DESIGN ULTRASONIC TESTING DEFECT CHARACTERIZATION APPS

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This report submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering

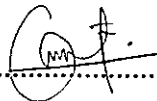**Faculty of Mechanical Engineering**
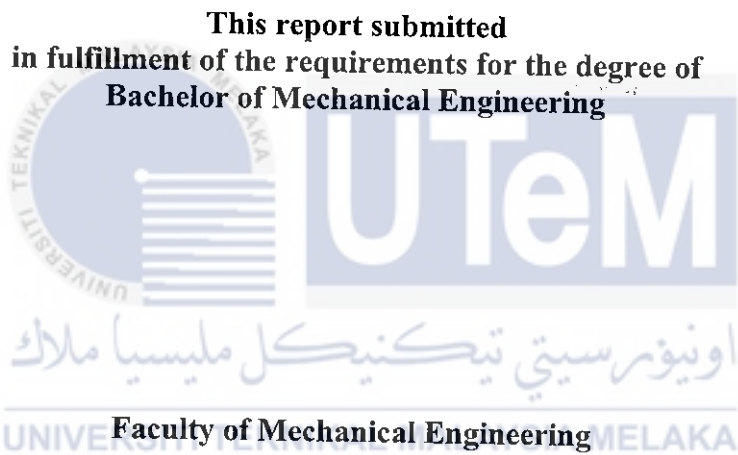
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

JULY 2021

DECLARATION

I declare that this project report entitled "Design Ultrasonic Testing Defect Characterization Apps" is the result of my own work except as cited in the references

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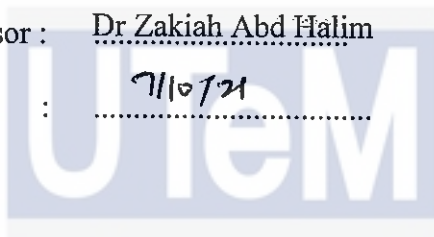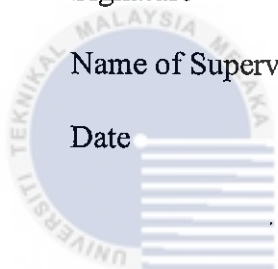
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APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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ABSTRACT

Ultrasonic testing is widely used in the NDT fields to detect the defect on the specimen and structure. Failure to detect the defect may lead to unwanted incident in future. To characterize the defect from ultrasonic testing data sometimes cause trouble to someone who is lack of skill in this field. Besides, since IR 4.0 the used of automations in NDT fields has increase. Automation in NDT fields makes defect detection easier than before. It also helps to reduce the time for detect and characterize the defect. Therefore, this project was carried out to develop an apps for ultrasonic defect characterization. This project has been carried out by studying the theory of ultrasonic defect characterization. In other to develop an apps for ultrasonic defect characterization a program has been written using python language in the PyCharm software. the program was then link with Tkinter in other to create the interface for the apps. To validate the result of the apps, a laboratory testing has been carried during the project. The result from the apps then being compared to the laboratory testing result.

ABSTRAK

Ujian ultrasonik digunakan secara meluas dalam bidang NDT untuk mengesan kecacatan pada spesimen dan struktur. Kegagalan mengesan kecacatan boleh menyebabkan kejadian yang tidak diingini pada masa akan datang. Untuk mencirikan kecacatan dari data ujian ultrasonik kadang-kadang menimbulkan masalah kepada seseorang yang kurang mahir dalam bidang ini. Selain itu, sejak IR 4.0 penggunaan automasi dalam bidang NDT telah meningkat. Automasi dalam bidang NDT menjadikan pengesanan kecacatan lebih mudah daripada sebelumnya. Ia juga membantu mengurangkan masa untuk mengesan dan mencirikan kecacatan. Oleh itu, projek ini dijalankan untuk membangunkan aplikasi untuk pencirian kecacatan ultrasonik. Projek ini telah dijalankan dengan mengkaji teori pencirian kecacatan ultrasonik. Untuk membangunkan aplikasi untuk pencirian kecacatan ultrasonik, program telah ditulis menggunakan python mengguakan perisian PyCharm. Program itu kemudian dihubungkan dengan Tkinter untuk membuat antara muka untuk aplikasi ini. Untuk mengesahkan hasil aplikasi, ujian makmal telah dilakukan semasa projek. Keputusan pencirian dari aplikasi kemudian dibandingkan dengan hasil ujian di dalam makmal.

