UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DIGITAL IMAGE CORRELATION ON PIPING CONDITION MONITORING USING SMARTPHONE

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours.

by

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ABSTRAK

Penyelidikan ini membuat kajian ke atas keadaan paip dengan mengaplikasikan kaedah *Digital Image Correlation* (DIC) yang menggunakan perisian sumber terbuka *Ncorr* yang dibina di platform *Matlab*. DIC adalah satu teknik inovatif baru yang berkembang di seluruh dunia. DIC adalah kaedah optikal bukan sentuhan yang menangkap imej digital pada permukaan objek yang digunakan untuk mengukur anjakan bidang penuh pada sesebuah objek. Imej yang ditangkap kemudiannya dianalisis dengan membandingkan imej rujukan (sebelum perubahan bentuk) dengan siri imej selepas perubahan bentuk berlaku. Kajian ini menggunakan kamera telefon pintar iaitu Honor 8 yang digunakan untuk menangkap imej sebelum dan selepas perubahan bentuk yang berlaku pada paip dengan kelajuan pam yang berbeza dan kadar aliran yang berbeza dalam paip. Dalam eksperimen terdapat dua jenis bahan paip yang digunakan untuk menilai perubahan bentuk iaitu paip tembaga dan paip PVC. Matlamat penyelidikan ini adalah untuk menyediakan kaedah DIC yang kos rendah dengan menggunakan kamera telefon pintar untuk menghasilkan keputusan yang baik dari anjakan bidang penuh pada paip. Kajian ini juga menyiasat kesan perubahan saiz *subset* terhadap keputusan pengukuran anjakan yang dilakukan oleh kaedah DIC. Keberkesanan kaedah ini ditunjukkan dengan menggunakan kaedah untuk pengukuran anjakan kemudian dibandingkan dengan kaedah konvensional yang menggunakan *Vibrometer Extech 407860* untuk pengesahan ukuran akhir. perbezaan dan ketidaktepatan yang berlaku dalam ukuran anjakan hasil akhir dibincangkan dalam karya ini. Kekangan dengan menggunakan kamera telefon pintar dengan keupayaan resolusi dan kelajuan kamera yang rendah adalah sebab penghasilan keputusannya kurang tepat.

ABSTRACT

This research examines the condition of piping by using Digital Image Correlation (DIC) which utilizing opensource Ncorr software which built on Matlab platform. DIC is a new innovative technique that has develop widely around the world. DIC is a non-contact optical method which captures of digital images of a surface that use to measure full-field deformation of an object. The captured images are then been analyzed by comparing reference image (before deformation) with the series of images after the deformation occurs. This research utilizes smartphone camera which is Honor 8 used to capture the image before and after deformation on the pipe with different speed of the pump and different flow rate in the pipe. In the experiment there are two type material of pipe is used to examine the deformation occur which are copper pipe and PVC pipe. The goal of this research is to provide a low-cost DIC method by using a smartphone to produce a good result of full-field displacement on the pipe. This study also investigates the effects of subset size changes on the displacement measurement results performed by the DIC method. The effectiveness of this method is demonstrated by applying the method to the measurement of the displacement then been compared with the conventional method which using Vibrometer Extech 407860 for validation of the final result. The different and error in displacement measurement of the final result is discussed in this paper. Limitation of using smartphone camera with considerably low frame per second capability and resolution are the reason that the result becomes less accurate.

DEDICATION

I dedicate my work to my family and other friends. Realize that every of challenging work is needed self-efforts as well as helps and guidance from elders and friends. Also, special feeling of gratitude to my beloved mother, Siti Murni Binti Harun whose words of encouragement and pushed, prayers of the day and night. I also dedicate my work to my supervisor and co-supervisor who have guided me to do the real of work-self until finish. From this supporter, I can handle the work even the challenger that very hard to face. Encouragement and advice from them, I am able to get such a success.

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LIST OF ABBREVIATIONS

2D-DIC	Two-Dimensional Digital Image Correlation
DIC	Digital Image Correlation
FPS	Frame per Second
GUI	Graphical User Interface
MATLAB	Matrix Laboratory
NDT	Non-Destructive Testing
ROI	Region of Interest
TIFF	Tagged Image File Format

CHAPTER 1

INTRODUCTION

1.1 Project Overview

This project encompasses the new technique/method utilization of Digital Image Correlation (DIC) as Non-Destructive Testing (NDT) tool for detecting irregularities/non-uniformity of materials/components and Non-Destructive Evaluation Technique in characterising mechanical properties of materials/components. The technique comprises of the use of a smartphone camera as acquisition hardware and Ncorr (opensource platform) as post-processing medium for digital image correlation deformation computation. The first half of the project is involved familiarization and training on digital image correlation fundamental working principle as well as Ncorr opensource platform utilization. The second half of the project is applied the use of DIC to real engineering scenario of the piping condition.

1.2 Background of Study

Digital Image Correlation is a modern technique that uses an optical method and use image analysis to measure the full-field displacement and strain measurement of an object surface. One of the earliest researchers in this method is Peter and Ranson in 1982 which use of computer image acquisition and deformation measurement in the material system (M. A. Sutton, Orteu, & Schreier, 2009). The original application implies the development of digital recording and field patterns full of subjecting ultrasonic waves to object before loading (reference image) and during the process of loading (deformed

images). DIC method suggested comparison for various small areas (known as a subset) in the entire image before and after deformation, find the position of the respective subset after deformation through digital image analysis (M. Sutton, Mingqi, Peters, Chao, & McNeill, 1986). In 1983, Sutton has developed numerical algorithms in DIC for analysis the recorded images by using the same approach as the previous technique. To prove that this technique is reliable Anderson and Chu performed a series of an experiment on rigid body motion measurement by applying the algorithm, indicating that the method can quantify deformed in the rigid body (M. A. Sutton et al., 2009).

