اونيۏرسيتي تيکنيکل مليسيا ملاک

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEFECT DETECTION ON WELDING PART BY USING MAGNETIC PARTICLE INSPECTION (MPI)

MUHAMMAD HAZIQ BIN ABD LATIF
B092010335

BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (MAINTAINANCE TECHNOLOGY) WITH HONOURS

2024

Faculty of Mechanical Technology And Engineering

DEFECT DETECTION ON WELDING PART BY USING MAGNETIC PARTICLE INSPECTION (MPI)

Muhammad Haziq Bin Abd Latif

Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honour

2024

DEFECT DETECTION ON WELDING PART BY USING MAGNETIC PARTICLE INSPECTION (MPI)

MUHAMMAD HAZIQ BIN ABD LATIF

A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours

Faculty of Mechanical Technology And Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **DEFECT DETECTION ON WELDING PART BY USING MAGNETIC PARTICLE INSPECTION (MPI)**

SESI PENGAJIAN: **2023-2024 Semester 2**

Saya **MUHAMMAD HAZIQ BIN ABD LATIF**

mengaku membenarkan tesis ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐	TERHAD	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)
☐	SULIT	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☑	TIDAK TERHAD	

Disahkan oleh:

Alamat Tetap:

NO 5 JALAN BISTARI 9
TAMAN BISTARI
43950 SUNGAI PELEK, SELANGOR

Tarikh: 7 JANUARI 2024

Cop Rasmi:

Tarikh: 7 JANUARI 2024

** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I declare that this Choose an item. entitled “Defect Detection On Welding Part By Using Magnetic Particle Inspection (MPI)” 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 : MIUHAMMAD HAZIQ BIN ABD LATIF

Date : 10 JANUARY 2024

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 Engineering Technology (Maintenance Technology) with Honours.

Signature : ....

Supervisor Name : TS. DR. NOR AZAZI BIN NGATIMAN

Date : 11 JANUARY 2024

DEDICATION

I dedicate my project to my parents, project supervisor and my close friends. An extra special thank you to my parents, Abd Latif Bin Ramli and Zaiton Binti Abdullah and also my brother, Muhammad Izzad Bin Abd Latif for support and love that have shown by them during the process of conducting my research. My almost gratitude to my project supervisor Ts. Dr. Nor Azazi Bin Ngatiman, for providing me with instruction and direction all the way process of finishing this project successfully. Last but not least, I want to express my deepest thank you to my beloved Nur Hazwani Binti Mohd Aziz who have been there for me when i needed through finishing this project.

ABSTRACT

Magnetic Particle Inspection (MPI), also known as Magnetic Particle Inspection (MPI), is a non-destructive testing method employed for the detection of surface and near-surface defects in ferromagnetic materials. MPI is widely used in various industries to ensure the integrity and safety of ferromagnetic components.The portability and sensitivity capabilities make MPI a versatile option from assessing tiny cracks around fastener sites in aircraft structures to detecting large subsurface hot tears in alloy steel welds of pipelines. Continued innovation focuses on automated scanning and interpretation to expand MPI applications for finding surface-breaking defects across critical systems, components and manufacturing lines. MPI techniques encompass using dry particles or particles suspended in wet carrier liquids along with varying magnetizing methods. Indication patterns can be enhanced for visibility through contrast MPI and further characterization. Applicable codes and standards guide the test materials, processes, equipment capabilities, demagnetization requirements, and personnel competencies for reliable inspection. MPI offers quick in-situ defect detection without needing to dismantle or clean test articles extensively. This technique also involves magnetizing the material and applying a magnetic particle medium, which allows the particles to align along the magnetic field lines at defect locations. These aligned particles create indications that are visible during inspection. The inspection process includes examining the surface using suitable techniques, interpreting the characteristics of the indications, and determining whether they represent defects or acceptable conditions based on established standards. Post-inspection, the magnetic particle medium is removed, and the surface is thoroughly cleaned.

ABSTRAK

Ujian Zarah Magnetik (MPI), juga dikenali sebagai Pemeriksaan Zarah Magnetik (MPI), ialah kaedah ujian tidak merosakkan yang digunakan untuk pengesanan kecacatan permukaan dan hampir permukaan dalam bahan feromagnetik. MPI digunakan secara meluas dalam pelbagai industri untuk memastikan integriti dan keselamatan komponen feromagnetik. Keupayaan mudah alih dan kepekaan menjadikan MPI pilihan serba boleh daripada menilai keretakan kecil di sekitar tapak pengikat dalam struktur pesawat kepada mengesan koyakan panas bawah permukaan yang besar dalam kimpalan keluli aloi saluran paip. Inovasi berterusan memfokuskan pada pengimbasan dan tafsiran automatik untuk mengembangkan aplikasi MPI bagi mencari kecacatan pecah permukaan merentas sistem kritikal, komponen dan barisan pembuatan. Teknik MPI merangkumi penggunaan zarah kering atau zarah terampai dalam cecair pembawa basah bersama-sama dengan kaedah magnetisasi yang berbeza-beza.Corak petunjuk boleh dipertingkatkan untuk keterlihatan melalui kontras MPI dan pencirian selanjutnya. Kod dan piawaian yang berkenaan membimbing bahan ujian, proses, keupayaan peralatan, keperluan penyahmagnetan dan kecekapan kakitangan untuk pemeriksaan yang boleh dipercayai. MPI menawarkan pengesanan kecacatan in-situ yang cepat tanpa perlu membongkar atau membersihkan artikel ujian secara meluas. Teknik ini juga melibatkan pengmagnetan bahan dan menggunakan medium zarah magnet, yang membolehkan zarah untuk menjajarkan sepanjang garis medan magnet di lokasi kecacatan. Zarah sejajar ini mencipta petunjuk yang boleh dilihat semasa pemeriksaan. Proses pemeriksaan termasuk memeriksa permukaan menggunakan teknik yang sesuai, mentafsir ciri-ciri petunjuk, dan menentukan sama ada ia mewakili kecacatan atau keadaan yang boleh diterima berdasarkan piawaian yang ditetapkan. Selepas pemeriksaan, medium zarah magnet dikeluarkan, dan permukaannya dibersihkan dengan teliti.

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my sustainer, for everything I received since the beginning of my life. I would like to extend my appreciation to the Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform.

