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REVIEW PAPER ON DIFFERENT CLASSIFICATION OF PIPE INSPECTION ROBOT

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Abstract : The manual cleaning of pipelines in various industrial environments is a risky and laborious task that poses a threat to the safety of human workers. In response, our project involves the design and fabrication of a fully autonomous industrial pipe-cleaning robot.

This robot features a Six-wheel system, a forward-reverse cleaning mechanism, and a robust body structure. The system is constructed with high-tension rubber tires for shock absorption and is enclosed within a Rectangle casing. Control over the robot's movement and cleaning mechanism is achieved through a microcontroller. The robot demonstrates the capability to traverse horizontally mounted pipes, detecting obstacles in its pathway using various sensors.

Implemented on a larger scale, this technology holds potential applications in the cleaning of chemical or multipurpose industrial pipelines, water pipelines, drain pipes, etc. The project represents a significant advancement in industrial maintenance, combining autonomous robotics, adaptive cleaning mechanisms, and obstacle detection for enhanced efficiency and worker safety.

1.INTRODUCTION

Several industrial sectors use robotic inspection. One use is monitoring the interior of channels and pipes to identify problems and provide solutions. The inside surface of a pipe can be automatically inspected by a mobile robot. Pipelines are susceptible to corrosion because they are usually placed underground, where they come into contact with the soil. This oxidation of the steel pipe wall results in a reduction in wall thickness. The world is changing daily due to the introduction of new technologies. The primary objective of technology is to simplify and ease human existence. People who have lost their hands, legs, or both temporarily or permanently as a result of disease or accident may need a voice-activated wheelchair. It is necessary to inspect the pipe to look for wear and corrosion damage while it is transporting fluids. This ability is particularly crucial for subsurface pipe inspection. This project involved the conception and construction of a Pipe Inspection Robot (PIR) that can navigate through both vertical and horizontal pipes. The robot is equipped with a driving motor and a camera for a monitoring station. Robotics is one of the engineering specialties that is now growing at the fastest rate.

Robots are designed to work in hard-to-reach places and carry out risky or labor-intensive jobs without the need for human intervention. Nevertheless, you will discover that such robots are far too costly if you check at their prices. The goal of this suggested system is to develop a different form of robot for pipeline inspection. Since we believe that having a robot that can adapt its construction to the pipe diameter while also being less expensive is advantageous [1].

2. PIPE INSPECTION ROBOT: CLASSIFICATION

Robots for pipe inspection can be broadly classified into two categories: in-pipe and out-of-pipe models. The out-pipe inspection robot (OPIR) traverses the exterior of the pipeline while using a device to hold onto the pipe. Subterranean and underwater pipelines can be thoroughly inspected by in-pipe inspection robots (IPIRs), which carry out the necessary inspection tasks by navigating within the inside of pipe line.

