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HORIZONTAL PIPE INSPECTION ROBOT

Amil Azeez, Nithin , Rizwan S , Prashanth Pai*

Department of Mechanical Engineering, P.A. College of Engineering, Karnataka, Mangalore, India

E-mail: prashanth_mech@pace.edu.in

Abstract

The pipelines are the major tools for the transportation of portable water, effluent water, fuel oils and gas. A lot of troubles caused by piping networks aging, corrosion, cracks, and mechanical damages are possible. The inspection of pipes may be relevant for improving security and efficiency in industrial plants. These specific operations as inspection, maintenance, cleaning etc. are expensive, thus the application of the robots appears to be one of the most attractive solutions. A pipe inspection robot is device that is inserted into pipes to check for obstruction or damage. These robots are traditionally manufactured offshore, are extremely expensive, and are often not adequately supported in the event of malfunction. This work details the fabrication and construction of such a robot.

1 INTRODUCTION

Pipelines have proven to be the safest means of transporting and distributing gases and liquids. Pipeline systems deteriorate progressively over time. Corrosion is accelerating and in the long term, deterioration leads to failure (fatigue cracking). Regular inspections are essential for pipelines, which can be accessed via online inspection tools. A pipe inspection

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robot can help in inspecting pipes. Robots are designed to remove the human element from heavy or dangerous work and to work in inaccessible places. Pipeline inspections can have an impact on improving plant safety and efficiency. The cost of certain tasks such as inspection, maintenance, cleaning, etc. is high, so the application of robots seems to be one of the best solutions currently used to become an important tool in the transportation of oil, gas and other liquids. The main problem lies in the design of the pipe inspection robot and its use is to combine personal mobility, personal stability, weight and size characteristics. A very important design aspect is to transfer the robot inside the pipe. Currently, the application of robots in pipeline maintenance is considered as one of the most attractive solutions.

John, Binil, and M. Shafeek[1] studied that pipe inspection robots are essential tools for maintaining pipeline infrastructure. They are classified into Out-pipe Inspection Robots (OPIRs) which move along the outer surface of pipelines and In-pipe Inspection Robots (IPIRs) which navigate the interior of pipelines. Wheel-driven IPIRs are commonly used, with simple structure and wall-press designs being the most prevalent. Jeon, Kwang-Woo, et al.[2] presented the development of an in-pipe inspection robot designed for large-diameter water pipes. Key features of the robot included dual-wheel drive for efficient propulsion and stability. Their tests have demonstrated the robot's ability to navigate pipelines, reducing the need for human intervention and improving inspection safety. Gargade, Atul, and Shantipal Ohol[3] explained the key advancements such as diameter adaptability for the optimized spring design which allows the robot to accommodate a wider range of pipe diameters. SolidWorks 16 was used to model the robot's components, including the driving and supporting leg systems, and connecting body.

Verma, A., Kaiwart, A.et al.[4] studied the navigation of the interior of pipelines using In-Pipe Inspection Robots. Key features of the study include wheel-driven IPIRs, having simple design and high speed, but limited ability to climb steep inclines and also track-driven IPIRs having more traction and climbing ability, but with complex mechanical design and potential for track damage. Michał Ciszewski, et al.[5] discussed about the adaptive drive

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mechanism and adaptive track systems which enable the robot to conform to different pipe geometries, ensuring optimal traction and stability. The study was successfully conducted in pipes with diameters exceeding 210 mm. Moshayedi, A. J., et al.[6] stated that development of an in-pipe inspection robot represents a significant advancement in pipeline maintenance. By providing detailed visual data, this technology can significantly improve the reliability and safety of pipeline infrastructure. They also highlighted Visual Inspection System, having a camera integrated into the robot to capture high-quality images of the pipeline's interior.

2 METHODOLOGY

The objective of the current work is to design and assemble a pipe inspection robot capable of navigating dry horizontal pipes using technologies such as 3-D Printing, Automation and Robotics. The work includes modeling, fabrication, post processing, assembly and testing phases.