My utmost appreciation goes to my main supervisor, Ts. Dr. Azazi Bin Ngatiman, Faculty of Mechanical and Manufacturing Engineering Technology, Universiti Teknikal Malaysia Melaka (UTeM) for all his support, advice and inspiration. His constant patience for guiding insight will forever be remembered. I am eternally grateful to him. His extensive experience has proven to be of tremendous use to me. I am thankful that he decided to take me on as a student and that he has maintained his trust in me during the course of the semester.

I am grateful for my family's unwavering, unquestioning, and affectionate support. I will be eternally grateful for the everlasting love and support I received during the thesis process and every day.

Thank you to my beloved Nur Hazwani Binti Mohd Aziz for always being there to listen to me through long days and through stressful moments, to make jokes when things get too serious and always give me advice and encouragement when I'm down.

Last but not least, I wanted to express my deepest gratitude and appreciation to our instructor for their assistance and advice during this degree. I am grateful to Universiti Teknikal Malaysia Melaka (UTeM) for enabling me to use laboratory's facilities for completion of my project.

TABLE OF CONTENTS

PAGE

LIST OF TABLES

LIST OF FIGURES

FIGURE **TITLE** **PAGE**

LIST OF SYMBOLS AND ABBREVIATIONS

MPT - Magnetic Particle Testing
MPI - Magnetic Particle Inspection
mm - Millimetre
NDT - Non Destructive Test
TIG - Tungsten Inert Gas
GTAW - Gas Tungsten Arc Welding
MIG - Metal Inert Gas
GMAW - Gas Metal Arc Welding
SMAW - Shielded Metal Arc Welding
HAZ - Heat Affected Zone

LIST OF APPENDICES

APPENDIX **TITLE** **PAGE**

CHAPTER 1

INTRODUCTION

1.1 Background

Non-destructive testing (NDT) is a method of testing the material without destroying. This means that the inspection, evaluating the welded joints material, components or any defects found in the welded part or the differences between the materials in characteristics without damaging the material. This means that the component- the casting, welding, and forging, can continue to be used and that the non -destructive testing method has done no harm. NDT can be used to check the quality of the material from the stages of raw material, fabrication and in-service inspection. NDT used to make sure that the material has the capacity to assure that they do not fail within the calculated time.

Non-destructive test (NDT) methods are used to locate defects present in the castings to provide insight into casting quality. Common NDT methods used in the steel casting industry include visual inspection, magnetic particle inspection (MPI), liquid penetrant testing (LPT), ultrasonic testing, and radiography testing. This method is widely used in various industries to ensure the quality and reliability of products without compromising their integrity. NDT is performed using a range of methods that rely on physical properties such as magnetic, acoustic, electromagnetic, radiography, and ultrasonic waves. These methods can detect surface or subsurface defects, measure the thickness of materials, or evaluate the composition and properties of the tested object.

NDT techniques are now being integrated into the manufacturing process, allowing for real-time monitoring and control of product quality. This ensures that any defects or anomalies are detected and corrected before the final product is completed, reducing the risk of failures and increasing the overall quality and reliability of the product.

1.2 Problem Statement

Welding is a fabrication process whereby two or more parts are fused together by means of heat, pressure or both forming a join as the parts cool. Welding is usually used on metals and thermoplastics but can also be used on wood. The completed welded joint may be referred to as a weldment.

The effects of welding defects can have significant implications on the quality, integrity, and performance of welded structures. These defects normally cause early pitting and crevice attacks in the weld metal. Sulphide inclusions are the most susceptible sites for pitting and crevice attack; however, other non-metallic inclusions are also capable of causing pit nucleation. The research aim to defect check on carbon steel weld standard block by using Magnetic Particle Testing (MPT).

From previous record for welding activities prepared by student there is no quality performance regarding the welded part. The purpose of this project is mainly to confirm the quality the product mention.

1.3 Research Objective

The main aim of this research is to perform defect check on carbon steel weld. Specifically, the objectives are as follows:

a) To perform defect check on carbon steel weld standard block by using Magnetic Particle Test (MPT)
b) To validate welding condition on sample block by using Magnetic Particle Test (MPT)

c) To compare the effectiveness of Magnetic Particle Test on student sample product.

1.4 Scope of Research

The scope of this research are as follows:

a) Investigating the effectiveness of Magnetic Particle Testing (MPT) in detecting defects in carbon steel welds.
b) Determining the factors that affect the accuracy of MPT, such as the type of material being tested, the size and shape of the defects, and the strength of the magnetic field.
c) The use of MPT to detect defects in welds made with different types of welding processes.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The theory and information that needed which is related to the scope of the projects will be discussed in this chapter. Other than that, discussion regarding the information and methods used in earlier research is also revised. In this chapter, the equipment related to the project that is Magnetic Particle Inspection (MPI) are explained in this chapter. The literature review is perusing of the works of other before initiating on examination work to acquire significant data and information and comparable projects done by others. The sources are taken from previous thesis, journal, conference paper, books and also the Internet. All the related topics were collected and is discussed in this chapter.

2.2 Non- Destructive Test

Non-destructive testing (NDT) has become increasingly important in the modern era, as industries have advanced in complexity, materials, and technology. The need for accurate and reliable inspection and evaluation of products and structures has become crucial to ensure the safety, reliability and efficiency of modern infrastructures and machinery. Non-destructive test is essential in many industries, including manufacturing, aerospace, automotive and others. It also identify possible issues early which is can prevent cost downtime. Beside that, it also reduce risk of catastrophic failure and ensure the safety and reliability of product and structures.

2.2.1 Magnetic Particle Inspection

Magnetic Particle Inspection (MPI), also known as magnetic particle test (MPT), is a non-destructive testing (NDT) method used to detect surface and near-surface defects in ferromagnetic materials. It is commonly applied to assess the integrity of welds, castings, forgings, and other components made from materials such as iron, steel, nickel, and cobalt.

Magnetic Particle Inspection (MPI) is widely employed in various industries due to its cost-effectiveness, speed, and ease of use. In the steel casting sector, it is the predominant method for identifying surface cracks. However, there is a notable gap in research regarding the reliability of this method specifically on steel castings and ways to enhance its dependability. This is crucial as defects escaping Magnetic Particle Inspection (MPI) could lead to catastrophic failures in real-world applications.

The primary purpose of magnetic particle testing is to identify discontinuities, such as cracks and other imperfections like lack of fusion or incomplete penetration, at the surface or near the surface (sub-surface) of ferromagnetic materials. Sensitivity is higher for both surface and sub-surface discontinuities but diminishes as the depth of breaks below the material's surface increases.

