CAAP Quarterly Report

Date of Report: 01/09/2023

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

Contract Number: 693JK32250004CAAP

Project Title: Development of Compatibility Assessment Model for Existing Pipelines for Handling Hydrogen-Containing Natural Gas

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For quarterly period ending: 09/30/2022 – 12/29/2022

Business and Activity Section

(a) Contract Activity

Contract modifications or proposed modifications:

The Agreement Officer Representative (AOR) for cooperative agreement has been changed from Brady Dague to Mary McDaniel.

Materials purchased

During this reporting period, we purchased two desktop computers that are used for data acquisition and equipment control. We are also in the process of purchasing two autoclaves that will be used for testing hydrogen embrittlement of pipeline materials.

(b) Status Update of Past Quarter Activities

During the first quarter of the project, progress was made on database development and experimental setup modifications. We have completed data collection and have begun data cleaning and reconciliation. The designs of autoclaves and their accessories have been completed, and a vendor has been identified. In order to facilitate the start of experimental investigations, we will continue the modification process. Furthermore, the kickoff meeting for the project was held on November 7, 2022. Participants from the University of Oklahoma and DOT PHMSA, as well as members of the technical advisory panel, attended the meeting.

(c) Cost share activity

There was no cost share activities during this reporting period.

(d) Task 1: Database Development and Maintenance

This task includes three subtasks that will be completed sequentially (Fig. 1). The first subtask is data collection (Subtask 1.1), which has been completed during this reporting period. To accomplish this subtask objective, a literature survey has been conducted to establish a comprehensive database of hydrogen embrittlement (HE) occurring in gaseous environments. Data related to HE measurements have been gathered to create a master database.

(e) Task 2: Experimental Investigations

Four subtasks will be conducted sequentially as part of this task. The first subtask that needs to be completed is setup modification (Subtask 1.1), which we have been working on since the project began. Modifications will be made to a test setup that was not designed for in-situ hydrogen embrittlement studies. Two autoclaves with their accessories were designed during the reporting period to conduct in-situ mechanical characterization in high-pressure hydrogen-containing gas with severe load fluctuations. In hydrogen environments, fracture mechanics and fatigue failure studies will be conducted in the autoclaves. Furthermore, we have developed a clip gage design for manufacturing strain sensors.

