured acoustic nonlinearity parameter β due to this material variability will be greater than the anticipated changes due to the accumulated fatigue and plastic damage.

1. ***Experimental Program in the 6th Quarter***

   2.1 Experimental design

   New PhD students Mr. Hengyu Yang demonstrated the ability to make NLU measurements of h β on multiple materials and specimens.

2. **Results and Discussions**

   Task 1 is mainly finished, and the measurements shows a great difference between different legacy materials which reflects inconsistency in material properties. Task 2 will cover NLU measurements on statically loaded specimens to quantify the effect of material plasticity on the measured NLU parameter β. The most important purpose of Task 2 is to determine whether the variability within the material is large enough to affect changes of β caused by material plasticity.

3. **Future work**

   Once the Georgia Tech campus and laboratories are reopened after the COVID-19, all three remaining types three types of specimens will be designed and manufactured and make the tensile testing and fatigue test specimens.