MPI is proficient in identifying surface and sub-surface defects in ferromagnetic components through the application of magnetization. This non-destructive testing method involves magnetizing the part by applying a current. In the presence of a discontinuity, the magnetic field lines are disrupted, causing magnetic flux leakage. Magnetic particles are then applied to the part, becoming attracted to the areas of flux leakage, resulting in the accumulation of magnetic particles on the part's surface.

Figure 2.1 : Magnetic Particle Inspection

2.2.1.1 Magnetic Particle Inspection Limitation

MPI has inherent limitations, the most significant among which is that it can only be applied to ferromagnetic substances. These non-ferromagnetic materials present problems for MPI aluminum, copper, brass, and authenticate stainless steel. The method is useless for finding defects in these non-ferromagnetic metals since they do not hold magnetic fields. Although while MPI is an effective tool in its own domain, its limited applicability emphasizes how crucial it is to use a variety of inspection methods in order to guarantee thorough material integrity assessment over a wide range of material kinds.

2.2.2 Ultrasonic Test

The ultrasonic testing was applied to detect the internal defects of welded materials. The principle of ultrasonic testing is more or less equal to echo sounding.[1] A small range of pulse from the ultrasonic sound is produced by the electric charge applied to a crystal called piezoelectric which will vibrate for a less period at a frequency that is equal to the thickness of the crystal. Ultrasonic detects the discontinuities by reflecting the transmitted sound waves in welded material.

Figure 2.2: Ultrasound

2.2.2.1 Ultrasonic Limitation

In terms of material, ultrasonic waves may struggle to penetrate specific materials, particularly those that are highly attentive or coarse-grained. Surface conditions also play a crucial role, requiring the material's surface to be accessible and free from heavy coatings or roughness that might impede the transmission of ultrasonic waves. Furthermore, UT encounters in geometric difficulties that make it challenging to check parts with complex geometries or irregular structures where ultrasonic waves might not propagate efficiently. There are drawbacks to this procedure when evaluating locations with restricted access or cramped spaces because it requires direct access to the examination area. Additional difficulties stem

---

[1] https://www.sciencedirect.com/science/article/pii/S2214785320392476

from the size and location of problems, as ultrasonic equipment's resolution may make it difficult to identify minute flaws or cracks.

2.2.3 Visual Inspection

Visual testing is the most common process of inspecting the material. It is a technique of overlooking a piece of material using the unaided or aided eye to search for defects by the trained inspector to visually inspect the material. Visual inspection testing can be used for the external and internal surface of the welded surface including the piping, pressure vessels and storage tanks and other equipment.

Figure 2.3: Visual Inspection

2.2.3.1 Visual Inspection Limitation

In order to detect surface imperfections, faults, or abnormalities in materials, visual inspection was used. this method depends on human visual acuity. it has limits even if it is easy to use and reasonably priced. Initially, its depth awareness is restricted, meaning that it works best on surface-level flaws and might overlook anomalies that are deeper in the material.

2.2.4 Liquid Penetration Test

Liquid penetrate testing is a process that is used to reveal the surface discontinuities by bleed out of a coloured visible and fluorescent dye from the defected area. It is one of the easiest and old NDT method to find out the defects. This method involves three materials namely cleaner, penetrate and developer. This method is a low-cost method and it is widely applied to locate surface-breaking defects in non-porous materials. This is applicable to all ferrous and non-ferrous materials. Materials that are commonly tested using LPT are metals (aluminium, steel, titanium, copper, etc.), glass, rubber, plastics. LPT is used to detect any defects in forging, welding defects like cracks, possibilities of leakage and fatigue cracks.

Figure 2.4: Liquid Dye Penetration

2.2.4.1 Liquid Penetration Test Limitation

Liquid Penetration Testing (LPT), also referred to as dye penetrate testing or penetration inspection, serves as a widely utilized non-destructive testing (NDT) method designed for identifying surface-breaking defects in non-porous materials.One significant limitation of

Liquid Penetrate Testing is related to surface accessibility. The method requires direct access to the surface being examined. In instances where the material has complex geometries or hard-to-reach areas, achieving the necessary access can be challenging. Another important consideration is the limitation to non-porous materials. Liquid Penetrate Testing is most effective on materials with low porosity. In materials with high porosity, such as certain types of castings or ceramics, the penetrate may be absorbed into the material, making it difficult to detect defects. The drying time can vary based on environmental conditions and the type of penetrate used. In situations where a quick inspection turnaround is required, the drying time becomes a significant consideration.

2.2.5 Radiography

Radiography uses an x-ray radiation which passes through the testing material and captured by a recording device. The x-rays have the ability to penetrate through the welded material. The specimen is tested by placing between the source of radiation and film. The film is used in radiography testing works recording medium. Both sides of the film base are covered by the protective coating and emulsion coating. The base is polyester and provides transparent medium. The emulsion coating increases the quantity of radiation absorbed

Figure 2.5: Radiography Test

2.2.5.1 Radiography Test Limitation

In order to detect flaws in materials, radiographic testing (RT) is a potent non-destructive testing (NDT) technique that uses ionising radiation, such as X-rays or gamma rays. RT is not without restrictions, despite its usefulness. To safeguard workers and the surrounding environment when using ionising radiation, strict safety measures must be taken. Its lower sensitivity to minute flaws makes the approach less useful for identifying even the smallest anomalies in materials, which is another drawback. Additionally, when inspecting complicated structures or parts with limited access, RT can be challenging because it usually requires access to all sides of the object being inspected.

2.3 Welding

Welding is the process of melting and fusing two or more pieces of metal or thermoplastic material together. It is a fundamental method applied in many sectors, including manufacturing, aerospace, automotive, construction, and more. The workpieces, or materials being joined, are heated to a high temperature during welding, which causes them to melt or become semi-liquid. Weld pools are the common name for the melted material. To provide strength and fill any gaps between the workpieces, a filler material—often in the form of a welding rod or wire—can be introduced to the weld pool.

2.3.1 Type of Welding

There are various different kinds of welding, each with unique traits, uses, and methods. A common welding technique is arc welding, which uses an electric arc to generate heat and melt the materials between an electrode and the workpiece.[2] Arc welding comes in a variety of forms, such as:

a) Shielded Metal Arc Welding (SMAW) is another name for stick welding. Which is uses a consumable electrode covered in flux to spark the arc and protect the weld pool from outside impurities.

