PHMSA Internal Quarterly Report

Date of Report: *4th Quarterly Report- September 20th, 2024*

Contract Number: *693JK323RA0001*

Prepared for: *PHMSA, Government Agency: DOT*

Project Title: *Dual Purpose PIG for Cleaning and Internal Integrity Assessment for Hazardous Liquid Pipelines*

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For quarterly period ending: *September 20th, 2024*

1. Items Completed During this Quarterly Period:

1.1. Team Project Activity: Development of the Attachment Set for Transferring the Cleaning Pigs into Dual-purpose Pigs

1.1.1. Fabrication of the Version 2 Attachment

The fabrication of the Version 2 attachment, conducted in the Mechanical Engineering Department at NDSU, has finished the final design stage, and the fabrication process is currently underway. The Version 2 is designed to be made using a solid aluminum block, which was then ground and cut to create pockets for the camera, battery, and other accessories.

The important equipment that was used for the fabrication process include:

1. ***CNC Lathe machine*:** this is a high-powered machine that surpasses the manual machine in terms of capability and productivity, enabling more precise fabrication. It is a computerized machine with a visual programming system capable of converting various part geometries into a code interface. The CNC lathe machine was utilized to precisely cut the aluminum block into the prescribed dimensions and thread the dome cover, housing, and base holder.

Figure 1. Picture of (a) HAAS CNC Lathe machine TL-1.

2. ***CNC Mill machine*:** this machine is equipped with advanced milling software that optimizes speed and performance, ensuring the necessary precision, rigidity, and stability for manufacturing. As with the lathe, jaws were specifically engineered and precisely shaped from the aluminum block to secure the components in place during the manufacturing process.

Figure 2. Picture of (a) HAAS CNC Mill machine VM 2.

1.1.2. Modified Experiment Setup for the Static Water Condition

Pipelines usually suffer from various defects during their operation; some were already highlighted in Q3; they include corrosion, blockage, dents, cracks, leakage, and metal loss. These defects are a great challenge in the industry as they impede the operation of oil and gas networks. Images for some defects (blockage and corrosion) in various light conditions were obtained and presented in report #3. Further images were obtained for blockage, crack, and dent under static water conditions, as shown in Fig. 3, in which the setup in Q3 was modified. An 8-inch diameter pipe with a length of 1 ft was added to the end of the original piece, and each was severed with dent and crack. Meanwhile, the assembly of components for the pressured water test is now in progress.

Figure 3. Lab test set-up with 8-in-diameter schedule 40 pipe with various defects.

1.1.3. Experimental Study for Pipeline Defects Inspection in Lab Environment

This experimental study focuses on the inspection of pipeline defects within a controlled laboratory setting, simulating real-world conditions. The primary objective is to evaluate the ability of the inspection system to detect and characterize defects such as blockages and cracks under a range of environmental scenarios.

1.1.3.1.Environmental Conditions of the Pipe

Continuing with the test design in Q3, the test carried out in the lab was done under various environmental conditions (Fig. 4). The dry condition is when the pipeline is totally dry, and there is no water in the pipeline. The defect under this condition is clearly observed, and the images are captured by the developed PIG-system. Similarly, the partially wet condition indicates the pipeline when the water is half filled, while the wet condition indicates when the pipeline is fully filled with water.

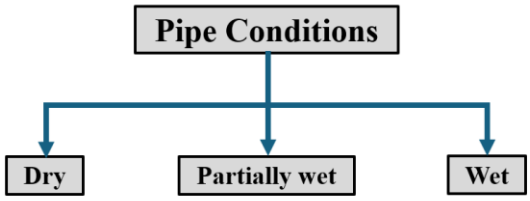

Figure 4. Different pipe conditions were tested in the laboratory.

1.1.3.2.Impact of Light Source Quantity and Orientation

Aligned with the studies conducted in Q3, all tests in this report considered the impact of light source quantity and orientation. A detailed experimental design of the number of lights and their orientations can be found in Q3. In general, the quality of the captured images is influenced by both the number and

positioning of the lights. Considering the different pipe conditions (dry, partially wet, and wet), there may arise scenarios in which the lights get completely or partially immersed in water. The phenomenon of light refraction in water will result in divergent image quality. The images would also be influenced by the bubbles produced by the motion of the PIG and the shadows created from the position of the light.

1.1.3.3.Fabrication of Pipeline Defects in the Laboratory Facility

Fig. 5 presents the pipeline defects that are studied in this project; the identified defects include dents, corrosion, cracks, leaks, and blockages. Under the current process, blockages, cracks, and dents are the top priorities for this project, as these are critical defects that the camera can effectively capture. Corrosion and leakage are typically associated with these defect areas. Therefore, the following discussions present a summary of these three significant defects. By capturing detailed images of blockages, cracks, and dents, we aim to develop more effective monitoring techniques. The correlation between these defects and the presence of corrosion and leakage will also be explored to better understand their combined effects on pipeline performance and safety.

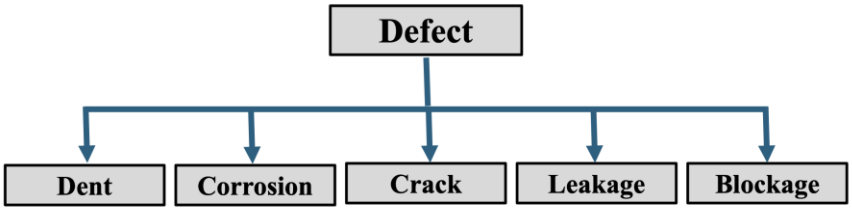

Figure 5. Common types of defects in pipelines.

1.1.4. Captured Images of Defective Pipe Areas Under Various Environmental Conditions

The study presents the images captured by the developed PIG system with the Version 1 attachment under static water conditions, showcasing defects such as blockages and cracks in dry, partially wet, and fully wet environments. The impact of varying lighting conditions and pipe states on image quality is also evaluated.

1.3.Team Project Activity: Machine Learning based Computer Vision Analysis for Pipeline Integrity Assessment of Hazardous Liquid Pipelines

Improving the quality of images captured inside pipelines poses significant challenges due to environmental factors such as low light, surface reflections, and the presence of debris or fluids. Various image processing and machine learning techniques are utilized for enhancing the accuracy and reliability of visual inspections in such environments. These methods range from traditional techniques like color correction, denoising, and deblurring, to advanced machine learning approaches, tailored to overcome challenges like noise, lighting conditions, and motion.

2. **Items Not-Completed During this Quarterly Period:**

The research team has reviewed the tasks for this quarter, and we confirm that the project is on time and aligns with our scheduled milestones and objectives.