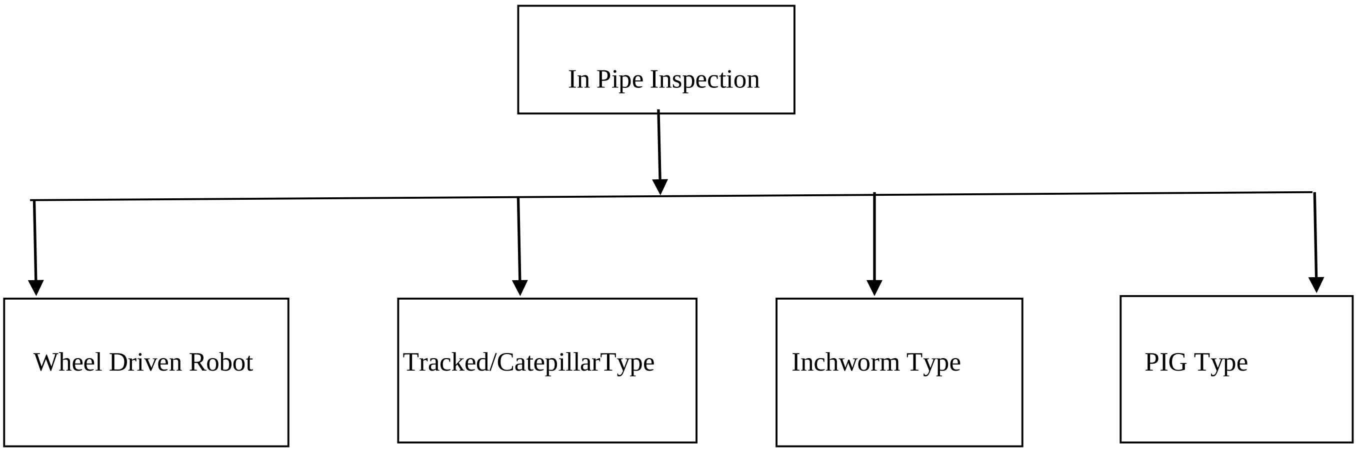

Fig.1. Classification of In-pipe Inspection Robot

2.1 Wheel Driven Pipe Inspection Robot

With a range of wheel-based designs available, wheel-driven pipe inspection robots are one of the most investigated forms of inspection robots. Simple structure robots and wall-press robots are the two categories of robots, as seen in Figure 1. The robot is propelled by gearmotors or actuators through its wheels. Most wheeled robots keep in contact with the surface using a variety of devices. Simple wheel-driven robots with a structured appearance resemble standard wheeled robots and are primarily utilized for horizontal pipe inspection. Since it lacks any, it has no extra linkages to maintain contact with the inside surface of the vertical pipelines. The Gunathilake group [1]

have successfully tested six wheeled, simple-structured, structured sewage inspection robots (fig. 2.a) in Sydney, Australia. The robot is equipped with an infrared laser profiling unit and stereo camera vision. An additional sort of inspection robot is the wall press type, which always makes contact with the interior surface of pipe lines due to its angled wheel modules.

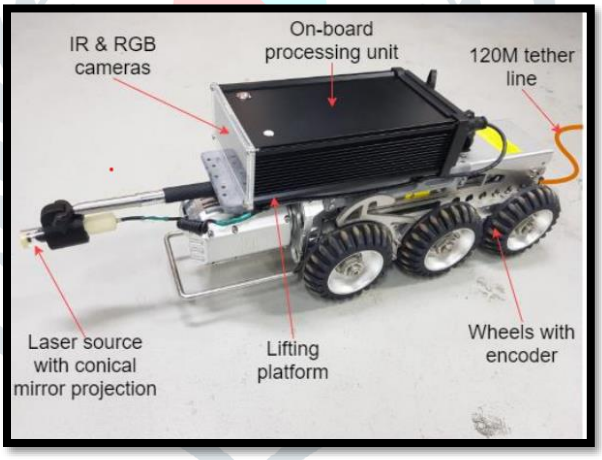

Fig.2. Simple Structured Wheel Driven Pipe Inspection Robot

2.2 Tracked/ Caterpillar Type Pipe Inspection Robot

The robots use tracks rather than wheels to move around the pipe inlets. Tracks improve traction and stability by expanding the surface area in contact with the pipe intake. Robots with tracking capabilities can hold heavier loads and greater body weight. The robots' limited mobility and slow speed are other drawbacks. Tracked robots come in two varieties: wall-press type and basic structured. A long-distance pipeline inspection robot system is discussed by Zhao et al. [2]. The robot has three electric putters and crawlers, each with a separate radius and speed control. They verified the stability of the robot's movements in a massive pipe. The robot's inner diameter ranges from 950 to 1200 mm, and it is intended for pipeline inspection. The robot has a lot of sensors packed into it. Encoder sensors are used to determine the robot's true speed, while pressure sensors are affixed to the crawlers to assess the traction.

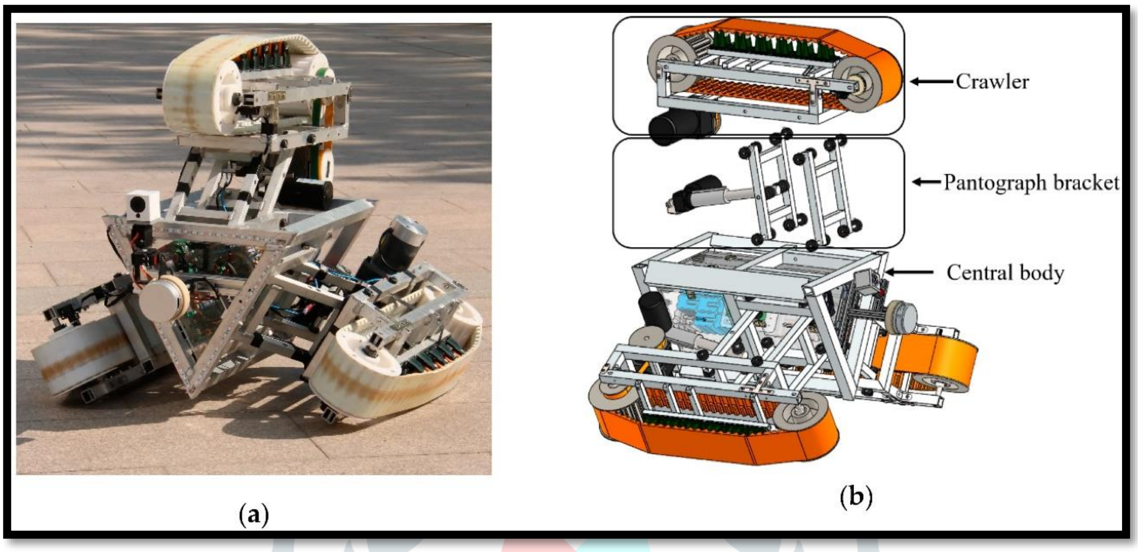

Fig.3.(a) Large in-pipe Robot prototype with three-wheel train, Fig(b) Solid Model