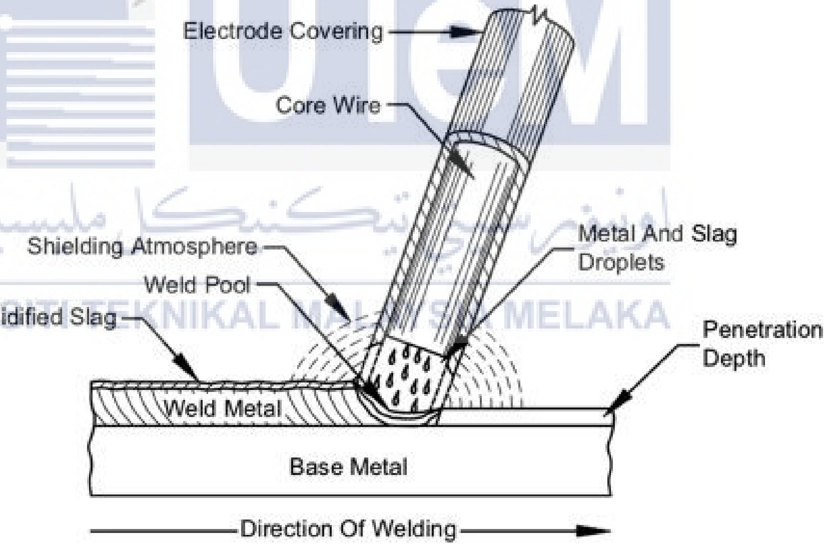


Figure 2.6: SMAW Welding

b) MIG (Metal Inert Gas) welding is another name for the process known as gas metal arc welding (GMAW), which uses a constantly supplied consumable wire electrode and a shielding gas to protect the weld pool.

---

[2] https://www.weldinghandbook.com/types-of-welding/

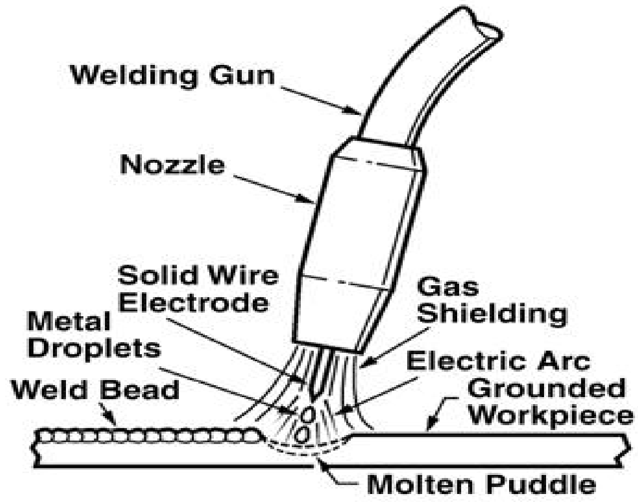


Figure 2.7: GMAW Welding

c) Gas Tungsten Arc Welding (GTAW) was Commonly known as TIG (Tungsten Inert Gas) welding, it uses a non-consumable tungsten electrode and an inert gas to protect the weld zone. Filler material can be added separately if needed.

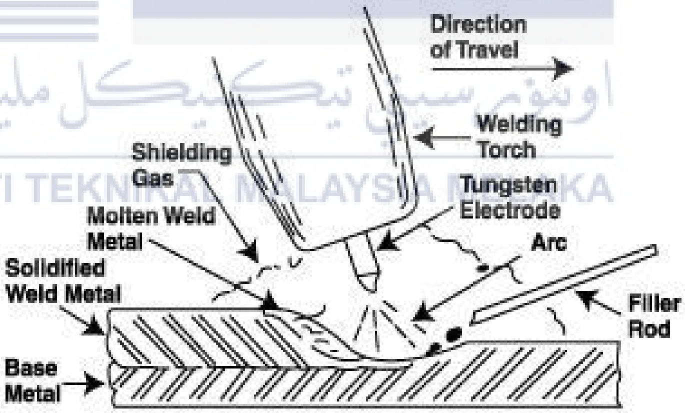


Figure 2.8: GTAW welding

2.4 Type of Welding Defect

The term "welding defect" describes flaws or inconsistencies that appear during the welding process and cause the weld to fall short of the desired standards or quality. Welding flaws can weaken the joint, compromise its integrity, and effect the function of the welded structure or component as a whole. There are several type of welding defects that can occur during the welding process.

2.4.1 Porosity

Porosity are referred to the presence of tiny cavities or gaps within the weld metal that caused by the entrapment of gas bubble during welding. This defect can make the welding more brittle and vulnerable to occur corrosion and fracture.

Figure 2.9 Porosity

2.4.2 Lack of Fusion

Lack of fusion occurs when there is an incomplete bond between the base metal and the weld metal. It can result from inadequate heat input, improper electrode manipulation, or insufficient penetration into the joint, leading to weak or unreliable welds.

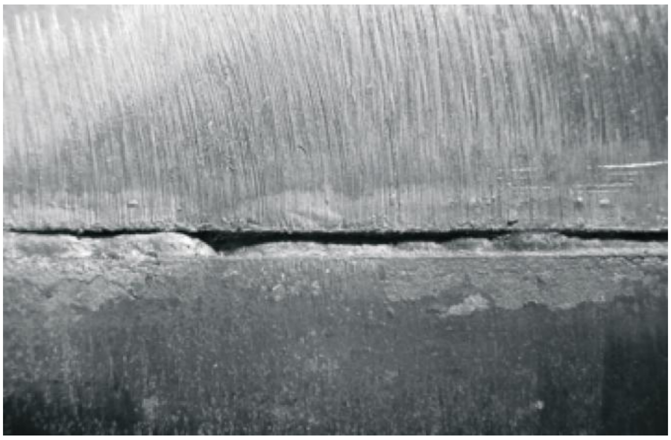


Figure 2.10: Lack of Fusion

2.4.3 Undercut

Undercut was a type of welding defect that occur when the edge of the weld joint melts that can cause grooves or indentation. It can happen for a few reasons such as too much heat, move the welding torch too fast or use not suitable type of electrode. Undercuts can weaken the weld joint and it can occur failure.

Figure 2.11: Undercut

2.4.4 Excessive Spatter

Weld spatter is a nuisance that occurs during welding. It is formed when molten metal droplets fly off the weld and cool into small, round balls. Spatter can cause burns, damage surrounding surfaces, and make the weld look unsightly. There are a number of ways to reduce spatter, including using the right welding techniques, equipment, and materials.

