PHMSA Quarterly Report – Public Page

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Contract Number: *693JK323RA0001*

Prepared for: *PHMSA, Government Agency: U.S. DOT*

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

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

1. Items Completed During this Quarterly Period:

1.1 Team Project Activity: Designing and manufacturing of the vision attachment

During the second quarter reporting period, the research team has been engaged in designing and manufacturing an attachment set intended to easily attach onto commercially available cleaning pigs with minimal impact to pig operations.

1.2.1 Summary of the current design

The current design of the Computer Vision Attachment housing (CVA Version 1: CVA.v.1) has been meticulously drafted and is presently undergoing fabrication, and the design's feasibility is being verified through a 1:1 scale 3D printed prototype. The attachment will be designed to resist pressure and water entry as required of underwater operations for liquid pipeline to fit pipeline working conditions.

1.2.2 Material selection for the CVA.v.1

When evaluating materials for the housing of a cleaning pig, a comprehensive comparison of aluminum alloy, stainless steel, and Polyvinyl Chloride (PVC) reveals distinct advantages and limitations associated with each material, guiding the decision-making process to meet specific operational requirements. Table 1 summarizes the key properties of the three candidate materials.

Stainless Steel, known for its high strength and exceptional corrosion resistance, offers significant advantages in terms of durability and resilience in harsh operational environments. It stands out for its ability to withstand extreme temperatures and corrosive substances, making it a robust material choice for industrial applications requiring long-term reliability. However, the primary drawback of stainless steel in the context of attaching the set to cleaning pig operations is its considerable weight. The addition of the housing, with its increased weight, can negatively impact the pig's ability to navigate through pipelines, especially those with complex geometries or long distances.

Polyvinyl Chloride (PVC) was initially considered for its versatility, cost-efficiency, low density, and lack of corrosion issues. However, its lower strength compared to metals such as aluminum alloy and stainless-steel limits its use. Therefore, the insufficient strength of PVC makes it an unsuitable solution for applications where durability and load-bearing capacities are crucial.

Aluminum Alloy has been chosen for its outstanding lightweight characteristics, corrosion resistance, and affordable cost. This material aligns with the critical objective of maintaining a compact and lightweight structure, which is essential for ensuring the cleaning pig can navigate through pipelines efficiently. The reduced weight of aluminum alloy facilitates easier handling and lower propulsion force, thereby enhancing operational efficiency and maneuverability within the pipeline. Additionally, the durability offered by aluminum's resistance to environmental factors contributes to the longevity and reliability of the cleaning pig.

In conclusion, the material selection for the cleaning pig housing necessitates a balance between weight, strength, corrosion resistance, operational efficiency, and cost. Aluminum Alloy emerges as the optimal choice, offering a superior balance of lightweight properties, sufficient strength, and corrosion resistance that meets the operational demands of cleaning pigs. Refer to Table 1

Table 1. Properties of aluminum and stainless steel

Property	**Aluminum**	**Stainless Steel**	**PVC**
Density (g/cm^3)	2.7	7.9 – 8.0	1.13 - 1.85
Tensile strength (MPa)	90 – 570	520 – 1100	14.3 - 55.2 MPa
Corrosion Resistance	Good	Excellent	Won't corrode
Heat Resistance (^{o}C)	Up to 600 – 660	Up to 750 – 1550	60
Melting point (^{o}C)	660	1400 – 1450	110 - 210
Thermal Conductivity (W/mk)	205 – 235	15 -25	0.120 - 0.190

Source: Industrial Metal service, and Matweb.

1.2.3 Development of various designs and feasibility verification through the utilization of 3D-printed prototypes

a) Design development for the attachment

During the development of CVA.v.1, a number of trials for the housing were made and the design was improved upon at multiple times before arriving at this present design. Therefore, three trail designs were prepared, and the designs were thereafter upgraded by addressing the flaws.

b) 3D Printing of models

To assess the viability of each design, 3D printed prototypes were created. Detailed information on the 3D printing process follows: Each prototype was printed using the Lulzbot Taz 6 printer. The designs, modeled in AutoCAD, were exported as .stl files and then imported into the Cura Lulzbot Edition software. In this software, the .stl file undergoes slicing and is saved as a .gcode file. This file is then transferred via a memory card to the Lulzbot printer, initiating the 3D printing process. The printer utilizes a filament with a diameter of 2.85mm (0.11 inches), which is fed to the tool head and extruded at approximately 210°C (410°F) to start the printing. Table 2 summarized printing times for each prototype.

