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Gas Pipe Leakage Inspection Robot With Real Time Monitoring System For Gas Industries

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Abstract: *The most popular method for transporting fluids and gases is through pipelines nowadays. Regular inspection is necessary for the pipelines to work correctly. Humans must not enter potentially dangerous environments to inspect these pipelines. As a result of this, pipeline robots came into existence. These pipe inspection robots help in pipeline inspection, protecting numerous people from harm since human beings cannot enter the pipes and inspect them in case there is any such or kind of damage that requires repair. Despite numerous improvements, pipeline robots still have several limitations. The introduction of this in pipe inspection robots helps to solve many problems, such as leakage of the gas or fluid pipelines, rustiness, and also if the pipe is broken from any part.*

Keywords: Inspection robot, Leakage, Pipeline, Broken

I. INTRODUCTION

Pipelines are now the most widely used method of transport for gases and liquids (63-65). Therefore, ongoing pipeline monitoring is necessary to assure its safety and health. The most widely utilized Non-Destructive Testing (NDT) inspection techniques are optical testing, radiographic testing, ultrasonic testing, and hydrostatic testing, among others. Gas can be detected using the sense of smell in both humans and animals. But in practice in everyday life this can endanger the safety of humans and animals because high concentrations of gas will poison the body causing death . To avoid this, conventional gas detection can be replaced with mobile robot technology. Using a mobile robot to track the position of a gas leak provides its own advantages because it minimizes the risk of work accidents when checking for gas leaks. This robot is equipped with LIDAR which serves as mapping in the room. The gas sensor used to detect gas leaks is an electrochemical sensor. This sensor was chosen because it has the ability to detect very small levels of gas, which is 1 ppb. Then mobile robot is also equipped with Internet of Things (IoT) which serves to monitor the levels of gas leaking or air pollutions around the room from a considerable distance.

II. LITRATURE REVIEW

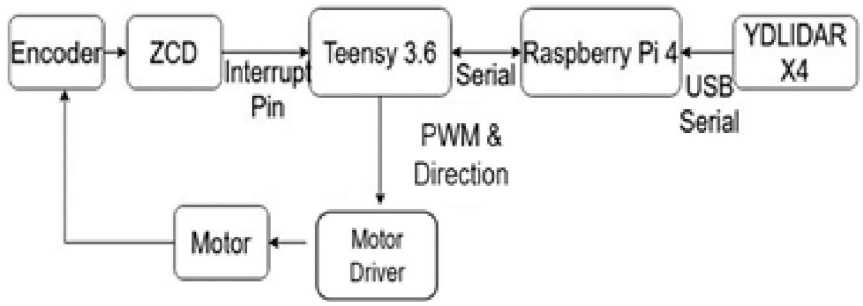
According to published research, many conventional wheeled robots use wheels that are symmetrically positioned at a 120° angle to ensure even loading and improved stability while moving through pipelines. The wall press characteristic is how the wheeled robots acquire this stability. According to, the inclusion of six wheels corrects the uneven motion that occurs along the circumferential axis of the pipeline in forward motion caused by the three-wheel arrangement in wheeled IPIR. The wheeled robot has a three-wheel layout and moves inside the pipelines using two different types of wheels. One has single wheels, whereas the other has double wheels n order to address the issue of irregular motion and motion singularity occurring in pipelines, a wheeled type IPIR is proposed and developed in this research. The wheels on this robot are different from those on conventional robots in that they are not fixed at a 120-degree angle from one another. The location of the wheels guarantees that the robot's wheels are always in contact with the pipe surface and prevents the robot from rolling over when moving along a curved pipeline. It also aids the robot's navigation through branched pipes. In-pipe robot is an integrative system of mechanism, electronics and measuring instruments which can execute some missions through tiny pipelines under manual operation or computer control.This paper presents the design and develop ment of a micro in-pipe inspection robot powered by Shape Memory Alloy (SMA) actuators. The proposed robot is intended to navigate narrow and complex pipeline environments for inspection and maintenance tasks. The key focus is on the mechani cal structure that leverages the unique properties of SMA materials — which contract upon heating and return to their original shape when cooled — to enable smooth, f lexible, and precise motion in confined pipe spaces. The robot's compact design incorporates a modular body with SMA-driven legs or limbs that adapt to varying pipe diameters, allowing it to crawl and maneuver inside pipelines. Wheels 1 and 2 encounter the most force when the pipeline diameter is increased to 340 mm, whilst wheel 3 experiences a decrease in forces. The forces pulling on the wheels then cease to exist. Wheel 3 experiences an increase in force when the robot enters the curved pipeline because the wheel loses touch with the concave portion of the inner pipeline surface. When the robot tries to travel through a curved pipe, it loses contact with one of the wheels and is unable to do so; however, the two wheels that are still in contact exert a force on the spring, which is why wheel 3 has a high spike after losing contact. The spring force causes the wheels to push the robot backward, which causes wheel 3 to hit the inside of the pipe and generate a huge force spike. Here, springs 1 and 2 refer to the springs in the front and back of the robot, respectively. When the robot passes through a pipeline with a 350 mm inner diameter, the force supplied by springs 1 and 2 ranges from 1.25 to 12.5 N. When the inner pipeline diameter reaches 340 mm, the force generated by springs 1 and 2 approaches 17.5 N. The robot cannot move through the curved pipeline because of motion singularity, which causes the force in spring 1 to decrease. Motion singularity causes the back half to exert a slight push at that precise moment because of the inertia of motion. As a result, the legs on the robot's back compress, producing a strong force of roughly 25 N at first before progressively reducing. It moves at an average linear velocity of 0.35 m/s while inside the 350 mm straight pipeline. The linear speed of the robot varies between0.30 and 0.35 m/s when the inner diameter of the pipeline drops to 340 mm. The robot then tries to enter the curved pipeline but is unable to do so due to motion singularity, causing a sharp fall in linear velocity.

