EFFECTIVENESS OF PORTABLE EDDY CURRENT INSPECTION ON WELDING PIPELINE

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DECLARATION

I declare that this thesis entitled "Effectiveness Of Portable Eddy Current Inspection on Welding Pipeline" 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	:	
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APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical and Manufacturing Engineering Technology (Maintenance) with Honours.

Signature	:	
Supervisor Name	:	Siti Norbaya binti Sahadan
Date	:	18th January 2022

DEDICATION

To my beloved family members and friends who have tirelessly stick and support me in an incredible journey of this 24 years of life.

ABSTRACT

Fatigue crack is one of the world oldest failure which has been studied by various researcher. Through those researcher, the humanity becomes more aware of fatigue failure which alway occurs on humans daily life. In this study, the fatigue crack in the welding has been studied throughly and the evaluation of the effectiveness of portable eddy current testing (ECT) method on welding has been inspect. However, before inspecting the weldment on the specimen, the material of the specimen must also be investigate first. The specimen selected is a pipeline removed by an industry because of it defect. The specimen material used in this study is a ferromagnetic material which has a good machinability with lower costing usage than any other materials and a conductive material in line with the use of Non-Destructive Tool (NDT) that will be used in this study. After that, the inspection on detecting the fatigue crack in the welding pipeline were inspected by using the ECT through two type of probe movement on three places on the weldment. These three place and type are right toe inspection, left toe inspection and cap inspection. The defect crack found in the welding will be recorded and analyze in three graph. Then, the next NDT inspection is Ultrasonic Testing (UT) will be used on inspecting the welding so that both of the NDT data can be comparised in order to deepen the understanding of using the portable ECT in inspecting the welding pipeline. After that, the effectiveness of portable ECT in inspecting the weldment can be evaluate.

ABSTRAK

Keretakan lesu adalah salah satu kegagalan tertua di dunia yang telah dikaji oleh pelbagai penyelidik. Melalui pengkaji tersebut, manusia lebih sedar tentang kegagalan keletihan yang selalu berlaku dalam kehidupan seharian manusia. Dalam kajian ini, keretakan lesu pada kimpalan telah dikaji secara menyeluruh dan penilaian keberkesanan kaedah ujian arus pusar mudah alih (ECT) terhadap kimpalan telah diperiksa. Walau bagaimanapun, sebelum memeriksa kimpalan pada spesimen tersebut, bahan spesimen juga mesti disiasat terlebih dahulu. Spesimen yang dipilih ialah saluran paip yang dibuang oleh industri kerana ia telah rosak.Bahan spesimen yang digunakan dalam kajian ini adalah bahan feromagnetik yang mempunyai kebolehmesinan yang baik dengan penggunaan kos yang lebih rendah berbanding bahan lain dan bahan konduktif selaras dengan penggunaan ujian tanpa musnah (NDT) yang akan digunakan dalam kajian ini. Selepas itu, pemeriksaan pengesanan retakan kelesuan pada saluran paip kimpalan diperiksa dengan menggunakan ujian arus pusar (ECT) melalui dua jenis pergerakan pengesan pada tiga tempat pada kimpalan.Tiga tempat dan jenis ini ialah pemeriksaan kanan kaki kimpalan, pemeriksaan kiri kaki kimpalan dan pemeriksaan atas kimpalan. Keretakan kecacatan yang terdapat dalam kimpalan akan direkodkan dan dianalisis di dalam tiga graf. Kemudian, pemeriksaan ujian tanpa musnah (NDT) seterusnya ialah ujian ultrasonik (UT) akan digunakan pada pemeriksaan kimpalan supaya kedua-dua data ujian tanpa musnah (NDT) dapat dibuat perbandingan bagi mendalami pemahaman penggunaan ujian arus pusar mudah alih (ECT) dalam pemeriksaan saluran paip kimpalan. Selepas itu, keberkesanan ujian arus pusar mudah alih (ECT) dalam memeriksa kimpalan boleh dinilai.

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LIST OF SYMBOLS AND ABBREVIATIONS

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N_f	-	Fatigue life
N_i	-	Crack initiation
N_p	-	Crack growth
σ_a	-	Stress amplitude
$\Delta\sigma$	-	Difference between the maximum and the minimum stress
σ_{max}	-	Maximum stress value
σ_{min}	-	Minimum stress
R	-	Ratio
P_{max}	-	Maximum load
P_{min}	-	Minimum load
A	-	Fatigue strength coefficient
B	-	Basquin exponent
T	-	Temperature
c	-	Temperature sensitivity parameter
ε_{ea}	-	Elastic strain amplitude
ε_{pa}	-	Plastic strain amplitude
σ'_f	-	Fatigue strength coefficient
E	-	Young modulus
b	-	Fatigue strength exponent
ε'_f	-	Fatigue ductility coefficient
c	-	Fatigue ductility exponent
$\frac{da}{dN}$	-	Fatigue crack growth
C	-	Material coefficients
ΔK	-	Stress intensity range
m	-	Constant/gradient in region II