Figure 2.12: Excessive Spatter

2.4.5 Slag Inclusion

Slag inculsion are non-metallic particle that can become trapped in the weld metal or at the weld interface. It can be caused by faulty welding technique or methoed, improper access to the joint or both. Sharp notches at joint boundaries or between weld passes can also promote to slag trapping. With proper welding technique, the slag inclusion will rise to the surface of molten weld and can be removed.

However, if slag inclusions are not removed, it can weaken the weld and make it more susceptible to corrosion. It can also create a stress riser, which can cause cracking. Therefore it important to take steps to prevent slag entry from occurring.

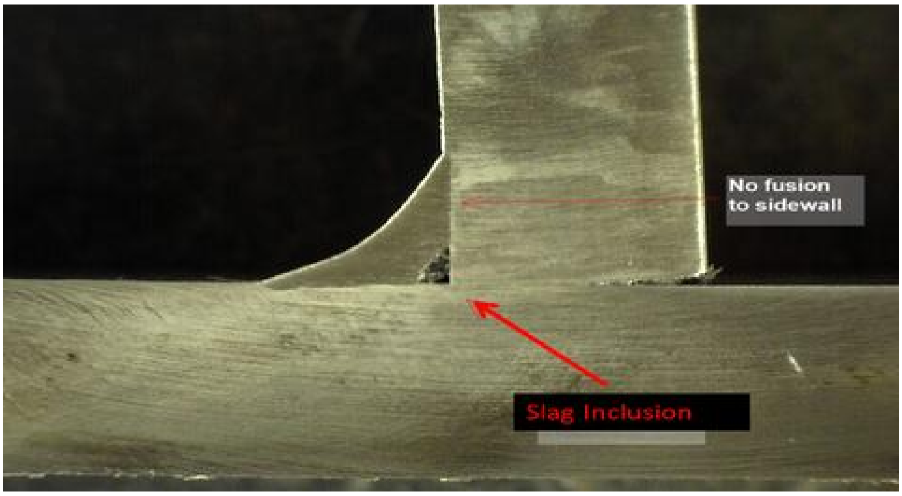


Figure 2.13: Slag Inclusion

2.5 Type of Welding Crack

A crack is a material separation that does not encompass the entire cross-section of a welding joint, component, or material, not yet causing it to fall apart. Cracks are in most cases starting points of a fracture. Welding cracks are linear imperfections with sharp tips. They can occur in the weld deposit, the heat-affected zone (HAZ), or the base material. Welding cracks form when the localized stresses exceed the ultimate tensile strength of the material. Initial Cracking usually starts at stress concentrations due to other defects or sharp notches (notches work as stress concentration) in the nearby area.

However, These stresses can be residual stresses caused by the welding or stresses got applied due to service or another external loading. Cracks can occur in a variety of ways during welding, and the type, appearance, and location of the cracks can have a significant impact on the service life of the components, especially when they are subjected to cyclic loading.

2.5.1 Hot Crack

Hot cracks can form in weldments due to a variety of factors. They are cracks that form as a result of molten or brittle phases present on grain boundaries at high temperatures. Solidification cracks are cracks that form in the weld area during the crystallization of the base material from the liquid phase. They can reach the surface of the weld metal and form either center cracks or end crater cracks. Solidification cracks can be found by visual inspection, liquid penetration testing, or magnetic particle testing.

Figure 2.14: Hot Crack

2.5.2 Cold Crack

Cold cracks form after the weld has solidified, and can appear hours or even days after welding is complete. They are also known as hydrogen cracks or delayed cracking, because they are caused by the presence of hydrogen in the weld. Cold cracks can occur in the heat-affected zone (HAZ), weld metal, or base metal. They can propagate through the grains or between the grains.

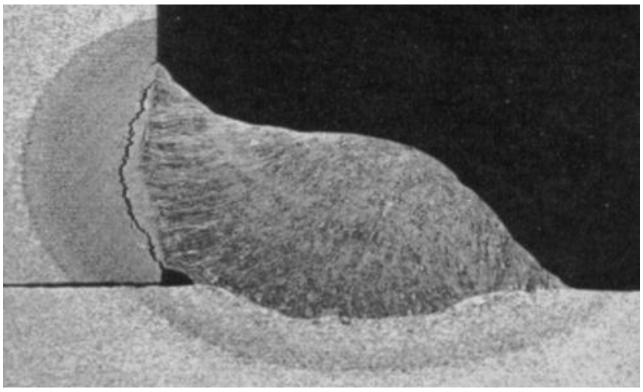


Figure 2.15: Cold Crack

2.5.3 Longitudinal Crack

A longitudinal crack is a type of weld defect that occurs parallel to the weld axis. It can appear in the weld metal, the heat-affected zone (HAZ), or the fusion line. Longitudinal cracks can be caused by a number of factors, including:

- **High cooling rate**: When welds cool too quickly, the weld metal can become brittle and crack. This is more likely to happen when welding small, thin pieces of material or when welding with high heat input.
- **High restraint**: When the weld metal is restrained from shrinking, it can develop high tensile stresses. These stresses can cause the weld metal to crack. Restraint can be caused by the design of the weld joint, the type of material being welded, or the presence of other welds in the vicinity.
- **Dissolved hydrogen**: Hydrogen can be dissolved in the weld metal during welding. If the hydrogen concentration is too high, it can cause the weld metal to crack. Hydrogen can be introduced into the weld metal from the atmosphere, the base material, or the welding consumables.
- **Porosity**: Porosity is the presence of holes in the weld metal. Pores can act as stress risers, which can make the weld metal more susceptible to cracking. Porosity can be caused by a number of factors, including poor welding technique, contaminated welding consumables, or poor shielding gas coverage.

2.5.4 Transverse

Transverse cracks are a type of weld defect that occurs perpendicular to the weld axis. They are typically smaller than longitudinal cracks and are usually confined to the width of the weld bead. Transverse cracks can propagate into the heat-affected zone (HAZ) and base metal, but they are most commonly found in the HAZ. Transverse cracks can be caused by a number of factors, including:

- **High strength materials**: Transverse cracks are more likely to occur in high-strength materials. This is because the weld metal in high-strength materials is typically low in ductility, which makes it more susceptible to cracking.
- **Low preheat**: Preheat helps to slow the cooling rate of the weld metal, which makes it less likely to crack. If preheat is not used, the weld metal can cool too quickly and become brittle, which can lead to cracking.
- **High hydrogen levels**: Hydrogen can be dissolved in the weld metal during welding. If the hydrogen concentration is too high, it can cause the weld metal to crack. Hydrogen can be introduced into the weld metal from the atmosphere, the base material, or the welding consumables.
- **Longitudinal shrinkage stresses**: As the weld metal cools, it shrinks. This shrinkage can cause tensile stresses in the weld metal. If these stresses are too high, they can cause the weld metal to crack.

