Faculty of Manufacturing Engineering

DEVELOPMENT OF PIPELINE CORROSION INSPECTION SYSTEM USING MACHINE VISION

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DEVELOPMENT OF PIPELINE CORROSION INSPECTION SYSTEM USING MACHINE VISION

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DECLARATION

I declare that this thesis entitled "Development of Pipeline Corrosion Inspection System Using Machine Vision" 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 read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature	:	---
Name	:	---
Date	:	---

DEDICATION

To my beloved father and mother,

who gave me the greatest gift anyone could give to another person:

They believed in me.

ABSTRACT

These days, utilization of camera as an inspection tool has been expanded. The flexible function of camera is adequate to obtain different kind of information. In Cawley (2001) review on NDT that was presented in 2001, Radiography, Ultrasonic, Eddy Current, Magnetic Particle, and Penetrant Testing were the top five techniques dominating the NDT market yet Visual Inspection is the most widely applied. Even though the popularity of visual inspection is higher compared to other NDT method, but due to the reliability issues it is often used together with other methods. This research work is focusing on developing a robust corrosion inspection system based on vision sensor that is able to accurately detect and classify corrosion based on the appearance features. By installing at an early stage, inspection system would be able to gather data and at the same time identify and analyse the collected data. Through the results, the analysed data is able to classify the corrosion type based on appearance. From the research work, the method of using image enhancement filters to improve accuracy of vision corrosion inspection system is identified. The detection of each macroscopic surface corrosion types; galvanic; crevice; erosion; pitting and exfoliation using vision inspection able to achieve 79% accuracy using the simulated dataset. The new method of corrosion inspection operation which able to generate prevention plan has qualified the Vision Corrosion Inspection System to be used during preliminary inspection. It is expected that the Vision Corrosion Inspection System can improve vision inspection as the pioneer in NDT method for corrosion inspection. In addition, framework of the developed Vision Corrosion Inspection system is applicable for other applications of vision inspection whereby it can be applied for other inspection process or extending its application to other problems.

ABSTRAK

Hari ini, penggunaan kamera sebagai alat pemeriksaan semakin meluas. Fleksibiliti fungsi kamera yang baik boleh mendapatkan pelbagai jenis maklumat. Dalam ulasan Cawley (2001) mengenai NDT, Radiography, Ultrasonic, Eddy Current, Magnetic Particle, dan Penetrant Testing adalah lima teknik yang mendominasi pasaran NDT, namun teknik Pemeriksaan Visual paling banyak digunakan. Walaupun populariti pemeriksaan visual lebih tinggi daripada kaedah NDT lain, disebabkan oleh isu kebolehpercayaan ia hanya digunakan sebagai alat bantuan untuk kaedah lain. Kerja penyelidikan ini tertumpu kepada pembangunan sistem pemeriksaan kakisan mengunakan sensor penglihatan yang mampu untuk mengesan dengan tepat dan mengelaskan kakisan berdasarkan ciri-ciri penampilan. Dengan memasang di peringkat awal, sistem pemeriksaan dapat mengumpul data dan pada masa yang sama menganalisis data yang dikumpul. Berdasarkan keputusan itu, data yang dianalisis dapat mengklasifikasikan jenis-jenis kakisan. Dari kerja penyelidikan ini kaedah menggunakan penapis bagi meningkatkan ketepatan sistem pemeriksaan kakisan dapat dikenalpasti. Pengesanan setiap jenis kakisan makroskopik menggunakan pemeriksaan penglihatan berjaya mencapai 79% ketepatan. Kaedah pemeriksaan karat yang baru ini mampu menjana rancangan pencegahan telah melayakkan Sistem Pemeriksaan kakisan mengunakan sensor penglihatan digunakan semasa pemeriksaan awal. Hasil penyelidikan ini akan menjadi satu kaedah baru pengesanan kakisan dan sebagai perintis dalam kaedah NDT untuk pemeriksaan kakisan. Tambahan lagi, rangka pembangunan Sistem Pemeriksaan kakisan mengunakan sensor penglihatan boleh digunakan untuk aplikasi mengunakan pemeriksaan penglihatan yang lain atau meluaskan pemakaiannya bagi masalah lain.

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LIST OF SYMBOLS, ABBREVIATIONS AND NOMENCLATURE

MHz	-	Mega Hertz
KHz	-	Kilo Hertz
MB/s	-	Megabyte per second
^{o}	-	Degree
s	-	Seconds
mm	-	millimetre
Cl^{-}	-	Chloride
H^{+}	-	Hydrogen
H_2O	-	Water
NaCl	-	Salt
Log_{10}	-	Logarithm (base 10)
BWP	-	Bar Wrapped Pipe
EM	-	Electromagnetic
AFO	-	Acoustic Fibre Optic
PCCP	-	Pre-Stressed Concrete Cylinder Pipe
IQA	-	Image Quality Assessment
MOS	-	Mean Opinion Score
ECI	-	Element Condition Index
AI	-	Artificial Intelligence
TCP/IP	-	Transmission Control Protocol/Internet Protocol
ANN	-	Artificial Neural Network