The D 300 wall press pipe inspection robot was created by Abidin et al. [3] to inspect sewage pipe lines with an interior diameter of 300 mm (fig 5). The robot is designed using a wall-pressed caterpillar, which may be utilized for elbows and pipes that are vertical or horizontal in orientation. This robot has ultrasonic sensors, a robust geared motor, and a high-performance CPU board for maneuvering around the corner of the pipeline engine. The three distinct drive modules that make up the IPR-D300 can alter speed in response to the peculiarities of the pipeline.

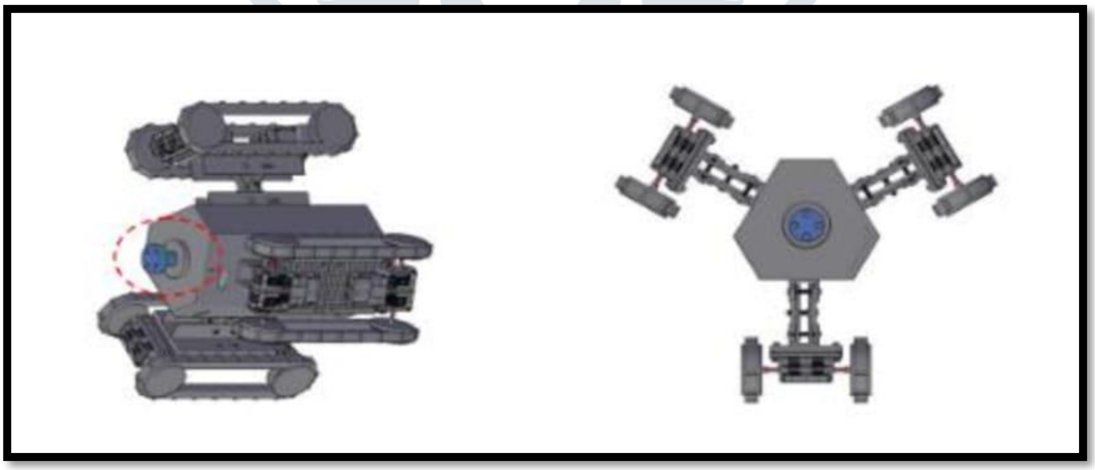

Fig.4. Conceptual Design of IPR-D300 2.3 Inchworm Type Pipe Inspection Robot

The worm-type robot is one of the bio-inspired robots made by IPIR. They move in a manner akin to an earthworm. The robot moves forward through repeated contraction and expansion movements. These move with a lot of friction force and at slower driving speeds. A pipe inspection robot created by Chablat et al. [4] imitates the movements of a caterpillar inside pipe lines. Three pieces make up the mechanism: two for the legs attached to the inner half of the pipe, and one for motion. The robot replicates caterpillar motion with the help of three legs equipped with slot follower systems. Using the Wrench equation and the static approach, the relationship between the contact force between the pipe and the legs has been addressed. coulombs law of friction. However, cooperative mobility of robots was not mentioned in the study. A robot that uses fluidic flexible actuators, or Extension type flexible pneumatic actuators (EFPAs), was created by Hayashi et al. [5]. The holding mechanism has been strengthened by the new ring-shaped tube provided at the ends of the nodes (it can provide 160 N clamp force). The improved retaining mechanism is constructed like an automobile tire wheel to minimize volume change during expansion. For pipe sizes of 75 and 50 mm, twin pipe holding mechanism pipe inspection robots have been created. The robot can steer in six directions by using three EFPA units (fig. 6.a). With this new design, there are no longer any problems with electric leakage or short circuit. The studies' results show that this robot can maneuver through intricate structures without becoming trapped.

