THE DESIGN AND DEVELOPMENT OF PIPELINE INSPECTION ROBOT

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THE DESIGN AND DEVELOPMENT OF PIPELINE INSPECTION ROBOT"

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DECLARATION

I declare that this thesis entitled "THE DESIGN AND DEVELOPMENT OF PIPELINE INSPECTION ROBOT" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have checked this report entitled "THE DESIGN AND DEVELOPMENT OF PIPELINE INSPECTION ROBOT" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature : .....

Supervisor Name : .....

Date : .....

DEDICATIONS

To my beloved mother and father

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ABSTRACT

Mobile robots have been developed and improved for decades in various designs with new specifications and features. Pipeline Inspection Robot (PIR) which is a type of mobile robot is operated autonomously with little to no human intervention, inspecting various field of the pipelines system and even cleaning the inner walls of the pipelines by using integrated programs. The development and application of mobile robot that is specifically used in monitoring the pipelines system are still not widely studied and applied although Malaysia is a nation that is vastly developing in the industrial fields. The proposed PIR can help in monitoring and inspecting pipes diameter ranging from 215mm to 280mm that are impossible to reach and hazardous to human life. In addition, the PIR is needed to make the inspecting operation easier and able to save work time. This project is focusing on the design and development of suitable PIR for pipeline system monitoring. The PIR is designed by using the *SOLIDWORKS* software and several simulations are conducted in the software such as the stress and strain analysis. The PIR is fabricated by using aluminium and uses the adaptive mechanism structure which allow the robot to adapt in pipe changing diameters. Moreover, the PIR is controlled by a microcontroller. Experiments are performed to verify the robot's performance such as the ability of the robot to adapt in the pipeline. The results shown that the PIR have an average speed of 0.0096m/s and can move accurately straight in the pipeline. Further modifications can be made to maximize the robot's capabilities.

ABSTRAK

Robot mudah alih telah dibangunkan dan ditambah baik selama beberapa dekad dalam pelbagai reka bentuk dengan spesifikasi dan ciri-ciri baru. Robot Pemeriksaan Paip (RPP) yang merupakan jenis robot mudah alih dikendalikan secara autonomi dengan sedikit intervensi manusia, memeriksa pelbagai jenis sistem paip dan juga membersihkan dinding dalaman saluran paip dengan menggunakan program bersepadu. Pengembangan dan penerapan robot mudah alih yang digunakan secara khusus dalam pemantauan sistem saluran paip masih belum diterapkan secara meluas walaupun Malaysia adalah sebuah negara yang sangat berkembang dalam bidang perindustrian. RPP yang dicadangkan boleh membantu dalam pemantauan dan pemeriksaan paip yang berukuran dari 215mm hingga 280mm yang mustahil dicapai dan berbahaya kepada manusia. Di samping itu, RPP diperlukan untuk membuat pemeriksaan paip lebih mudah dan dapat menjimatkan masa kerja. Projek ini memberi tumpuan kepada reka bentuk dan pembangunan RPP yang sesuai untuk pemantauan sistem saluran paip. RPP direka bentuk dengan menggunakan perisian *SOLIDWORKS* dan beberapa simulasi dijalankan dalam perisian tersebut seperti analisis stres dan ketegangan. RPP ini dibentuk dengan menggunakan aluminium dan ia menggunakan struktur mekanisme penyesuaian yang membolehkan robot menyesuaikan diri dengan perubahan diameter paip. Selain itu, RPP dikawal oleh mikropengawal. Eksperimen dilakukan untuk mengesahkan prestasi robot seperti keupayaan robot untuk menyesuaikan diri di dalam paip. Hasil eksperimen yang dijalankan didapati bahawa robot tersebut dapat bergerak dengan kelajuan 0.0096m/s dan dapat bergerak dengan tepat dan lurus di dalam paip yang disediakan. Pengubahsuaian lanjut boleh dibuat untuk memaksimumkan keupayaan robot.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

PIR	-	Pipeline Inspection Robot
RPP	-	Robot Pemeriksaan Paip
mm	-	Milimeter
cm	-	Centimeter
m	-	Meter
kg	-	Kilogram
N	-	Newton
m/s	-	Meter per second
FYP	-	Final Year Project
V	-	Volt
A	-	Ampere
DC	-	Direct current
Kb	-	Kilobyte
Mhz	-	Megahertz
PWM	-	Pulse width modulation
USB	-	Universal serial bus
RAM	-	Random access memory
CCD	-	Charged-couple device

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Robotics are undoubtedly, one of the quickest engineering developments branches in this globalization era. Robots are developed and intended to abolish human intervention escalated and life-threatening job as well as to perform in unreachable environment [1]. The inspection of pipes is one of the tasks that is implemented in robots as it emerges to be one of the most engaging solutions [2].