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UT   Ultrasonic Testing

NDT   Non-Destructive Testing

LIST OF SYMBOL

θ	=	Angle of refraction
μ	=	Mean
$\sum$	=	Variance
SkD	=	Skip Distance
SA	=	Sound Path
D	=	Depth
w	=	Length of weld cap
T	=	Specimen's thickness

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Non-Destructive Testing defect characterization is to find out the information of defect on the material. Through defect characterizing, the size, orientation, and shape of the defect can be determined. It is important to know the shape of the defect in other to find the best possible way to treat the defect. This is because the different type of defect will cause different effects on the performance of the material and has its own way to be treated. "The aim of ultrasonic non-destructive evaluation includes the detection and characterization of defects, and an understanding of the nature of defects is essential for the assessment of structural integrity in safety critical systems" (Velichko et al., 2017, p. 56). There are several methods to perform Non-Destructive Testing on the material and one of the methods was Ultrasonic Testing.

Ultrasonic Testing is one of the common NDT methods use in the industry. Ultrasonic testing is one of the best non-destructive evaluation methods produced to detect and evaluate surface, subsurface and internal defects (Honarvar & Varvani-Farahani, 2020, p. 106227). Ultrasonic testing uses very high frequency of sound wave to analyze the characteristic of thematerial and to detect the presence of a defect in the material. The Ultrasonic Testing systemonly needs simple preparation and equipment. Three important functional units in the Ultrasonic Testing system are pulser/receiver which is an electronic device that can produce high voltage electrical signals, a transducer used for transforming electrical signals to sound waves, and a display device to display the signal from the wave.

Advanced study on ultrasonic defect characterization helps a lot towards production of automation system for defect characterization. The use of automation system is the enormous improvement in non-destructive testing field. Development of automation system such as machine learning and computer software have reduced the time consume for defect characterization analysis over the decade.

This report proposes the development of an application for Automation of Ultrasonic Testing Defect Characterization. The application is expected to help evaluate defect characterization automatically. The algorithm for the application is encode based on the standard of defect characterization in non-destructive testing. This application will run full evaluation of defect characterization automatically using the data gained from the ultrasonic testing. The output of the software will display the type of defect presence, the orientation of defect, and the size of the defect.

1.2 PROBLEM STATEMENT

From the ultrasonic testing as shown in Figure 1.1, defect information will be gathered in term of signal. Thus, from the information gathered, defect can be analyze using defect characterization method. Currently, to analyze defect, analyst or engineer need to do it manually by using defect characterization method and procedure. The introduction of the Data-Driven Analysis of Ultrasonic Inspection Data of Pressure Tubes, (Zacharis et al., 2018,p. 159), states that "The analysis of data obtained from the ultrasonic inspection is time- consuming and often requires manual assessment due to the complexity of distinguishing between noise and signals indicating defective areas". This method is time consuming and could affect the total production or profit gain by the company. This is the major drawback of the current defect characterization

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process. Thus, analysts and engineers started to develop an automation system for defect characterization to overcome this drawback. In line with industrial revolution 4.0 an application to evaluate the defect in the material automatically could be developed in other to make defect characterization easier and less time consume on the process.
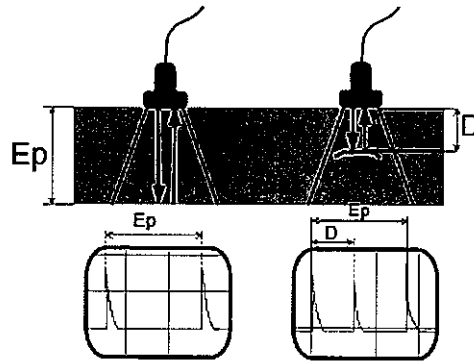
Figure 1.1: Ultrasonic Testing Overview