In the modeling phase, Fusion 360 was used to create an initial 3-D assembly model and extruded 2-D parts of the robot. The 3-D model of the robot along with the list of parts are shown in Fig. 1. In the fabrication phase, the required parts were made using Sovol 3-D Printer, shown in Fig. 2. Various parameters are to be set up for printing the model using the Sovol software. After all the parameters are set, the model is sliced to get the time required for printing each part. After printing all the parts, the support structures are to be removed in the post processing phase. After all the support structures are removed, the parts are filed to get a clean surface finish. The 3-D printed parts are now ready to be assembled. The list of parts printed are shown in Table 1.

The outer bodies are joined together to get the central body of the robot. The links shown in Fig. 3 are then joined to the outer and inner body of the robot. Medium links are joined to the outer body, 3 on each sides at an angle of 120° from each other, using nuts and bolts. The long links are then joined between two medium links on all three sides. This

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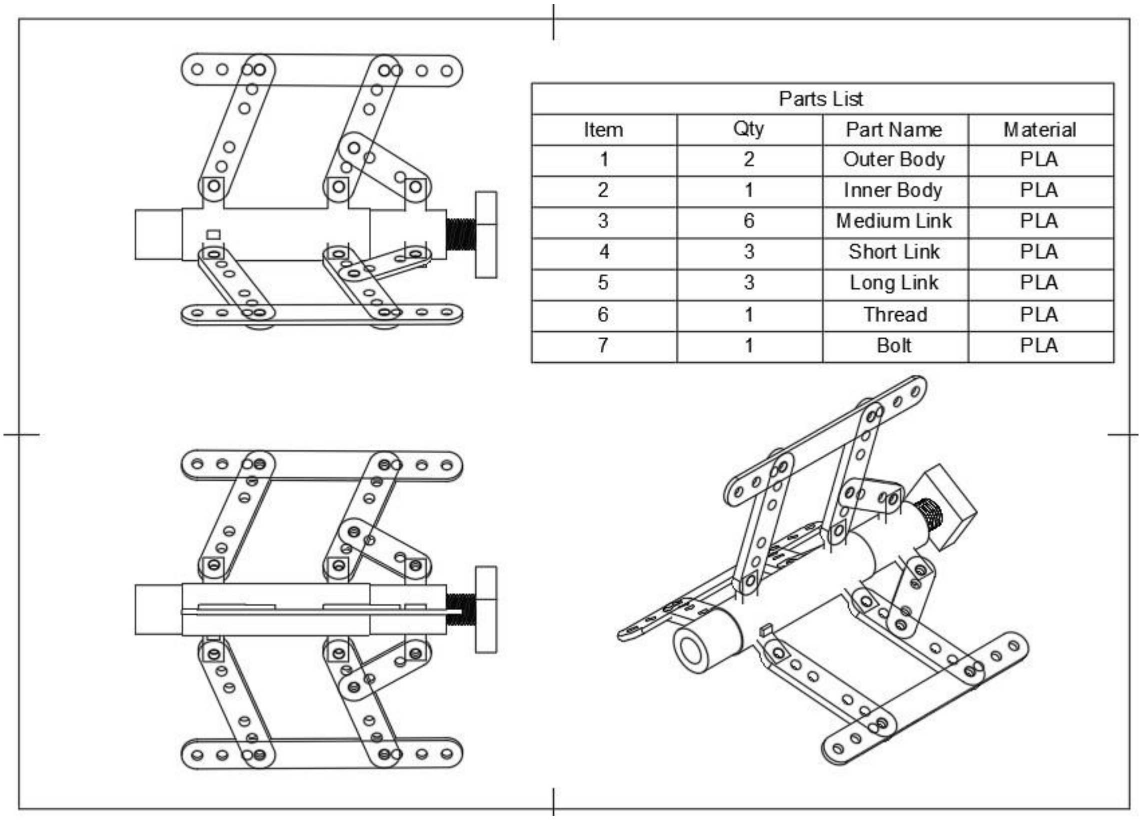