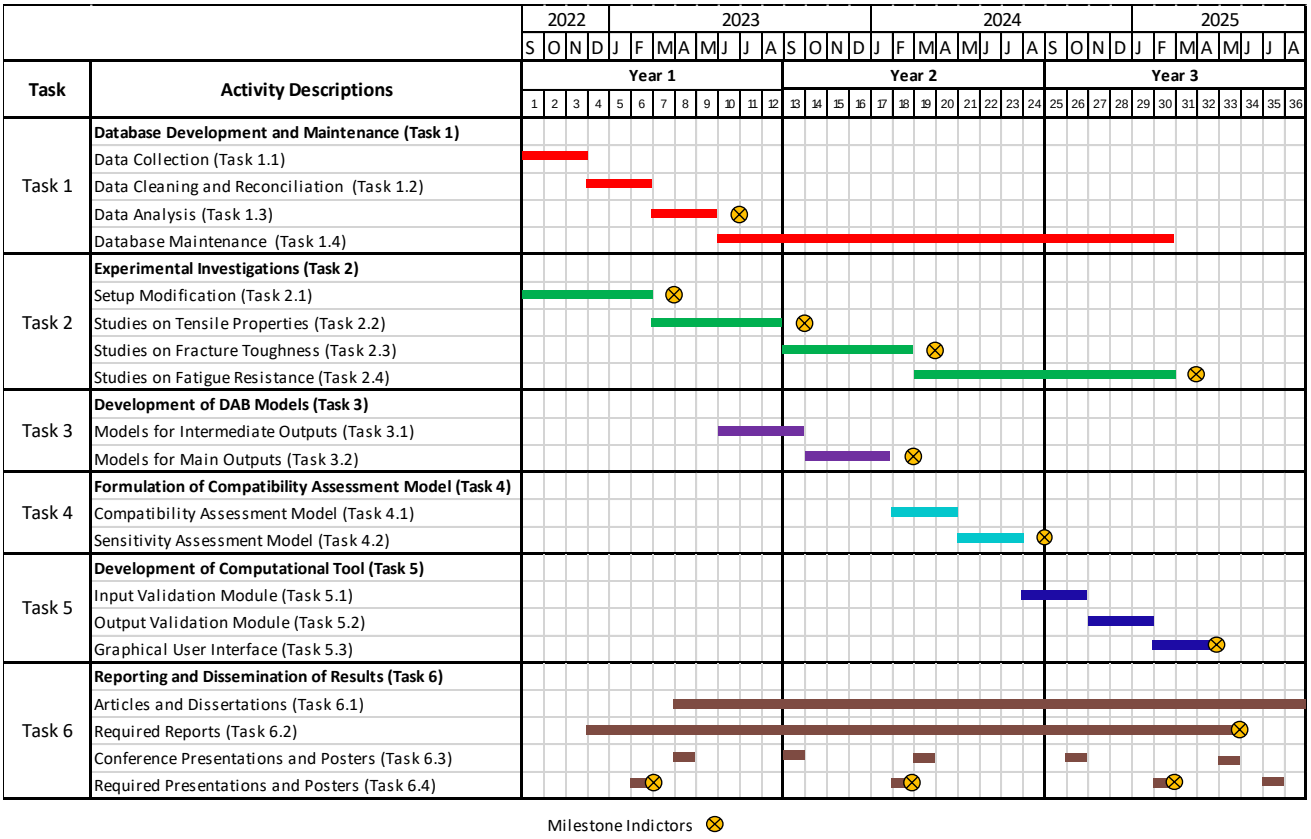

Fig. 1: project schedule

1. Background and Objectives in the 1st Quarter

1.1 Background

According to the project schedule presented in Fig. 1, the first quarter is dedicated to conducting data collection (Subtask 1.1) and experimental setup modifications (Subtask 2.1). Data collection is required to develop a database to perform data analysis and formulate data analytic-based (DAB) models that can assess the mechanical degradation of a material due to the hydrogen embrittlement phenomenon. We are focusing on collecting relevant data that shows the relationship between the performance characteristics of pipeline materials and various influential factors. Based on the DAB models' requirements, the database's completeness will be evaluated in Subtask 1.3. Further experiments will be conducted to supplement missing data sets. Hydrogen embrittlement failure experiments will be performed by modifying an existing test setup. We will replace the existing autoclaves, which are not designed to conduct in-situ mechanical characterization studies, with those specially designed for conducting in-situ mechanical characterization under high-pressure hydrogen-containing gas conditions with severe load fluctuations.

1.2 Objectives in the 1st Quarter

The first quarter of the project is aimed at establishing a database that summarizes publicly available HE data that can be used to develop a master database, which is needed to perform data analysis to establish DAB models. Besides data collection and database development, this quarter's objectives include modification of the existing experimental setup.

2. Experimental Program in the 1st Quarter

2.1 Experimental design

The proposed HE failure experiments will be performed by modifying an existing test setup. After modification, the experimental setup (Fig. 2) will have: i) two jacketed autoclaves (test cell) with a maximum working pressure of 5000 psi; ii) four supply gas cylinders filled with different research-grade gases used for testing (H2, blended gas, and natural gas) and purging (N2); iii) gas metering and two injection cylinders (capacity 250 ml each) to accurately control the composition of the gas phase in the test cell and boost supply gas pressure; iv) Temperature Control Unit (TCU) to maintain autoclave temperature at the desired level; v) computer-controlled syringe pump with hydraulic cylinders; and data collection instruments and a data acquisition system. During this quarter, we prepared designs (Fig. 3) of two autoclaves with their accessories for conducting in-situ mechanical characterization in high-pressure hydrogen-containing gas. We also developed a clip gauge design (Fig. 4) for measuring strain.