Since the industrial revolution 4.0, development of automation system is common in the NDT. The fourth industrial revolution was the optimization of the computerization from Industry 3.0. Fundamentally, in the past five years, computers started to become connected and come to conclusion without human participation. Industry 4.0 has become a reality with a combination of cyber-physical networks, the Internet of Things, and the Internet of Systems. Industry revolution 4.0 is contributing to NDT by improving real-time decision-making, delivering predictive maintenance, and accelerating the manufacturing process by analysing the mass quantities of data stored by robots. For organizations, this helps them save more money by reducing the time it takes to test parts and resolve any consumer issues much more effectively. Through Industry 4.0, organization can control every aspect of the manufacturing phase from the start to the final completed project and make changes that are efficient and cost effective (Rahul Alreja, 2019).

1.3 OBJECTIVES

The objectives of this project are as follows:

i. To identify defect characterization procedure for ultrasonic testing

ii. To design an application for defect characterization using design thinking method.

iii. To develop an application for defect characterization using agile method.

1.4 SCOPE

This study is focusing on developing an application for Ultrasonic Testing Defect Characterization. This study provides the conceptual framework for understanding on Ultrasonic Testing Defect Characterization, design of application for Ultrasonic Testing Defect Characterization and development of a software for Ultrasonic Testing Defect Characterization. In this study the development of the apps is focusing on single V-grove welding defect characterization. The characterization process only focuses on the depth of the defect and the category of defect whether it is internal or external.

CHAPTER 2

LITERATURE REVIEW

2.1 AUTOMATION SYSTEM IN NDT

There are several automation systems for defect characterization that had been developed and proposes. The automation system for defect characterization not only focusing on one automation method. There are several methods that had been developed such as Optical devices, computer software, and machine learning program. Since the study of automation defect characterization began, many improvements have been made and successfully applied in the NDT field. Advance methods in characterization and the increase of computational power have led to the ability to characterize defects using 3D data. The improvement from 2D characterization to 3D characterization has provided analysis for a much larger class of material systems and applications (Rowenhorst et al., 2020). Improvements in Non-Destructive Testing field and the development of automation systems have made NDT field more efficient and helped analysts obtain most accurate data with a small percentage of errors. Established standards are also able to coordinate all the data from testing and reduce the problem of result differences.

2.2 OPTICAL DEVICES

Optical devices have been widely used in the NDT fields as one of their automation methods. The purpose of using optical device in NDT is to extract information from an image representing the process and surrounding area in the visible spectrum. The use of optical devices such as High Dynamic Range Camera (HDR), Figure 2.1. HDR camera able to offset

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powerful arc light and capture more detailed imaging of process (Bacioiu et al., 2019). It helps analysts to monitor the defect occur during welding or drilling process. Optical device can record the real time image of the process and instantly detect when the defect occurs.

This method consumes big size of data as the image recorded is in high quality. The used ofcomputation is needed in this case in other to reduces the input dimensionality, eventually arriving at desired labels. Neural Network Architecture is one of the computation methods that can help analyst to converge the large set of data to represent dataset's probability distribution. Neural network Architecture consist of an input layer for receiving the image and an output layer for the classification label.
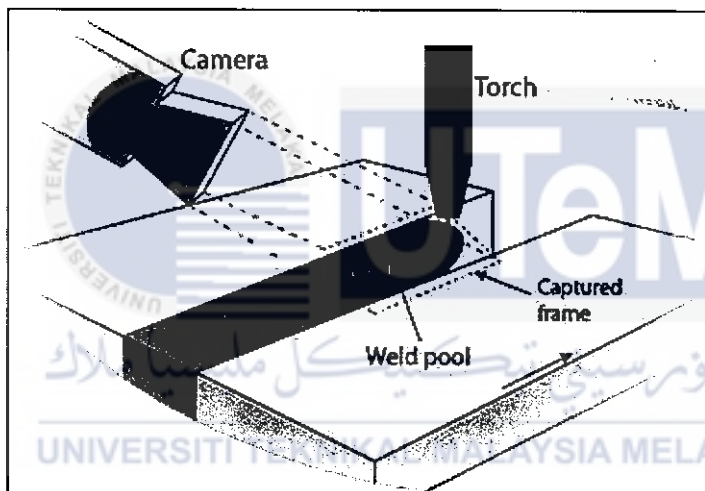
Figure 2.1: Optical Device in Defect Detection

