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PIPELINE INSPECTION USING A LOW-COST WIFI BASED INTELLIGENT PIGGING SOLUTION

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Abstract
This study presents a low-cost smart pipeline inspection gauge (PIG) designed for pipeline defect (leakage) detection, and for quick data access and recovery for the purpose of analysis, utilizing locally sourced materials and off-the-shelf sensors and electronics. The PIG's electronic circuit is designed to house the sensors and allow for easy reception and transfer of pressure measurements to the pipeline manager's laptop via a WiFi module. A pressure sensor, a motion sensor, a wireless communicator, and an Arduino Microcontroller are utilized in the development of this PIG. The PIG was tested experimentally by being put through stationary, no load-no defect, and no load-defect tests respectively. The PIG was kept still during the stationary tests but was conveyed within a 160 mm diameter Polyvinyl Chloride (PVC) conduit with a length of 6.7 m for both the no load-no defect and no load-defect tests, using a 0.125 Hp direct current (DC) motor, with a gearbox attachment to pull from one end to the other. Using a WiFi module and the PuTTY program, the pressure values were retrieved. The test results revealed that P_1 (front pressure) values were higher than P_2 (rear pressure) values for the no load tests. P_1 readings ranged from 1213 to 1214 Pa, with an average of 1213.86 Pa for the no load-no defect tests. The average P_2 value was 1094.24 Pa, with a range of 1094.24 Pa to 1094.75 Pa. The pressure values for the no load-defect cases began at 1226.8 Pa and steadily decreased for the first 1.5 minutes, then remained at an average of 1214.2 Pa for the next 20 seconds until they arrived at the first defected point, where a value of 1216.1 Pa was recorded. The PIG traversed the pipeline until it had caught all of the pressure pulses at the defective sites. The higher pressure pulses (spikes) observed at the points of defects created along the pipeline in the experimental results from the no load-defect tests indicates that the Smart PIG was capable of detecting the created defects and demonstrated that the low-cost Smart PIG can be used to detect leakages on a pipe and can also be deployed in real life situations.

Keywords: Low-cost, Smart PIG, Pipeline Defect Detection, WiFi.

1.0 INTRODUCTION

Visual examination is costly and time intensive, therefore predicting the inner or exterior state of a buried pipeline is difficult. Pipelines are regarded as the most effective method of delivering substantial quantities of oil, refined petroleum products, and natural gas over land from the time they were first introduced in the mid to late 1800s. These pipelines serve a major part in modern society, as they provide essential fuels for vital tasks such as power generation, heating, and transportation[1].Pipelines are the arteries of theoil and gas transportation industry, and any disruption would result in a massive loss of energy and financial resources [2]. Because they transport highly combustible gases and liquids, there is also a risk of explosion from leaks.

Pipelines are critical components of the oil and gas delivery system, hence they must be maintained. Pipeline Inspection Gauge (PIG) has been effectively used as a maintenance approach in scenarios such as cleaning, product separation, and pipe integrity inspection [3]. PIGs are the sole way to see damage in pipelines because seeing the inside surface of the pipeline using any other method is usually difficult [4]. PIGs are cleaning, and inspection devices that are inserted into a pipeline and travel along it. Some devices, such as magnetic flux leakage (MFL) sensors, are usually mounted to a smart pig to identify surface pipeline problems and their locations [4].

There are two types of leak detection technologies for pipelines now available: internal detection and external detection. Negative pressure wave, acoustic correlation, and optical fibre leakage are examples of the latter. All of these are commonly employed in land pipelines that are designed to identify leaks and can only detect leak rates of 1% of total flow for oil pipelines and 5% for gas pipelines [5]. Traditional internal detectors, such as PIGs, move forward as a result of pressure variations between the front and back of the detectors, collecting data on corrosion, defect, and weld states on the pipeline's inside walls [6]. The Pipeline Inspection Gauge, on the other hand, is big and fits near to the pipe wall, which makes a lot of noise due to friction between the Pipeline Inspection Gauge's wheels and the pipe wall when travelling along the pipe, making it difficult to extract the weak leak noise [7].

Mechanical pressure clamps are examples of cutting-edge tools used in the oil and gas sector to stop leaks from damaged pipelines. Clamps are not normally suggested if leaks occur as a result of a pipeline rupture. As a result, inspecting the leaky pipeline is critical when deciding on a repair approach [8]. Traditional inspection instruments (Intelligent PIGs) are expensive to operate and come with a large payment toll. An intelligent pigging operation might cost several hundred thousand dollars and cover a considerable area. More intricate pipelines are frequently charged far higher than this, necessitating periodic cleaning and inspection activities. As a result, pipelines are neglected and deteriorate quickly [9].

PIGs serve four (4) important purposes, according to Jasper [10]:

1. Physical separation of different fluids running through the pipeline;
2. Internal cleaning of pipelines;
3. Inspection of pipeline walls (also known as Inline Inspection);
4. Capturing and recording geometric information about pipelines (e.g., position and size).

Pipeline infrastructure is one of the most common ways to move items such as crude oil, gas, water, and chemicals around the world. Regular monitoring and maintenance of the pipeline is required to maintain it safe from disaster, which could result in a variety of environmental risks, reduced flow efficiency, and threats to human life. However, because of the tools and manpower necessary for the monitoring, this examination usually comes at a considerable cost.

Furthermore, most traditional Pipeline Inspection Gauges (PIGs) have exorbitant procurement and operational costs, and they typically come in enormous sizes, making them prohibitively heavy to install. Magnetic Flux Leakage Inspection Tools and Ultrasonic Inspection Tools are two examples of such tools. They also necessitate extensive planning prior to their operational actions; as a result, cases requiring immediate attention are difficult to handle. To avoid leak accidents and reduce potential security threats in pipeline operations, prompt methods to detect and find minor leaking in these pipes must be performed. With the use of some specialized sensors, this study provides a cheaper and better approach of constructing a smart pig that can inspect and detect leaks along pipes delivering water and petroleum products.

This study also provides a significant approach for producing a low-cost in-line inspection instrument to assure regular inspection of pipelines with defects. This will aid in the prompt assessment of pipelines, extending their longevity. The use of PIGs for pipeline line monitoring from previous research exists. According to Murayama [11], there are now only a few sensors that can do non-destructive testing in a high-temperature setting. At temperatures above 50 degrees Celsius, the ultrasonic sensor is typically not employed. A particular sensor for high temperatures is also already available, although it has a number of limitations and has not yet achieved a level of utility in industry. As a result, this study developed a new sensor system that uses a long waveguide to send an ultrasonic wave across a long distance. Muggleton and Brennan [12] in their investigation on the sound attenuation in plastic pipelines submerged in water verified that tracing acoustic transmission on water pipeline at depth of 12 m would not represent a significant barrier and may even prove to be easier than land based pipelines. Lima et al. [13] used pressure transducers and Hall Effect sensors to estimate the speed and pressure of a PIG around defective areas of a pipe. To research speed control strategies for PIGs, a testing facility with a testing loop and a supervisory system was constructed. With the use of data from the supervisory system, pressure transducers were put on the pipeline outside walls to identify PIG movement and leakage region. At the same time, data from the odometer was received by the electronic board inside the PIG, which estimated