Figure 2.16: Transverse

2.5.5 Crater Crack

Crater cracks was a type of hot crack that can occur when fusion welding processes, such as stick welding, MIG welding, or TIG welding, are not properly terminated. Crater cracks were caused by the rapid cooling of the weld pool, which creates high tensile stresses in the weld metal. These stresses can cause the weld metal to crack.

Crater cracks are more likely to occur in materials with high thermal conductivity, such as authenticate stainless steel or aluminium. This is because these materials dissipate heat very quickly, which can lead to rapid cooling and high tensile stresses. To prevent crater cracks, it is important to properly terminate the weld. This can be done by back filling the crater with weld metal or by using a technique called crater reinforcement.

Crater reinforcement involves depositing a small amount of weld metal in the crater and then weaving the arc back and forth over the reinforcement. This helps to slow the cooling rate of the weld pool and reduce the likelihood of cracking.

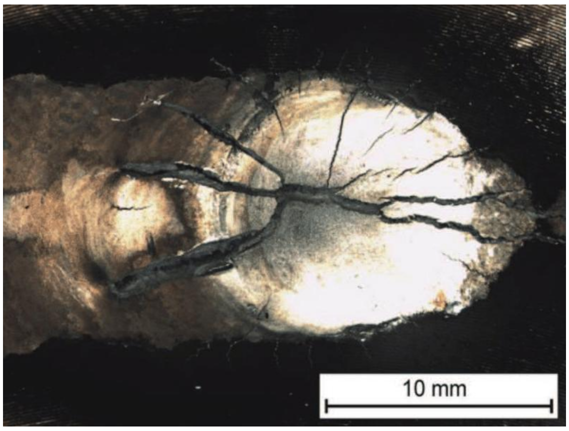


Figure 2.17: Carter Crack

2.5.6 Toe Crack

Toe cracks are a type of cold crack that can occur at the toes of fillet or groove welds. These cracks were caused by the high stresses that can occur at the toes of welds, and they can start from the base metal area approximately halfway through the weld. Toe cracks that are open to the surface can be easily detected by visual inspection and surface non-destructive testing (NDT) methods, such as penetrant testing and magnetic particle testing.

Toe cracks occur due to the thermal stresses created by welding. These stresses can cause the base metal to lose its ductility, or ability to bend without breaking. When this happens, the weld zone is not able to withstand the stresses and cracks can form.

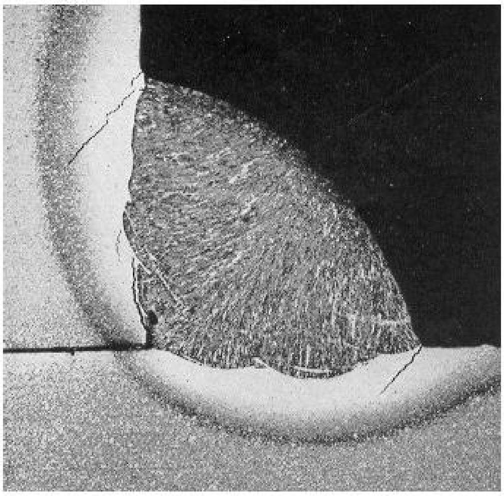


Figure 2.18: Toe Crack

2.5.7 Root Crack

Root cracks are cracks that occur at the root of a weld. They can be longitudinal, meaning they run along the length of the weld, or transverse, meaning it run across the width of the weld. Root crack can occur on the root surface or within root. Root cracks are caused by the shrinkage of the weld metal as it cools. This shrinkage can create tensile stresses in the weld metal which can cause it to crack. Root cracks are often difficult to detect because they may be hidden beneath the weld bead.

However, there are a number of methods that can be used to detect root cracks, including ultrasonic testing, magnetic particle testing, and dye penetrant testing. If a root crack is detected, it must be repaired immediately. The repair process typically involves welding over the crack. However, it is important to address the root cause of the crack, such as poor welding technique or improper joint preparation. Otherwise, the crack is likely to reoccur.

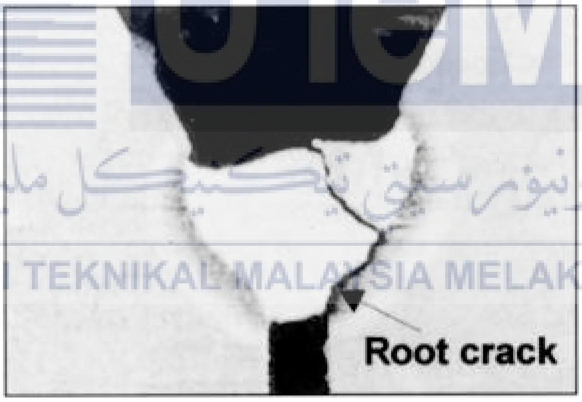


Figure 2.19: Root Crack

2.6 Standard Guidelines

To ensure the effectiveness and consistency of MPI procedures, standard guidelines have been established to provide a framework for conducting inspections. MPI works on the principle that discontinuities distort the magnetic field within a magnetized component, causing magnetic flux leakage that can be detected using iron particles applied to the surface.

There are a few standards that can used in magnetic particle inspection. Table 1 show that standard has been used in magnetic particle inspection.

Table 2.1: Standard of Magnetic Particle Inspection

Standard	**Focus**	**Description**	**Applicable Industries**
ASTM E1444	Standard Practice for Magnetic Particle Testing	Covers all aspects of MPI, including equipment, materials, surface, magnetization techniques, particle application, inspection, reporting, and qualification	All industries using MPI
ASTM E709	Standard Guide for Magnetic Particle Testing	Provides general guidance on MPI principles, applications, limitations, and safety precautions.	All industries using MPI
ISO 15614-1	Specification and qualification of welding procedures for metallic materials -	Includes MPI as a recommended NDE method for weld inspection.	Manufacturing, construction, transportation

	Welding procedure test Arc and gas welding of steels and arc welding of nickel and nickel alloys		
ASME BPVC Section V, Nondestructive Examination	Boiler and Pressure Vessel Code	Requires MPI for certain types of welds in pressure vessels and boilers.	Power generation, chemical processing, oil and gas
AWS D1.1	Structural Welding Code - Steel	Specifies acceptance criteria for MPI indications on welds.	Construction, fabrication, shipbuilding
API 5L	Specification for Line Pipe	Recommends MPI for certain grades and thicknesses of line pipe.	Oil and gas pipelines
MIL-STD-271	Nondestructive Testing Requirements for Metals	Sets MPI requirements for military equipment and materials.	Aerospace, defense