In recent years the improvement of DIC accuracy has been developed by many researchers. Several improvements in core computational algorithm have been proposed and implemented in order to get a more accurate result (J. Blaber, Adair, & Antoniou, 2015). There are several software have been developed to the calculated algorithm in the image correlation analysis. One of the software is an open-source 2D subset-based digital image correlation software package (Ncorr). The function of this software is to merge modern algorithms in DIC analysis by using Matlab platform. Matlab is widely used for numerical computing, and for DIC case it uses to analyze the correlation of an image and develop the algorithm. To operate Ncorr in Matlab it must have Microsoft Visual C++ compiler which works together with MATLAB through the MEX interface for greatest efficiency (Justin Blaber & Antoniou, 2017). All the mentioned software are required to work together in order to run the DIC analysis. The advantage of using Ncorr is cost effective and can reduce the cost of DIC compare to commercial software. Besides that, Ncorr open-source software user-friendly as could be modified as per user requirements. Furthermore, it is capable of measuring strain and displacement on a surface of the object from a given reference image (Harilal & Ramji, 2014).

1.3 Problem Statement

Nowadays, in the fast-growing economy is now looking forward to the better production of company products and advanced techniques in order to detect problem arise on the equipment. In order to ensure the optimum performance of the equipment, it requires the best testing technique. Generally known, non-destructive test (NDT) is a very useful technique for analyzing and evaluation on the material under uniaxial loading. 2D-DIC is one of the methods in NDT technique to measure the deformation on the surface of an object (Amiot et al., 2013). Basically, the advanced techniques in NDT are required high skill, higher cost and more complicated system to operate, such as thermography, ultrasound etc. In contrast, 2D-DIC by using Ncorr is very economical compared to other common software that use to measure deformation on the material. Besides that, it also uncomplicated technique and required less skill to run the analysis of strain distribution on composite material.

As we know, the piping system is used for conveying fluid or gas from one place to another place. It is also an important component that needs to be maintained to prevent leakages that may result in losses and even worse case can be dangerous to individual's life when the leaks are flammable gas or flammable liquids. Furthermore, it will also interfere with the operation of the plant in the event of leakage to the piping system. This will certainly cause severe damage and losses to the plant. So, using DIC analysis will help to detect the resulting cracking on the pipe from the beginning and can prevent it from getting worse. Besides that, DIC also study about the mechanical behavior of the piping material that can use to study of the impact of these phenomena in materials can be used to develop better applications of the materials in the piping system.

The other problem is the conventional method by using strain gauge only detect the strain deformation on a specific area that the gauge is located. It cannot detect for full field of the specimen's surface. But by using DIC technique it can measure full-field displacement and strain measurement. Other than that, some of the equipment is cannot have contact such as on the pipeline which is a very high temperature. Therefore, by having this DIC technique still can determine the amount of strain on the equipment even though with that condition because it uses the non-contact optical testing method.

1.4 Objective

The aims of this project are following as:

i. To apply Digital Image Correlation technique as non-destructive testing and evaluation on piping condition.
ii. To explore parameters which affect the displacement measurement on Ncorr open source platform using the DIC technique.
iii. To study the effect of water flow rate and speed of the pump in a change of displacement on the pipe.

1.5 Scope of Study

The focus of this study is performing Digital Image Correlation on piping under a given pressure. Besides that, this study also focusing on performing image correlation to obtain displacement measurement using open source software Ncorr. By using Ncorr in 2D-DIC can achieve a good quality in determining the displacement distribution in a piping material. In addition, this study is utilizing smartphone camera as hardware of recording image of pipe under a given pressure. Besides that, this project is focused on the use of Digital Image Correlation on piping condition monitoring. This project is utilizing copper pipe and PVC pipe as the specimen under test. The deformation occurs on the pipe will be analyzed by 2D-DIC using Ncorr software to measure the full-field displacement measurement in the pipe.

CHAPTER 2

LITERATURE REVIEW

2.1 Digital Image Correlation

2.1.1 Introduction to Digital Image Correlation

Digital Image Correlation (DIC) one of the new advance technique to measure strain and deformation on the surface of an object. It is a non-contact technique that uses the optical method which captures of digital images of a surface of an object then performs the images analysis to measure the deformation of the object (A. F. Ab Ghani, M. B. Ali, S. DharMalingam, & J. Mahmud, 2016). The registration algorithm is utilized in order to track the relative displacements of material points between reference images (before deform) and current images (after deform) (J. Blaber et al., 2015). Deform image will provide difference dot pattern compared to the initial non-deform reference image. From the dot pattern that obtained it can be calculated by performing correlation pixels of the reference image and any deformed image then be analyzed by computed to obtain full-field displacement measurement (A. F. Ab Ghani et al., 2016). Characteristic of the dot pattern is used to compare the subset and extract full-field information about displacement and strain deformation of the object.

Unlike another non-destructive testing (NDT) technique such ultrasonic, AE technique, thermography etc that is expensive, DIC only use digital camera that assists by computational software to measure strain deformation on an object (Risbet, Feissel, Roland, Brancherie, & Roelandt, 2010). The ability of DIC to record images of the deformed surface, allowing for accurate analysis of the material being applied load (A. F.