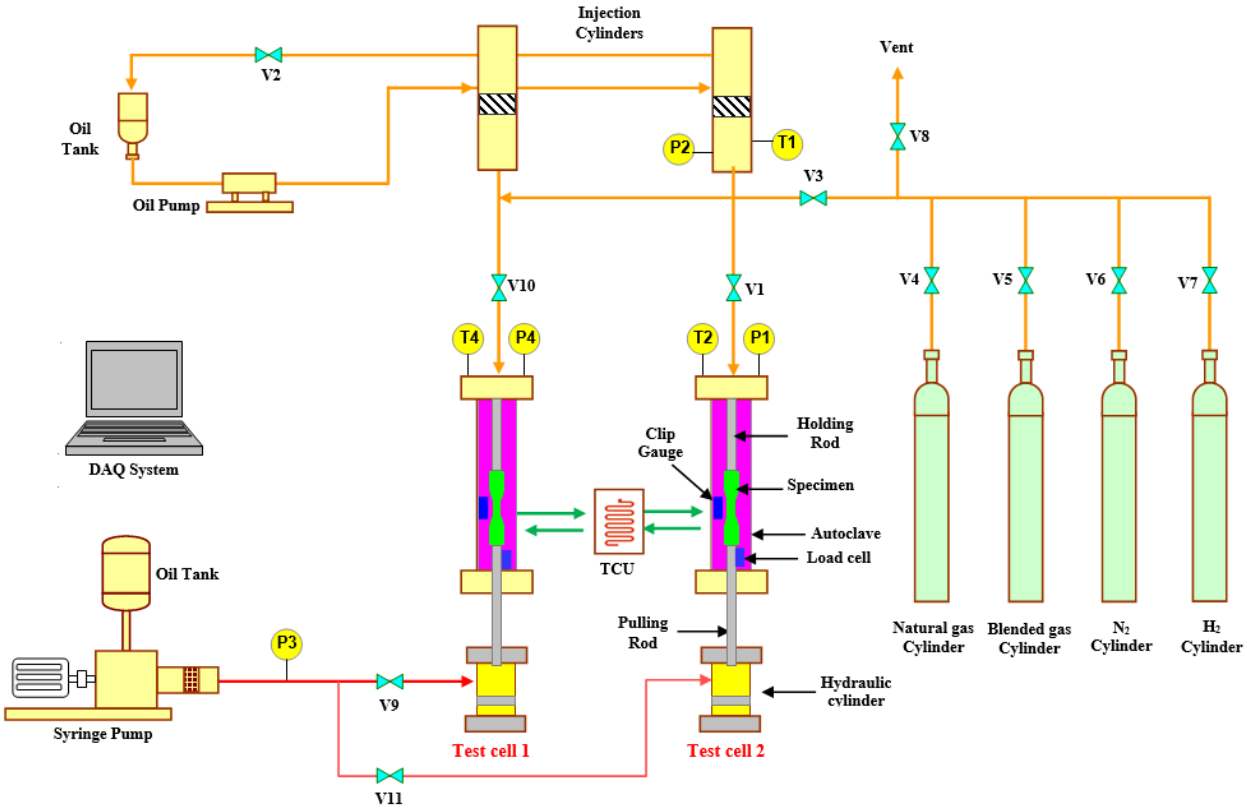

Fig. 2: Schematic of HE investigation setup

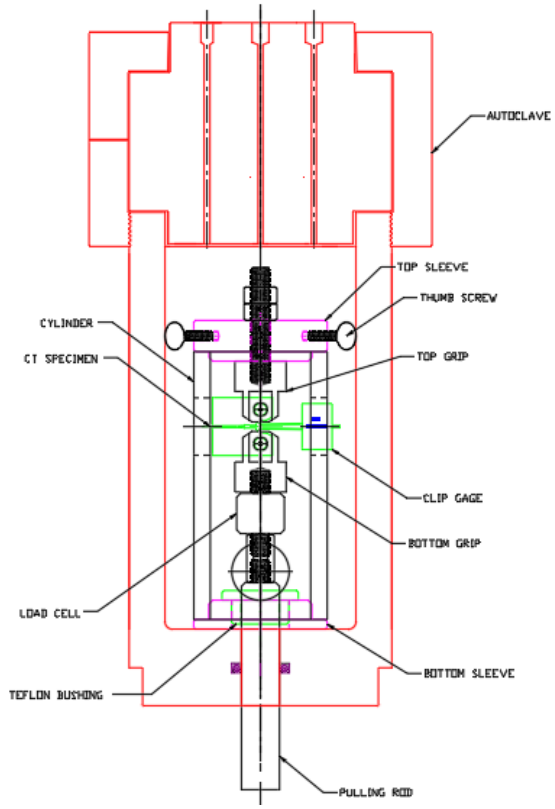

Fig. 3: Autoclave design

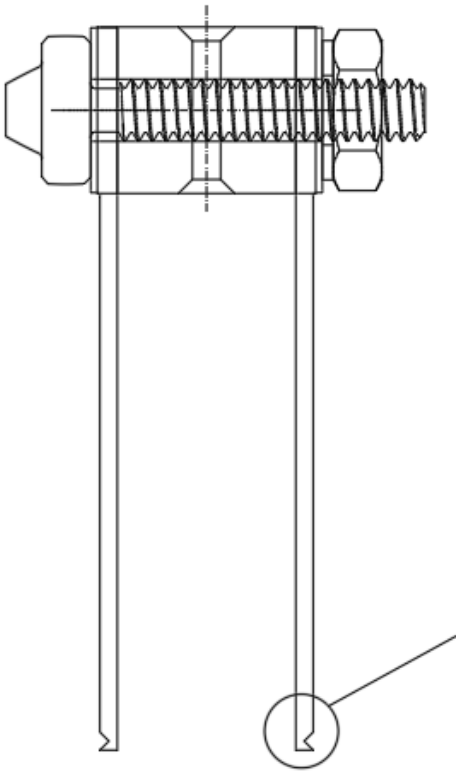

Fig. 4: Clip gage design

3. Results and Discussions

Over 1400 hydrogen embrittlement measurements have been collected from publicly available reports and papers. The data covers a wide range of materials used in pipelines (X42, X 52, X 65, X70) and structural steels. Measurements are obtained from different cases including fatigue experiments, tensile strength tests, and fracture toughness experiments. It is necessary to clean and reconcile the data to identify and resolve inaccuracies and inconsistencies.

4. Future work

Our plan for the next quarter is to perform data cleaning and reconciliation (Subtask 1.2). We will continue adding new measurements to the database as we do the cleaning and reconciliation. We will employ available DAB techniques to resolve missing data issues by imputation or removing the data sets. Imputation is used for cases with limited missing data. Established data analytics techniques will be employed to guess the absence of data. Furthermore, we will continue modifying and upgrading the experimental setup. The order for autoclaves will be placed in the coming days. It is expected to take 14-18 weeks for the autoclaves to be manufactured. The installation of the instruments and manufacturing of their accessories, including autoclave jackets, clip gages, and specimen grips, will be completed while we await their arrival. We will also manufacture some compact tension specimens for the planned tests.

References

Ahmed, R. and Teodoriu, C. 2022. Development of Compatibility Assessment Model for Existing Pipelines for Handling Hydrogen-Containing Natural Gas, research proposal submitted to DOT PHMSA.