EN 13445	Non-destructive examination - Magnetic particle inspection - Part 1: Method for welds	Similar to ASTM E1444, but focuses on weld inspection.	Manufacturing, construction, transportation
JIS Z 2321	Magnetic particle inspection	Japanese standard for MPI, similar to ISO 15614-1.	Manufacturing, construction, transportation

2.6.1 Safety Precautions

As Magnetic Particle Inspection may require the use of toxic, flammable and or volatile chemicals, Safety Precautions are a mandatory, prime consideration. All Chemicals and ancillary equipment should always be used with caution and in accordance with the relevant manufacturer's instructions and Company COSHH Assessments. All Work Areas shall be adequately ventilated and remote from sources of heat, sparks and naked lights. All work shall be carried out in accordance with current Company Procedures regarding Health, Safety, Pollution and Storage etc. When using UV-A sources care should be taken to ensure that no unfiltered radiation from the source comes into direct eye contact with the operators. All UV-A Filters should be maintained in a good, clean condition. All Work Areas shall be adequately ventilated and remote from sources of heat, sparks and naked lights. All work shall be carried out in accordance with current Government Legislation regarding Health, Safety, Pollution and Storage etc.

2.6.2 Magnetizing Equipment

Magnetizing equipment is the backbone of magnetic particle inspection (MPI), a non-destructive testing (NDT) method for detecting surface and near-surface cracks, flaws, and discontinuities in ferromagnetic materials. Unless otherwise agreed the following types of A.C. magnetising equipment shall be used:

a) Electromagnetic Yokes.

b) Current Flow Equipment with prods.

c) Adjacent or threaded conductors, or coil techniques.

2.7 Application Technique

2.7.1 Field Directions and Inspection Area

The detection of an imperfection depends on the angle of its major axis with respect to the direction of the magnetic field. Figure 21 shows this for one direction of magnetization In an effort to ensure defect detection all test surfaces should be tested in at least two approximately perpendicular directions with a maximum deviation of 30° to each other. One or more magnetizing methods may be to achieve this.

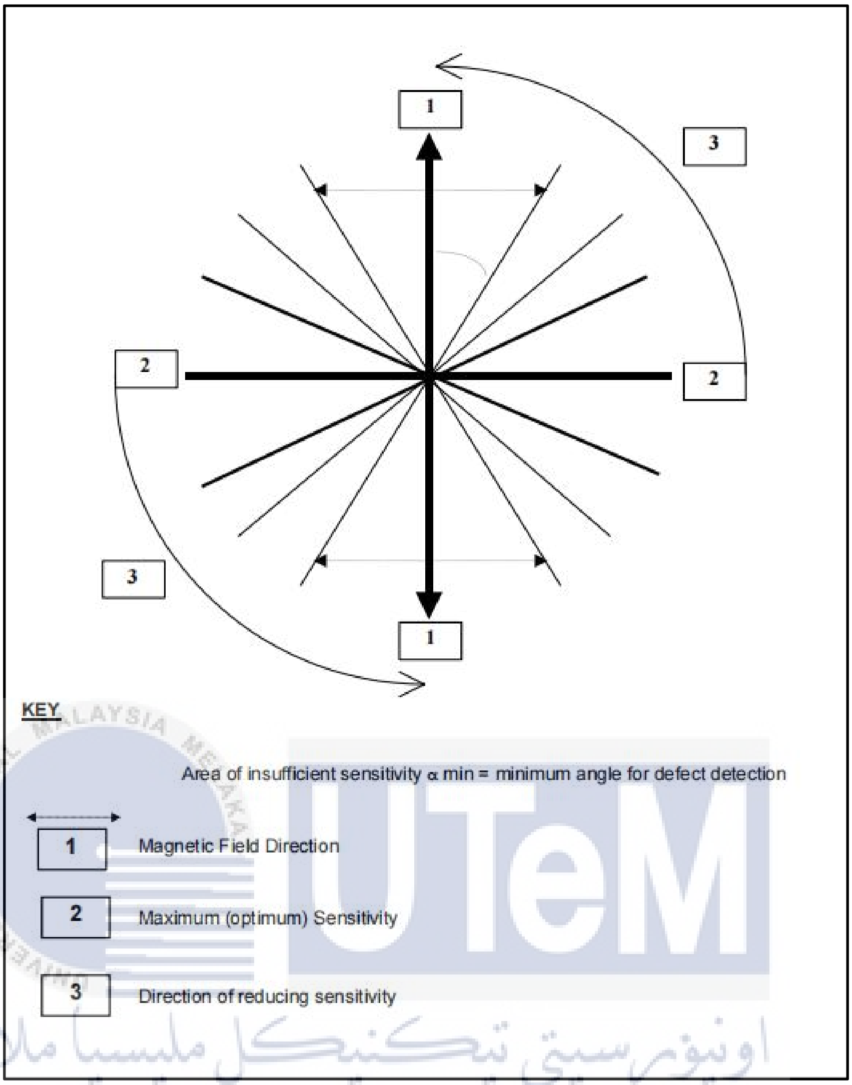


Figure 2.20 Direction of Detectable Imperfection

Single field direction magnetization shall be subject to prior contractual agreement. When using prods or electromagnets, the areas around the pole locations will not be examined due to excessive field strength. These areas must be covered by the overlapping of examination areas. This overlapping must also ensure the full coverage as required. Suitable overlap schemes are shown in Figures 22 and 23.