The Pipelines Inspection Robot is a mobile robot that is equipped with a camera and specifically used to inspect various fields of the pipelines systems. The PIRs are used vastly in the supply of water, petrochemical and industries that working on fluid transportation [3]. On the other hand, the pipelines are the crucial equipment for transporting fuel oils and gas, delivering drinking water and transferring pollutants [4]. Piping networks can cause a lot of inconvenience such as corrosion, aging, cracks, and mechanical abrasion. Hence, the need of constant inspection, maintenance and repairs are massively needed [5]. The pipeline inspection robots are utilized to investigate internal disintegration, fractures and defects which are mainly due to many causes such as corrosion, degradation, and overheating [6]. With the decades of enormous developments in the robotics field, the pipeline robots have numerous designs such as the wheel typerobot, caterpillar type robot, wall-press robot, legged type robot, inchworm type robot and screw type robot [2].

In this project, a PIR is to be designed and developed by using the *SOLIDWORKS* software and the designs of the robot are specifically to apply in a straight pipeline system

and it can adapt in a various pipelines diameter. The PIR will be programmed by a microcontroller which is the Arduino Mega2560. The performance of the PIR will be based on its ability to move in a various pipeline diameter and its ability to inspect the pipelines.

The aim of this project is to design and develop the PIR by using the *SOLIDWORKS* software, fabricate the robot and to analyze its performance. The goal of this project is to design and develop a PIR that is not too complex, low cost, able to adapt in various pipelines and multifunctional. However, the performance of other types of complex robot are detailed in this project.

1.2 Motivation

The pipelines are generally used for fluid transportation from place to place. The usage and application of pipelines across all over Malaysian industries are growing massively [7]. There are several industries that are very well known to the pipeline industries namely Lembaga Air Sarawak, Telekom Malaysia, Petronas and Indah Water. As an example, Petronas themselves is responsible to operate a huge number of 2500km of gas transmission pipeline in our country [8]. Nowadays, modern housing and town planning in Malaysia are mostly having centralized sewage system. With the utilization of the new sewage systems, all houses' pipelines will be connected to one station for each district. In addition, there will eventually be more future network of pipelines that will be constructed. These pipelines will require the constant need of maintenance and technology as the pipelines repair has become more vital [9].

There have been a series of accidents involving pipelines throughout the years. As claimed by Carl Weimer [10], the executive director of the Pipeline Safety, 135 excavation tragedy that involved pipelines have occurred in which the pipelines are transporting

dangerous chemicals such as crude oil and petroleum over the last 10 years. This incident can be summarized that roughly one incident happens every month. A part from that, on the 31st of July 2014, gas explosion series had occurred in the the Cianjhen and Lingya districts of Kaohsiung, Taiwan. Earlier that evening, there were reports of gas spills and unfortunately, after the blasts, thirty-two people did not survive and a number of 321 others were wounded [11]. Recently this year, on the 1st of August, another series of natural gas pipeline explosion in Midland Country, Texas has occurred and five people were sent to hospital, leaving them with critical burn injuries. The cause of the explosions was unknown, the officials said [12].

These series of accidents could have been avoided if the pipelines were thoroughly inspected, maintained and repaired. Leaking of dangerous gas from the pipelines have cause casualties and other unfortunate events. By using and applying the pipelines inspection robot, the condition of the pipelines could be maintained and safety of human lives can be improved. This project is to design and develop a Pipeline Inspection Robot which can adapt in various pipe diameters in the pipelines and low cost that can be used to inspect the pipelines with a long-lasting life.