Using optical devices as the automation system can captured good weld and defective well. The modification of the welding parameter, each at one time can assist with the defectintroduction. as well. The captured image of the weld then being divided into several category following the data represent the defect. The categories are good weld and defective weld. Defective weld can be categorized into five category which is, burn through, contamination, lack of fusion, misalignment, and lack of penetration. The

example of captured image is shown in the Figure 2.2.

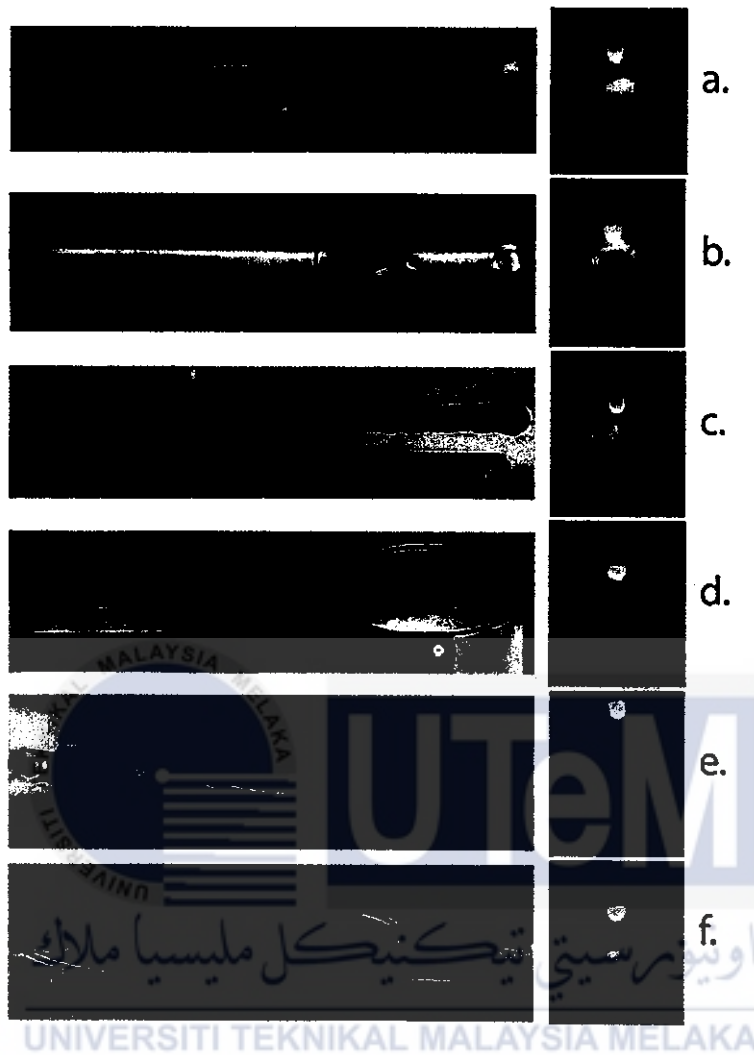Figure 2.2: Captured Image samples of aluminium TIG welding. (a) good weld; (b) burn through; (c) contamination; (d) lack of fusion; (e) misalignment; (f) lack of penetration.