III. PROBLEM IDENTIFICATION

Traditional wheeled IPIRs have wheels that are 120 degrees apart from one another. The angle is calculated between the centers of each wheel and the central axis of the robot body. The homogeneous wheel mounting angle results in the motion singularity. The prismatic junction between the three legs allows them to compress uniformly as they pass through the pipeline. Motion singularity consequently develops inside curved pipelines. Wheel 1 rotates with a greater angular velocity than wheels 2 and 3, which remain stationary. The three wheels' angular velocity is constant as the inner diameter of the pipe shrinks. The robot then attempts to enter the curved pipeline, but wheel 3 loses contact, preventing the robot from doing so. It demonstrates that wheel 3's angular velocity, which should have been high when it traversed the concave region of the pipe, has remained constant in magnitude. The fact that it lost contact with the pipe wall is thus demonstrated. A maximum force of approximately 11.25 N is applied to wheels 1, 2, and 3 as the robot goes through a 350 mm pipeline.

IV. METHODOLOGY USED

This section contains an explanation of the overall design of the system starting from the design of the hardware and software during the research. The main sensors used in the experiment are the YDLIDAR X4 and the gas sensors. Data from LIDAR was taken by the Raspberry Pi 4 and gas sensor data was obtained from the Teensy 3.6 microcontroller. The ROS system includes mapping using Hector SLAM. The YDLIDAR X4 sensor is placed at the top, while the gas sensors are located at the front of the mobile robot. The motor used for this mobile robot is Sankyo JLN4B02. The output of the encoder signal is processed first using a Zero CrossingDetector (ZCD) so that the signal can be received by teensy 3.6 module. In Fig. 1, Teensy module controls the speed of the motor using the PWM pin and adjusts the direction of the motor's rotation using the directors' pin. Electrochemical gas sensors are used as devices that measure the concentration of the target by oxidizing or reducing the gas in the electrode and generating current [7]. This type of sensor has sensing electrodes and counter electrodes separated by a thin layer of electrolytes or catalysts. The structure and reaction of the gases on the electrochemical sensors are shown in Fig. 2 and Fig. 3, respectively. Counter electrodes serve to balance the electrode sense reaction.

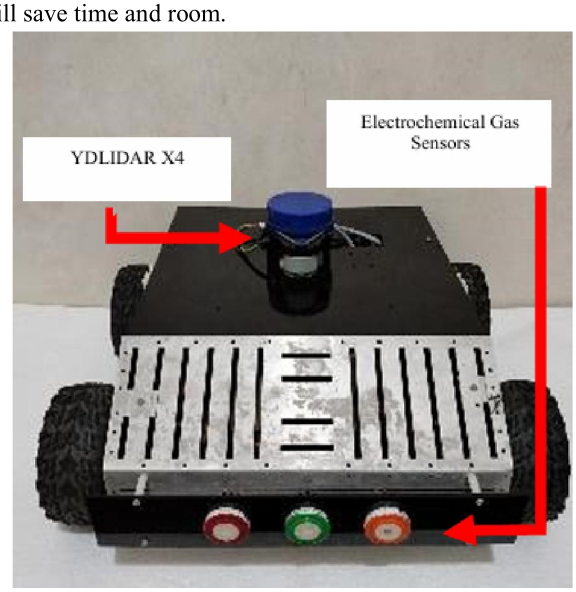


If the sense electrode oxidizes the gas, then the counter electrode must reduce some other molecule to produce an equivalent current. In this study, we used CO-B4, SO2-BF, and H2S-B4 electrochemical gas sensors that provide electric current, with sensitivities of 535 nA/ppm, 390 nA/ppm and 2025 nA/ppm, respectively.

4.2 ROBOTS FOR INSPECTING PIPELINES

(1) Extreme security: Use the pipeline robot to enter the pipeline to efficiently discover the interior conditions of the pipeline or remove any concealed dangers. Because of the high labor intensity and greater safety risks associated with manual labor, these jobs are not good for employees' health. The Easy Sight pipeline robot's intelligent operation may significantly enhance the operation's performance in terms of safety.