LIST OF ABREVIATION

ASTM	-	American Society For Testing Materials
NDT	-	Non-Destructive Test
QC-NDT	-	Quality Control Non-Destructive Test
UT	-	Ultrasonic Testing
RT	-	Radiographic Testing
IRT	-	Infrared Thermography Testing
THz	-	Terahertz
ECT	-	Eddy-Current Testing
EC	-	Eddy Current
Ni	-	Nickel
Fe	-	Iron
Co	-	Cobalt
SCC	-	Stress Corrosion Cracking
LCF	-	Low Cycle Fatigue
HCF	-	High Cycle Fatigue
MPI	-	Magnetic Particle Inspection
MFL	-	Magnetic Flux Leakage
PMP	-	Permanent Magnetic Perturbation
PEC	-	Pulsed Eddy Current
ISO	-	Isometric View

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CHAPTER 1

INTRODUCTION

1.1 Background

In the beginning of 19th century, the assessments of structure and material fatigue failures have been started to thrive in engineering. There are various failures on engineering components and structures such as fracture, creep, rusting, fatigue failure and others. Failure process which occurs due to repetitive stress or strain loads are known as a cracking phenomenon caused by a number of repetitive load cycles (Leuders et al., 2017). The unexpected cracking and sudden breakdown of components will occur due to the fact that tensile stresses, which can originate from various manufacture processes at different production stages, added to the in-service stress reduce the component life (Han & Yang, 2021).

Generally, fatigue cracking consists of three main stages namely (i) crack initiation, (ii) crack propagation and (iii) final rupture. This problem of fatigue failure becomes an important issue in various fields due to the fatigue failure occurs without signal (Sánchez et al., 2021).Thus, the ability of a component that can optimally function will be affected by the damage came from those components. Deterioration of component performance can also cause by several other factors. If all the damage detected not maintained from the early stage then failure can occur more often and the components or machine will become total lost which is cannot being used at all again (Jiao et al., 2016).

According to the definition of fatigue stated in the American Society for Testing Materials (ASTM), fatigue is the process of permanently changes in the structure of a material occurs when the material is subjected to stress and strain repeatedly. This process is a progressive process that is focused on the local area where the area cracks or fractures occur when the load cycle reaches the limit on certain number of cycles (Sánchez et al., 2021). Fatigue is the condition where a material cracks or fails because of repeated (cyclic) stresses applied below the final strength of the material. The term "Fatigue Cyclic", for instance, is an analogy to cycles which will be counted on mechanisms comprising revolving axes, gears and chains, but it becomes a challenge to define what a cycle really means within the multiaxial loading context (de Lacerda et al., 2017).

Crack is a major concern in ensuring the durability, safety and serviceability of structures. This is because the presence of crack can cause the reduction in the effective loading area which lead to the increase of stress and subsequently failure of the materials or structures. Cracking seems unavoidable and appears in wide variety of structures such as concrete wall, beam and brick walls. Various types of defects also can be found in pipeline applications (Dadfarnia et al., 2019). Slit and crack are the examples of defects that commonly found especially in the ferromagnetic materials. The presence of defects will affect the reliability, safety and the consistency of materials' quality. Therefore, it is crucial to test and evaluate the materials or structure to detect cracking for the safety and health of the structure. The presence of such cracks can be detected by using various types of Non-Destructive Test (NDT).

The NDT is an engineering evolution of science for engineer to evaluate any specimen which being test without causing any destructive and it guarantee the safety, reliability and integrity of engineering structure and components. The NDT inspection was first being used for Quality Control NDT (QC-NDT) and then applicated widely because of its effectiveness in practice(Trampus et al., 2019). Thus, NDT is the most practicable for inspection the fatigue fracture test which really sensitive on any additional impact. Combination of different NDT is a good way to inspect the defect and abnormalities of the structures. In many cases, more than one NDT method is use in the process of defect inspection. To ensure the effectiveness of the inspection process, more understanding on the backgrounds, advantages and limitations of each NDT technique is necessary. Understanding one non-destructive method alone may not be enough to obtain the accurate results from the testing process (Dwivedi et al., 2018).