Table 2. Time taken to complete the 3D printed prototypes

Description	Cover	Cylindrical body/base
1st trial	5hrs 13mins	16hrs 32mins
2nd trial	6hrs 36mins	12hrs 05mins
3rd trial	6hrs 25mins	12hrs 05mins

1.2.4 Final design of the attachment with detailed dimensions

Following the iterative process detailed in Section 1.2.3, we arrived at the current design CVA.v.1 of the attachment housing showcased in this section. To facilitate waterproof installation and adequately accommodate electronic components, the attachment is ingeniously divided into two primary parts: the cover and the base housing.

1.2.5 Accessories selection: light source, camera, batteries, and miscellaneous

For the preliminary testing of the CVA.v.1 housing, the following types of Accessories will be utilized:

(1) Camera was selected for with anti-vibration capabilities and ability to capture high-quality images under low-light conditions.

(2) The chosen light source is anticipated to furnish sufficient illumination to facilitate image capture within the pipeline environment. For the purposes of this test, one pair of these lights will be utilized for testing and evaluation purposes.

(3) The LED light will be affixed to the drain plug kit, which in turn will be secured to the housing cover using screws. The drain plug, crafted from brass to leverage its high strength, corrosion resistance, and wear durability, features a diameter of 1 inch and a 0.5-inch NPT thread. This threading matches that of the LED light, ensuring a seamless and secure connection.

(4) Considering the working condition in the pipeline, marine adhesive sealant will be used to seal the gaps in the housing. This sealant, designed for effectiveness in underwater conditions, will ensure a waterproof seal at all joints and will also be utilized to secure the tempered glass to the cover.

(5) Compact batteries are chosen to preserve the housing's portability. These batteries are essential for supplying continuous power to the camera and the light sources.

(6) Appropriate connectors will be employed to establish connections between the lights, camera, and batteries, ensuring a reliable power supply.

(7) Tempered glass will be utilized to ensure camera visibility and to protect the lens while also preventing liquid leakage into the housing.

1.2.6 Facilities utilized for the fabrication process

The production of components for CVA.v.1 is currently underway a machine shop. The fabrication process utilizes a variety of equipment, including:

1. Mach 500 Waterjet: The Mach 500 4020 Waterjet is a high-powered machine that utilizes water at extremely high pressures (up to 94,000 psi) to achieve high precision and fast cutting speeds, making it ideally suited for cutting through the holes in the base plate and the cover. This computer-controlled machine is equipped with the FlowMaster suite for 2D designs or the

FlowXpert suite for both 2D and 3D designs, ensuring precise cuts. The software provides a live feed of the cutting process, which allows for pauses and resumes as necessary. An image of the waterjet is displayed in Figure 1, with some of the machine's specifications detailed in the table below.

Table 3. General specification of Mach 500 Waterjet

Parameter	**Value**
Linear Positional accuracy	+/- 0.001in
Rapid traverse maximum	700in/min
Acceleration	0.1g
Repeatability	+/- 0.0008 in
Ballbar circularity	+/- 0.0025 in
Z-axis travel	12in, 24in
Work envelope	Mach 500 4020: 13’-1’’ x 6’-6’’
Pump technology	94,000 psi

Source: Flow Water Jet

Figure 1. Picture of Mach 500 4020 waterjet

2. Lathe machine: Lathe machine: the lathe machine would be used to cut and shape the parts. The threading of the cover and the basement will also be done using the lathe machine. Figure 2 shows the image of the lathe machine, and the specifications of the machine are shown in Table 6.