2.3 MACHINE LEARNING PROGRAM

Machine learning program is one of the most advanced and fastest growing technologies in the industry. There are several types of machine learning programs that have been introduced in the NDT field. Among the types that have been introduced are robotic system and automation machining system. The use of robotics is starting to play a key role in automating the data collection process in Non-Destructive Testing (NDT). The aim of using robotics in NDT is to reduce the problem of huge amount of data collect during the

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testing. The use of robotic systems that capable of automatically determining the direction of the robot to move by identifying the area that consist of defect has reduced unnecessary data during the testing process (Fuentes et al., 2020). The robot is program to find the area within a component being inspected, with the highest damage index. The robot decision is formed in every iteration regarding the next most optimal physical area for putting an observation. This is achieved by modelling the 2-Dimensional field of novelty indexes, which are derived from a robust outlier analysis procedure. The steps of the autonomous inspection algorithm are shown in Figure 2.3.
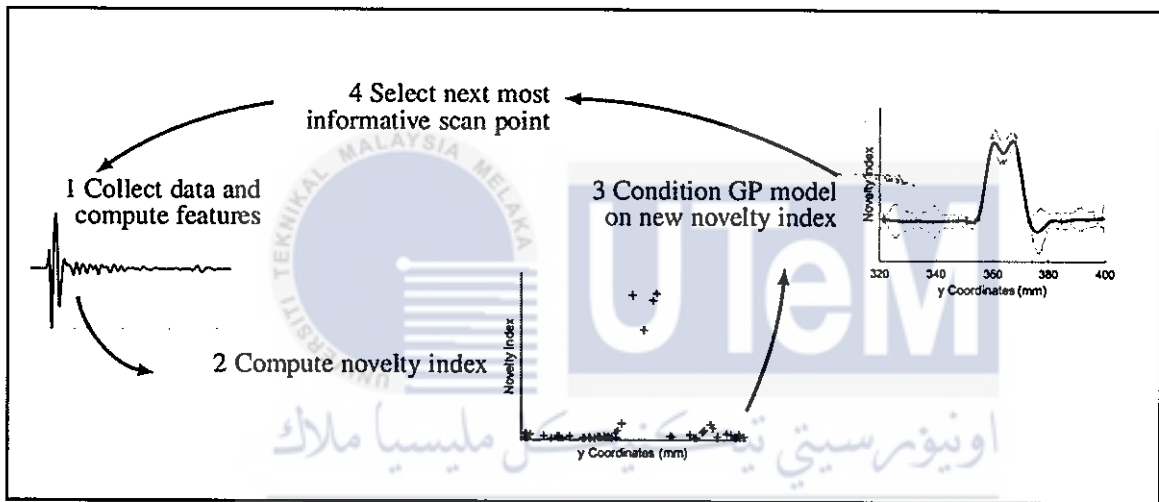

Figure 2.3: Steps involved in autonomous inspection.

There are two main components of the autonomous inspection framework which is robust outlier analysis and Bayesian optimisation. The process of outlier analysis basically involves the determination of a distance metric, that determine how far away any given observation lies from the centre of the data mass, relative to its spread. (Fuentes et al., 2020)In the case of the Gaussian-distributed data assumption, the appropriate metric is the Mahala Nobis Squared-Distance (MSD), Eq. (2.1)

$$d_i = (y_i - \mu)^T \Sigma^{-1} (y_i - \mu) \tag{2.1}$$

Where the μ and Σ are the mean and variance, respectively. The two parameters that characterise a Gaussian density. The multivariate observation vector y represents the data features and T represent novelty threshold for the novelty indexes.

Bayesian optimization is typically used to find the correct function that maximizes or minimizes an objective function. When one analyses the data and finds that at the end of the scan, the greatest novelty score falls within a novelty threshold, then confidence in the absence of anomalies can be defined. On the other hand, one or a large number of observations are above the threshold of novelty, it indicates a problem. (Fuentes et al., 2020) The task of inspection is therefore a task of searching for regions which are the most unique from the rest, which contain the highest score of novelty. The problem of searching for outliers in a spatial domain can therefore be presented as a problem of optimization, where the objective, or cost function of the novelty score is being maximised.