1.2 Problem Statement

The current NDT methods used for inspection is include ultrasonic testing (UT), radiographic testing (RT), infrared thermography testing (IRT), terahertz (THz) imaging technology, and eddy-current testing (ECT). A deep understanding on the foundation, advantages and limitations of each NDT technique is necessary to ensure the effectiveness of the inspection process (Dwivedi et al., 2018). Non-destructive eddy current evaluation techniques have been globally used in the inspection of conduction structures for the diagnosis of surface and near-surface cracks. The basic eddy current (EC) is a cylindrical coil used to generate and sense the electrical current in the metallic part simultaneously. However, there are various improvement on traditional eddy current testing in previous study. (Ge et al., 2021) state that eddy current inspections are performed using a uniform eddy current probe driven with 10 kHz, and all of the fatigue cracks are detected with clear signals. (Almeida et al., 2013) propose a new type of eddy current probe with enhanced lift-off immunity and improved sensitivity and estimates a new NDT system. The inspection of non-destructive monitoring of microstructural changes in austenitic steels under cyclic loading as well as the lifetime prediction by combining high-accuracy acoustic monitoring of elastic anisotropy and eddy current monitoring of volume fraction of the martensite. This combined approach allows estimation of fatigue life as well as the information on the past loading history (Mishakin et al., 2020).

In NDT, the eddy current testing is one of the most inspection which has a high sensitivity. Its sensitivity primary on to the surface defects and able to detect defects of 0.5mm in length under favourable conditions. Eddy current also able to observe through several layers. The ability to spot defects in multi-layer structures (up to about 14 layers), without meddle from the planar interfaces. Its accuracy on conductivity measurements also acceptable and dedicated conductivity measurement instruments operated. Eddy current also has a little pre-cleaning required. Only major soils and loose or uneven surface coatings need to be removed, reducing preparation time. However, this method is basically used for conductive materials and more difficult to determine the defects that embedded in the specimen. Theoretically, phase measured signal can be used to characterize the defect depth. However, it is complicated to evaluate the phase of signals in reality (Tong et al., 2020). Eddy current also will not detect defects parallel to surface. Without exception the flow of eddy currents will always be parallel to the surface. If a planar defect does not intercept or interfere with the current then the defect will not be easily spotted. Then, eddy current is not suitable for large areas and/or complex geometries. Although the large area scanning can be accomplished, but it needs the aid of some type of area scanning device which is usually supported by a computer it is not inexpensive. The more complex the geometry becomes, the more difficult it is to differentiate defect signals from geometry effect signals.

The simplified version of eddy current method is the portable ECT equipment that has been widely used in a lot of industry. However, the appearance of other NDT equipment significantly made the usage of eddy current method become declining depends on the advantages and the disadvantages of these NDT. Therefore, this study will be conduct on investigation the effectiveness of eddy current method in the aspect of detecting the fatigue crack in the welding pipeline compared with the UT method. The results of previous researchers found that, ECT is a popular approach for inspecting conductive materials but its complexity necessitates a strong processing unit. Remote access is an unique move in the field, since research in this area has shown to improve ECT efficiency (Rosado, 2020). Therefore, analysis on portable ECT will be expected to be less efficient.

1.3 Research Objective

The main objectives for this research are as follows:

a) To conduct fatigue crack test for weldment of ferromagnetic materials.

b) To collect eddy current signals in detecting crack in a welding of ferromagnetic pipeline.

c) To confirm the crack detection of eddy current testing using ultrasonic testing.

1.4 Scope of Research

The scope of this research are as follows:

- This experiment will only be conduct in laboratory scales.
- In this experiment, the specimen that need to be observed as a sample is limited only for ferrous metal because of the inspection method that was used is magnetic flux eddy current method.
- The inspection is only using the portable or conventional eddy current testing.
- The comparison data is only by using the portable ultrasonic test.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Essentially, this chapter will describe the literature review of the history of previous studies that have been conducted, which have a correlation between work done in this study. The samples history which are applications and advantages the use of ferromagnetic materials is discussed to reinforce the importance of the study run. Ferromagnetic materials have already infiltrated our lives with applications from the magnets in people's refrigerator to the hard drives of our computers. Ferromagnetic material beginning with their earliest usage as compass needles in China since 12th century. They were historically even more researched, but the crucial elements for Maxwell's theory of electromagnetic and quantum mechanics was not found until the last two centuries (Enya Vermeyen, 2019).

Focus on literature review and basic concepts in the approach fatigue failure is also discussed. The fatigue life approach is divided into three commonly used approaches are life-stress, life-strain and mechanical methods linear elastic fracture. Although failures related to structural integrity are not a new problem in the field of engineering, studies in this field are still very active especially involving fatigue failures on metal and alloy materials (da Costa Mattos, 2017). In addition, fatigue failure occurs in local areas where it occurs only in areas that experience high stresses or strains as a result of actions such as external loads, temperature changes and residual stresses. This process does not apply to entire components or structures (Guimaraes et al., 2016).