Table 4. General specification of Kingston Heavy Duty 34 – Model: HR 3000

Parameter	**Value**
Swing over cross slide	34’’
Swing over gap (up to C.C 160’’ only)	45.6’’
Distance between centres	120’’
Width of bed	22’’
Height from floor to work center	48.6’’
Spindle bore	4.09’’
Taper of spindle bore & centre	ASA#450 x M.T. #6
Type of spindle Nose	D1-11
Number of spindle speeds	16
Spindle speed	8-800 RPM (12-1200)

Number of feed changes	Fine (20), Normal (40), Course (30)
Range of feeds per revolution	0.0024'' – 0.0337''
Longitudinal Cross	½ of longitudinal feed
Leadscrew diameter & Threads per inch	1.9'' / 2 TPI
Threading	Inch/metric
Threading range whitworth	2 to 28 TPI(40)/ Coarse 5/8'' to 8'' pitch (16)
Threading range metric	1 to 14mm (31) / Coarse 16 to 200mm pitch (61)
Threading range module	0.5 to 7M (20)/ Coarse 8 to 56 M (30)
Threading range D.P.	56 to 4 D.P (40)/Coarse 3.5'' to .5'' D.P. (30)
Maximum travel of compound	9.4''
Maximum travel of cross slide	21.25''
Tailstock Quill Travel	11.8''
Tailstock Quill Diameter	5.125''
Tailstock centre	M.T. #6
Main drive motor	20HP (15kw)
Coolant pump motor	¼ HP

Source: Worldwide Machine tool

Figure 2. Picture of Kingston Heavy Duty 34 – Model: HR 3000 lathe machine

3. Welding machine: The housing is composed of several components that are assembled to create the intended unit. Following the cutting of pieces with the previously described machines, each part is meticulously positioned and subsequently joined using arc welding. A photograph of the welding machine is displayed in Figure 3.

Figure 3. Picture of Miller welding machine

2. Project Financial Tracking During this Quarterly Period:

The following figure including the project financial tracking during this quarterly period:

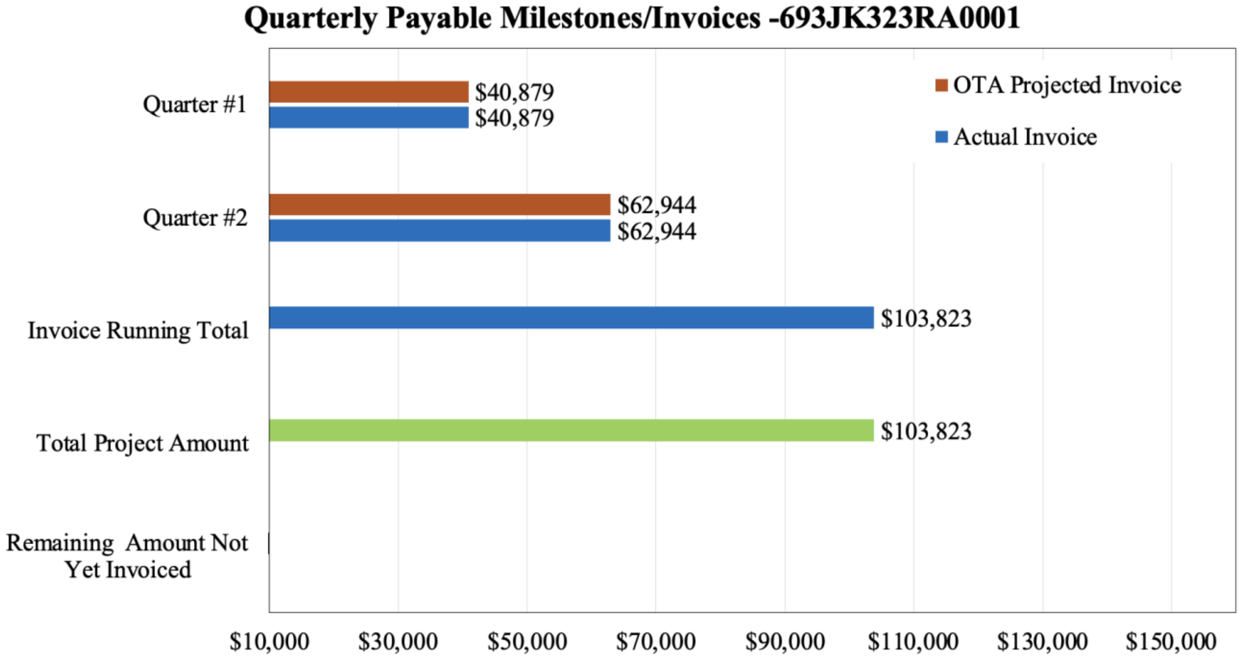

Figure 14. Project financial tracking

3. 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.