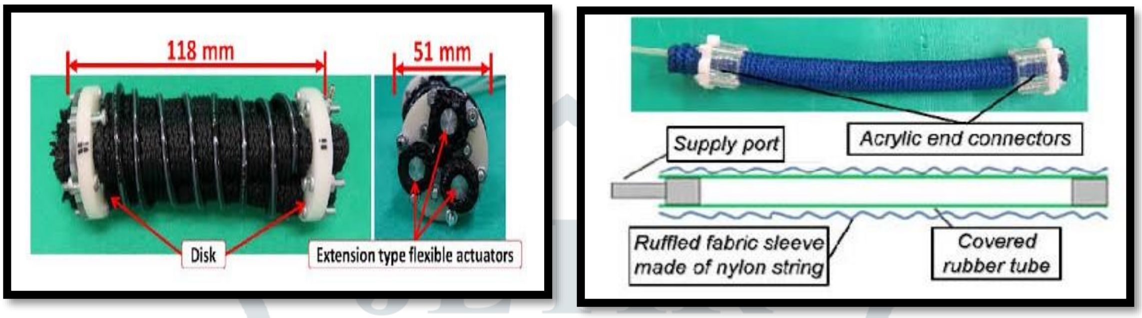

Fig.5.(a) Sliding/bending mechanism using three FFPAs, (b) Inner construction of thinner type sliding/bending mechanism

2.4 Pipe Inspection Gauge (PIG) Robot

One common kind of pipeline inspection robot is the Pipe Inspection Gauge (PIG) Type robot. It was mostly utilized in the gas and oil industries. The fluid velocity is one method used to control the robot's mobility, among others. The one drawback of this kind of model is that it is made specifically for a single diameter. To search for cracks and other irregularities, the robot has several sensors connected. These robots are wireless, thus they come with a battery module. The inspection results are verified only after the PIG robot is received.

The PIG robot will pass through the predetermined spots to enter and exit the pipes. Because the PIG robot is difficult to navigate, complicated constructions do not employ it. Nguyen and associates [6], The dynamic design and analysis of a PIG-type robot for 90-degree bent pipes is presented in this work. They divided the 90-degree bend into three portions, and they used the Lagrange equation to obtain the dynamic model.Both the upstream and downstream issues have been resolved, and simulations were used to assess the effectiveness of the generated models. A PIG pipeline inspection robot that can travel independently for cross-country crude oil pipe lines was proposed by Mishra et al. [7]. A power source is located within the robot to power its sensors. Additionally, the inspection robot is not powered; therefore, it is crucial to regulate the robot's speed inside the pipeline to prevent equipment damage. They have estimated the robot's position inside the pipeline using a kinematic model.

Fig.6. Pipe Inspection Gauge (PIG) Robot

3. RESULTS AND DISCUSSION

The primary advanced papers in each subject discuss several kinds of Pipe Inspection robots. Table 1 presents the robots' comparative analysis. It is clear that the predominant class of robots is IPIR wall pressing robots. The robots can be selected based on the individual requirements. Wall pressing robots are unnecessary and a waste of time and effort when it comes to applications where the inspections are limited to horizontal pipes.

Therefore, under these situations, simple-structured robots are beneficial, and these robots' design, manufacture, and operation are all quite straightforward. Yet, it is typically challenging to use these wheeled robots when the horizontal pipes that need to be inspected are sewage pipes. Robots with legs or tracks can be employed in these kinds of situations.

Despite their intricacy, the effectiveness of the inspection process will make up for it. PIG robots can inspect pipelines with constant section diameter and characteristics, such as long, large oil and gas pipelines. However, prior to using PIG robots to inspect a pipeline, a number of procedures are typically followed, such as cleaning the pipeline and looking for any internal bulging that could endanger the inspection robot.

These processes add time to the PIG robot inspection process. Although they move very slowly, inchworm-type robots are best suited for pipelines with small dimensions since they can fit inside them with efficiency. Despite the fact that inch worms are the ideal fix for pipes with tiny diameters. Robots of the tracked or caterpillar variety are appropriate for medium- and large-sized pipelines, as they possess the ability to transport bulky equipment and have strong traction properties. These characteristics make it appropriate for heavy equipment-intensive examinations.

	Wheel Driven Type	Tracked/ Caterpillar Type	Inchworm Type	PIG type
Manoeuvrability	High	Low	Low	No
Adaptability	High	High	Low	No
Horizontal Movement	High	High	High	High
Vertical Movement	Medium	Medium	Low	No
Stability	Medium	High	Low	Low
Drive Speed	Medium	Low	Low	Medium

4. CONCLUSION

The paper discusses various pipeline inspection robots and presents the findings of a comparative analysis. A variety of pipeline inspection robots are available, including wheeled, legged, tracked/caterpillar, inchworm, and more. Each of these robots is made specifically for a given application that calls for a certain pipe diameter and level of complexity. Because of this, the robots can only process in a specific set of pipelines. Selecting the robots based on the needs New research directions for pipe inspection robots are also included in the report.The ability to move across a variety of surfaces is possessed by amphibious robots, and pipeline robots are being designed with this in mind. A significant step toward bringing the robot closer to its practical use will be pipeline inspection, and further developments in this area are anticipated. The article provides a comprehensive summary of pipe inspection robots and the most recent developments in the industry.

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