(2) Labor-saving: Small and lightweight, the pipe inspection robot can be controlled by one person. The controller can be put on the vehicle, which will save time and room.



(3) Increased effectiveness and caliber: The smart pipeline robot from Easy Sight can display real-time data such date and time, crawler inclination (pipeline slope), air pressure, crawling distance (meters of line), laser measurement results, and azimuth in addition to accurate positioning (optional). The function keys allow you to control the clock display of **the lens angle of view as well as the display status of this information (positioning of pipeline defects).**

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(4) Great level of protection: There is no need to be concerned about the pipe camera's quality because it has a high level of protection, airtight protection, and the material is waterproof, anti-rust, and corrosion resistant..

(5) Receiving and releasing cables won't interfere with one another with a high-precision cable reel, and the length is configurable. The pipe inspection robot can inspect pipelines with diameters ranging from 100 mm to 2000 mm. It can raise productivity and save labor in addition to enhancing task precision. Additionally, it can maintain the pipeline in some locations where manual labor is not appropriate and quickly identify the internal sources of pipeline degradation.

4.3 WHEELED IPIR DESIGN MODIFICATION

The suggested wheeled design Inspection of the Pipe The wheels are asymmetrically and at various angles mounted by the robot. The arrangement of the wheels results in angles that are 120°, 104.88°, and 135.12° apart from one another. Calculations are made to determine the angle between the central axes of each wheel and the body of the robot. In the curved pipeline, a robot With the exception of the wheel mounting angle, it uses the same mechanism as a conventional robot with wheels. The motion singularity in the curved pipeline is therefore avoided by the suggested design. The angular velocity of all three wheels remains constant as the robot moves through a straight pipeline with an inner diameter of 350 mm. When the inner pipeline diameter was reduced to 340 mm, small spikes in angular velocity were observed. After then, it moves via a straight pipeline with a constant angular velocity for the three wheels. The angular velocity of wheel 3 increases while that of wheels 1 and 2 decreases as the robot moves along the curved pipeline.

TABLE I. LIDAR MEASUREMENT RESULTS

Actual Distance (m)	Measured Distance (m)	Error (%)
0,5	0,54	7,41
1	0,99	1,00
1,5	1,53	1,96
2	2,03	1,48
2,5	2,55	1,96
3	3,07	2,28
3,5	3,54	1,13
4	4,06	1,48
4,5	4,53	0,66
5	5,13	2,53
5,5	5,62	2,14
6	6,16	2,60
6,5	6,63	1,96
7	7,15	2,10
7,5	7,73	2,98
8	8,19	2,32
8,5	8,63	1,51
9	9,14	1,53
	Error Average	2,17

V. FUTURE SCOPE

1. **Autonomous Navigation and Mapping:** Research and implement robust SLAM (Simultaneous Localization and Mapping) al gorithms tailored for pipe interiors to enable autonomous exploration. Enhance obsta cle detection and avoidance capabilities to safely navigate complex pipe geometries and debris.

2. **Non-Destructive Testing (NDT) Integration:** Investigate incorporating advanced NDT techniques such as ultrasonic phased array, magnetic flux leakage, or eddy current testing to precisely characterize pipe defects. Explore real-time processing of NDT data onboard the robot for immediate assess ment.

3. **Robotic Manipulation and Repair:** Design and prototype robotic arms or manipulators capable of performing repair tasks such as applying sealants, welding, or installing liners inside pipes. Study modular re pair units that can be attached or detached depending on the task and pipe conditions.

4.**Communication and Data Handling:** Enhance wireless communication protocols by adopting mesh networks or 5G for im proved reliability and bandwidth in underground or remote environments. Develop cloud-based analytics platforms to store, visualize, and analyze inspection data, en abling better decision-making.

5. **Mechanical Design Improvements:** Explore lightweight, modular, and foldable robot designs to increase maneuverability through varying pipe sizes and bends. Research materials and coatings for water proofing, corrosion resistance, and explosion-proof capabilities to widen application scenarios.

6. **Energy Efficiency and Power Management:** Investigate energy harvesting methods (e.g., from pipeline vibrations or thermal gra dients) to extend operational duration. Optimize battery technologies and power man agement algorithms for longer mission endurance.

VI. CONCLUSION

In this work, we contrast the suggested wheeled type IPIR with the wheeled type IPIR that is currently in use. The three wheels are mounted on the current design at a 120° angle from one another. Both the suggested and conventional wheeled forms of IPIR are simulated. The ideal angles are 104.88°, 135.12°, and 120°. Results of velocity and force analyses for each wheel demonstrate how this design brings the wheels into contact with the pipelines. The created robot did not experience the unequal force experienced by the robot with a wheel mounting angle of 120° when traversing the curved pipeline. Also discussed are the effects of the in-pipe wheel robots.

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