1.3 Problems Statement

The utilization of pipelines is very crucial in delivering unrefined and refined petroleum fuels such as oil, natural gas and biofuels and other different fluids including sewage, water, hot water or steam in a smaller reach. Next, pipelines are very useful for delivering water for drinking or water system over long gaps when it needs to move over slopes, or where trenches or channels are poor options because of evaporation, pollutions, or natural effect. These pipelines need to be inspected and maintained as the pipelines can suffer

damages and corrosion if no repairs are to be done. However, the pipelines contain many dangerous substances to human and it is hard to investigate the pipelines by using only human power. Not only that, by using conventional ways of inspecting pipelines, the amount of work time increases.

Thus, robots are introduced and recently, many Pipeline Inspection Robot systems have been developed. The pipelines robot usually is equipped with camera and they are used to inspect the pipelines and to detect damages such as internal erosion, fractures and defects which are mainly due to many causes such as corrosion, degradation, and overheating. Therefore, by using the PIR, safety can be improved.

Furthermore, there are many Pipeline Inspection Robots that have been designed throughout the years. However, most of these robots are quite expensive to fabricate and develop because the robots are used in the pipelines and therefore the robots must be waterproof, long-lasting, high durability and other requirement factors. Thus, it is necessary to improve the performance of pipelines inspection robot performance in terms of the factor requirements.

Moreover, these robots have many types and their own way of mobility in the pipelines. Some of the pipelines robots that have been designed have adaptive mechanism in which they can adapt to the size of different diameter in the pipelines. However, these types of robots have different performance and efficiency throughout its journey in the pipelines. Therefore, it is necessary to analyse the performance of each type of robots based on its way of mobility.

1.4 Objectives

In this project, there are three objectives that are going to be achieved:

i) To design and analyze the Pipeline Inspection Robot by using *SOLIDWORKS* software.

ii) To develop and fabricate the Pipeline Inspection Robot.

iii) To analyse and investigate the performance of the Pipeline Inspection Robot.

1.5 The Scope and Limitations of the Project

The main scope of this project is to design and develop a Pipeline Inspection Robot with the integration of the adaptive mechanism on the robot. The designation of the PIR is carried out by using the *SOLIDWORKS* software and the stress and strain analysis and simulation is to carry out in the software as well. The size of the designed robot is to fit a straight pipeline with the diameter of 215-280mm. The robot has three sets of linkage that is connected between the wheels and the body. Each set of linkage consist of 2 sets of wheels and each linkage has a DC motor connected to the 2 sets of wheels. The programming is written and load into a microcontroller board (Arduino Mega2560) that is attached inside the robot's body.

1.6 Summary

As the conclusion of this chapter, it explains the importance of Pipeline Inspection Robot usage in the piping system and industries. The design and development of the Pipeline Inspection Robots must be carried out thoroughly in terms of durability, performance, materials and the design itself. The aim of this project is to design and develop PIR with the utilization of the adaptive mechanism and to analyse its performance in the pipeline systems.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, literature review is discussed from journals or conference papers that are affiliated to this study in order to accomplish the objectives of this research. There are many papers have been studied in order to design and develop the Pipeline Inspection Robot. Seven categories of the Pipeline Inspection Robot designs are reviewed in this chapter. Furthermore, the microcontroller for the designed robots are also discussed in this chapter.

2.2 Types of Robot Designs

There are many types of robots, especially in the pipeline category, many robot designs have been developed. These type of pipeline robots have specific designs and can be classified as the Wheel Type Robot, Helical/Screw Type Robot, Inchworm Type Robot, Legged Type Robots, Caterpillar Wall Press Type Robot, Wheeled Wall Press Type Robot and Wall Press Wheeled Screw Type Robot.

2.2.1 Wheel Type Robots

The wheel type robots have simple and plain structure as well as improve velocity maneuver with small car-like-structure [3]. The Wheel Type Robot resemblance the ordinary mobile robot and a few researchers have presented on usage of in-pipes mobile mechanism with even compact than 1inch inner diameter [2]. As proposed by M. F. Yusoff *et al*, the wheel type robots, in order to get the desired type of mobility, the wheels are connected directly to the DC motor [13]. The robot can move similarly to a car like forward, backward,