2.4 COMPUTER SOFTWARE

Since 4.0 industrial revolution, computer software is extremely used in every engineering field. Computer software are programmed using human expert knowledge and understanding into an algorithm that produce result of the testing as the output has been shown in Figure 2.4. NDT field are one of the fields that focusing on developing software that helps engineer and analyst to ease them with their analysis and testing. Like other software development, development of software in NDT also has its own advantages and disadvantages. The major advantage of software development in NDT are access to historical result (Wallace et al., 2019). Human analyst can review the previous test result available in the software history and compare with the current result in other to inspect and interpret the result of the testing. Besides, computer

software also provides multistage review compared to human analysis process which requires more than one professional analyst to compare the result of their analysis before deciding the final review of their analysis.
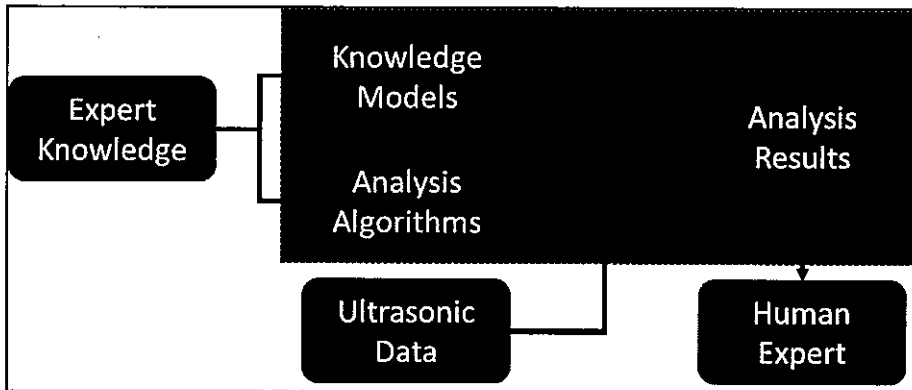

Figure 2.4: Layout of computer software process

Classification of types are based on the basis of a set of laws derived from information from human experts. These rules, work with reasonable precision, based on the size and location of the flaws, as shown during testing, but the extremely random nature of many debris flaws has restricted the applicability of this method. Applicability of neural networks to detect and analyze defect using ultrasound. A set of labelled data with a set of features (characteristics of the defects) is available, against which a machine learning model can be developed, and provided the broad historical archive of research results. This method allows a predictive relationship to be extracted based on the parameters of each defect and its corresponding mark, rather than using explicit domain information (Wallace et al., 2019). Neural Network Model can be develop using an archive of analysed defect, labelled training and test datasets following parameters as features:

1. Axial Start – The axial start position of the flaw in the tube (mm)

2. Rotary Start – The rotary start position of the flaw in the tube (°)

3. Length – The axial extent of the flaw in the tube (mm)

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4. The rotary extent of the flaw in the tube (°)

5. Amplitude – The amplitude of the flagged region containing the flaw (dB)

6. Depth - The maximum measured depth (mm)

This configuration was determined experimentally to converge quickly on an accurate predictive model however further work is required in order to optimize the structure to generate a model with an average accuracy of 95%, compared to the verified analysis results.

2.5 ULTRASONIC TESTING AND DATA

2.5.1 Location of Defect

According to (Weldments, 2020), Ultrasonic testing has been the most preferred method to detect flaw in the welding application. The safety and accuracy of ultrasonic testing has pushed this method to the front in NDT fields. The data obtained from the ultrasonic testing can be used to determine the location of the defect. The first step of ultrasonic testing is to locate any laminations in or near the heat-affected zone by performing the test using a straight beam transducer that produce a longitudinal wave at normal incidence as shown in Figure 2.5. This is very important step as angle beam transducer cannot provide a return signal from a laminar flow. In conjunction, test also will use angle beam transducer to detect the defect as shown in Figure 2.6.
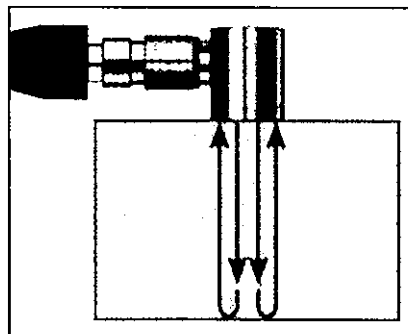

Figure 2.5: Straight Beam transducer

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