Parts List			
Item	Qty	Part Name	Material
1	2	Outer Body	PLA
2	1	Inner Body	PLA
3	6	Medium Link	PLA
4	3	Short Link	PLA
5	3	Long Link	PLA
6	1	Thread	PLA
7	1	Bolt	PLA

Figure 1: 1: 3-D Model made using Autodesk Fusion 360

Figure 2: 2: Sovol 3-D printer

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Table 1: Components of the pipe inspection robot

Item No.	Qty	Part Name	Dimensions
1	2	Outer Body	Length 100mm Outer Diameter 30mm Thickness 2.5mm
2	1	Inner Body	Length 140mm Outer Diameter 26mm Thickness 2.5mm
3	6	Medium Link	Length 115mm Thickness 25mm
4	3	Short Link	Length 70mm Thickness 25mm
5	3	Long Link	Length 230mm Thickness 25mm

formed the robot chassis as shown in Fig. 4. The small links are joined to the inner body at one end, separated by an angle of 120° as shown in Fig. 5. The inner body is then placed inside the outer body and the small links are joined to the medium links. This formed the complete body of the pipe inspection robot.

For the driving mechanism, 12V DC motors are used as shown in Fig. 6. Six of the motors along with the wheels attached to them are joined at the ends of the large link. A breadboard tied to the outer body and all the wirings from the motors are joined to it at one position. The wirings from the 3-way switch as shown in Fig. 7 are connected to the same point on the breadboard to form the complete circuit. The motion is controlled in such a way that the robot moves forward and backward depending on the direction of the closed circuit while it doesn't move when the circuit is open. Finally a camera as shown in Fig. 8 is attached to the front of the robot. The camera is connected via Bluetooth to a mobile phone to obtain a live footage of the area under inspection inside the pipeline. The assembled pipe inspection robot can move through pipes having diameters ranging from 280mm – 380mm. For testing, a pipe of diameter 300mm is used. The robot is then placed inside the pipe and it detected the spots present inside the pipe as shown in Fig. 9.

Fig. 3: 3-D Printed Links

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Figure 3:

Figure 4:

Figure 5: Fig. (a). Small Link Fig. (b). Medium Link Fig. (c). Long Link

Figure 6:

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Figure 7: Fig. 4. Robot Chassis Fig. 5. Inner Body Mechanism

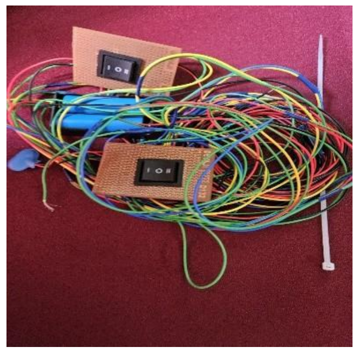

Figure 8:

Figure 9: Fig. 6. DC Motors with wheels attached Fig. 7. Wirings with 3-way switch

3 CONCLUSION

Robots play an important role in inside pipe-network maintenance and their repairing. Robots can be used for pipe line inspections for better detection of defects. This work successfully developed a functional pipe inspection robot capable of navigating through pipes. The robot's design, using 3-D modeling and 3-D printing techniques, resulted in a lightweight and durable structure. The integration of the camera enabled the robot to

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Figure 10: 8. Camera

collect visual data on pipe conditions. The robot's navigation capabilities, facilitated by its driving mechanism, ensured efficient inspection processes. The developed inspection robot can be used for pipe diameters ranging from 280mm- 380mm. While the robot demonstrated promising results, future improvements could include automating the motion of the robot by using AURDINO, changing the structure of the robot to enable it to move through complex pipe systems, enabling 360° motion of the camera to get a better view and reducing friction

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Figure 11: 9. Image showing spots inside the pipe

between the links.

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