SVM	-	Support Vector Machine
PSNR	-	Peak Signal to Noise Ratio
GUI	-	Graphical User Interface
NDT	-	Non-destructive Testing
MSE	-	Mean Square Error
PVC	-	Polyvinyl Chloride
PIGs	-	Pipeline Inspection Gauges
IP	-	Intelligent Pigs
ROI	-	Region of Interest
RGB	-	Additive Colour Model in Which Red, Green, and Blue
USB	-	Universal Serial Bus
ROV	-	Remotely Operated Vehicle
AUV	-	Automated Underwater Vehicle
NDE	-	Non-destructive Evaluation
CFA	-	Colour Filter Array
CASS	-	Cast Austenitic Stainless Steel
TOFD	-	Time-of-flight Diffraction
ET	-	Electromagnetic Testing
AC	-	Alternating Currents
GMR	-	Giant Magneto Resistive
PCB	-	Printed Circuit Boards
MFL	-	Magnetic Flux Leakage
ASNT	-	American Society for Non-destructive Testing
3D	-	Three Dimension
UI	-	User Interface

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CHAPTER 1

INTRODUCTION

1.1 Background

An inspection is an organized detailed examination or evaluation exercise. An inspection activity involves the measurements, tests, and gauges applied to certain characteristics in regard to an object or activity (Chaturvedi, 2008). The results are compared to specified requirements or standards for determining whether the item or activity is in line with these targets. Corrosion inspection and monitoring are key activities in ensuring asset integrity and control of corrosion. Field information and the outcomes of research laboratory evaluations should be slanted to obtain up-to-date corrosion information. Corrosion inspection and monitoring includes assessment of (Davis, 2000):

- In-line systems cover installation of devices directly into the process.
- On-line monitoring includes deployment of corrosion monitoring directly
- Off-line monitoring is achieved through the use of NDT techniques

The costs of corrosion vary considerably from industry to industry. One of the industries that is highly impacted by corrosion is oil and gas industry. This is because, steel pipeline use to transfer medium oil and gas between places. However, steel pipe can corrode in service and may suffer degradation from defects. Therefore, the first step in any corrosion prevention program is to identify and quantify the present of corrosion (Davis, 2000).

In May 2013, in the City of Calgary, a deteriorated Bar Wrapped Pipe (BWP) due to corrosion was detected by Pure Technology during scheduled inspection (Pure Technology, 2013). Due to the pipe useful life is nearing the end, the pipe section was replaced. However, by replacing BWP earlier then its end life, the cost compare to the usage has increased. This can be avoided by using adequate inspection system that is able to detect earlier and suggest the prevention method to prolonged the pipe useful life. Another case of early detection occurrence is in 2012 when Tucson Water (2012) went into emergency mode when several wire breaks occurred in a short period of time on one of its 96-inch PCCP water transmission mains which indicates there was a high risk of failure. Tucson Water was able to react quickly to the wire breaks by reducing the pressure in the pipe and diverting the water from another main to serve its customers, subsequently preventing a failure. This is the second time it happens, with the first occurrence in 1999. After the first occurrence, Tucson Water has developed a pipeline management program inclusive of electromagnetic (EM) assessment (Groysman, 2009) and Acoustic Fibre Optic (AFO) monitoring (Maalej et al., 2004). Even if a catastrophe is avoided, should the system able to detect and at the same time suggest a solution, an emergency situation can be avoided.

There is a lot of different experiments and analysis methods used to identify corrosion damage for inspection and monitoring purposes. One of the methods is mechanical measurements by calculating weight loss, chemical analysis, and visual inspections. Corrosion occurs in several widely differing forms. Classification is usually based on one of three factors (Liang et al., 2010):

- Nature of corrode- Corrosion can be classified as “wet” or “dry”.
- Mechanism of corrosion- Involves electrochemical or direct chemical reactions.
- Appearance of the corroded metal- Either uniform (metal corrodes at the same rate over the entire surface, or localized which only small areas are affected).

Through using visual as corrosion inspections, the corrosion level identification requires an expert who can clearly determine the corrosion based on experience as well as types of corrosion, with red rust as a common experience. Usually, the corrosion process produces rough surfaces, and image analysis based on textural features can be used for quantification and discrimination of corrosion extent and type (Livens et al., 1996), (Pidaparti et al., 2013). Additional to textural features, colour progressions of metallic surfaces are also used for the detection of corrosion because of different metal oxides and other corrosion products (Medeiros et al., 2010).

With the abilities to classify corrosion based on the appearance of the corroded metal, this research work proposes a new approach on corrosion detection by using vision system as corrosion is either uniform and the metal corrodes at the same rate over the entire surface, or localized, in which case only small areas are affected. The detection of the corrosion "areas" is detected by means of visual sensor, using camera or video that is able to determine and analyse the sensed areas.

The proposed visual inspection system is to be implemented in a monitoring stage. During the monitoring, the visual inspection system would be able to gather data and at the same time process and analyse the collected data. With the results, the analysed data are able to be used to classify the corrosion type and also determine the actions to be taken.

Corrosion detection method using vision for a pipeline inspection system is able to improve current corrosion detection and reduce overall time for inspection. By using the images as the inspection data, the analogue signal loss due to the communication interference can be eliminated, as the image data are able to recover required features based on other features. Furthermore, the system is able to adapt to the unrefined environment, thus, making the proposed system robust and useful for other detection applications.