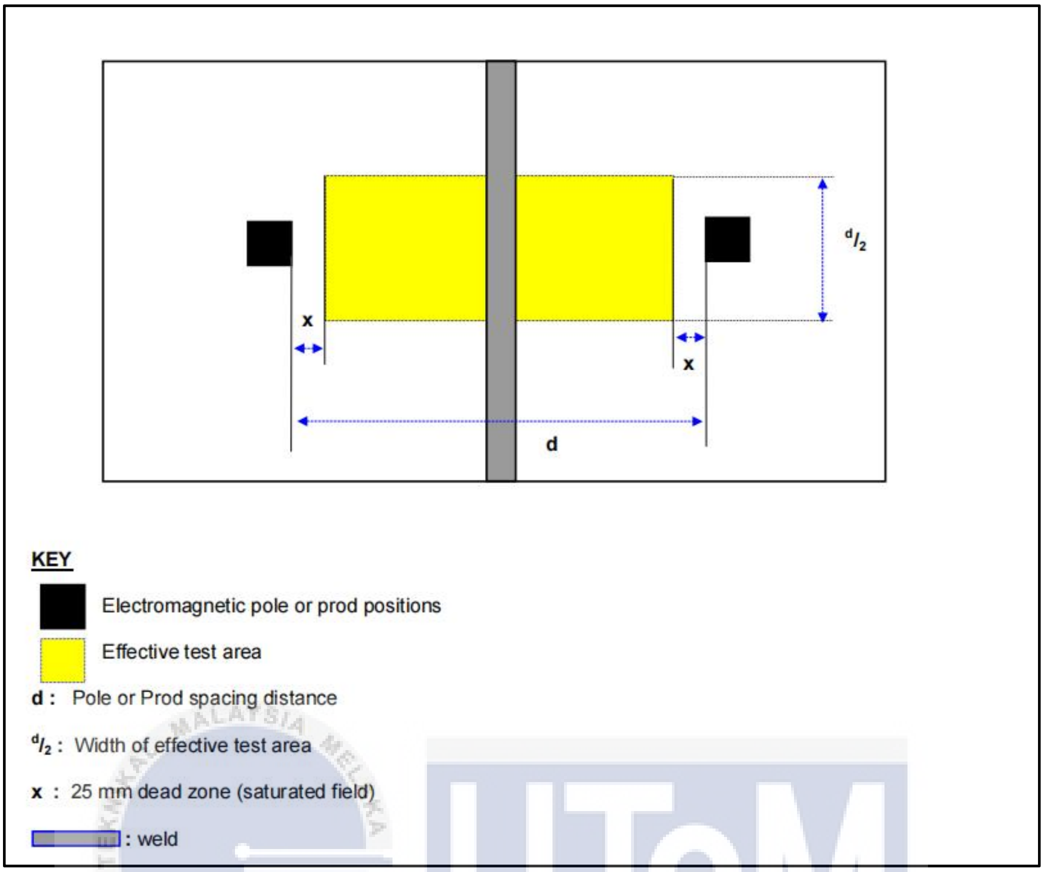


Figure 2.21: Overlap of Effective Areas

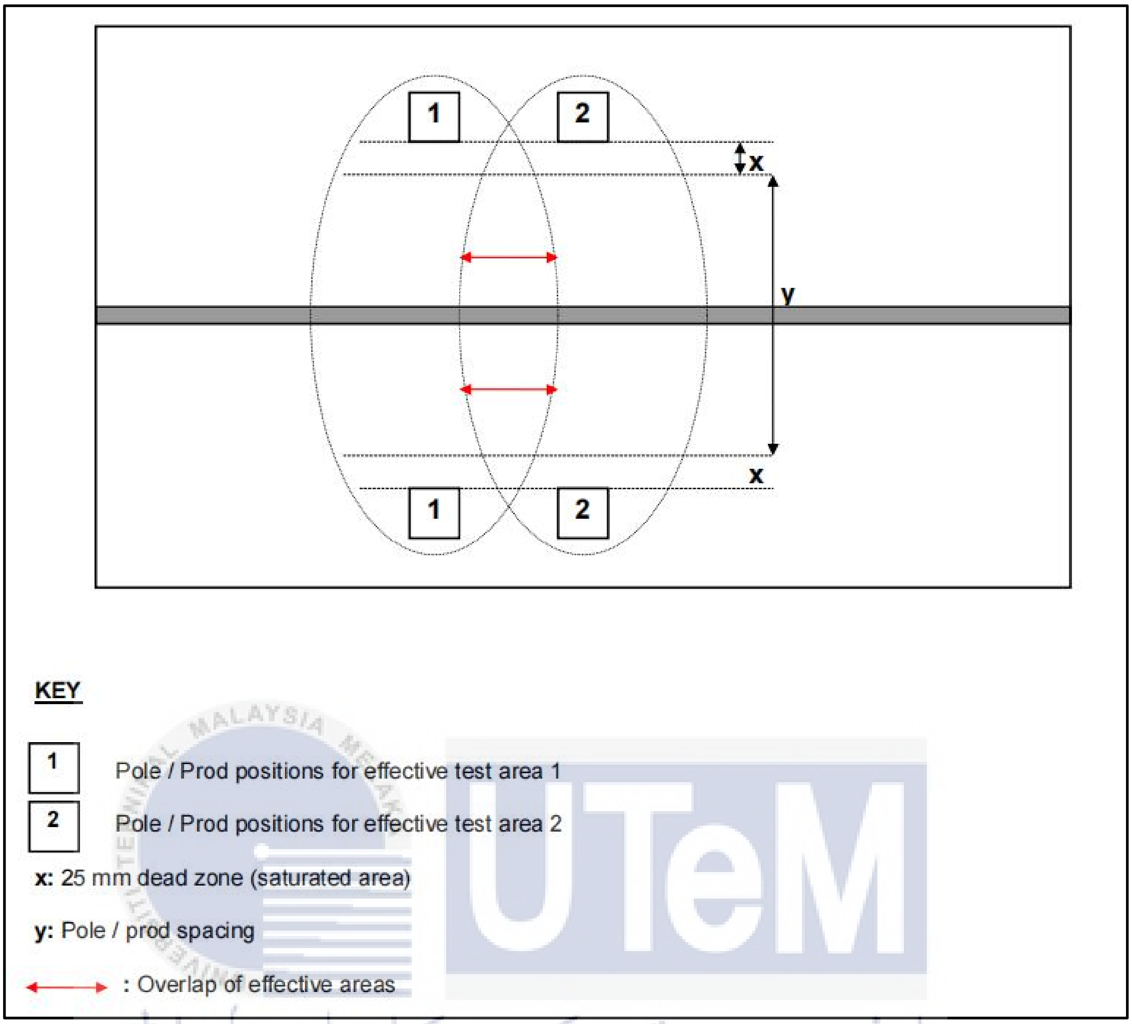


Figure 2.22: Examples of Effective Examination Areas when using Electromagnetic Yokes or Prods

2.7.2 Typical Magnetic Inspection Techniques

The applications of magnetic particle examination for common weld configurations are shown in Figures 24, 25 & 26. These should be used as a guide for the types of weld shown and for other similar types of weld set-up. The value given in the figure are guidance only.

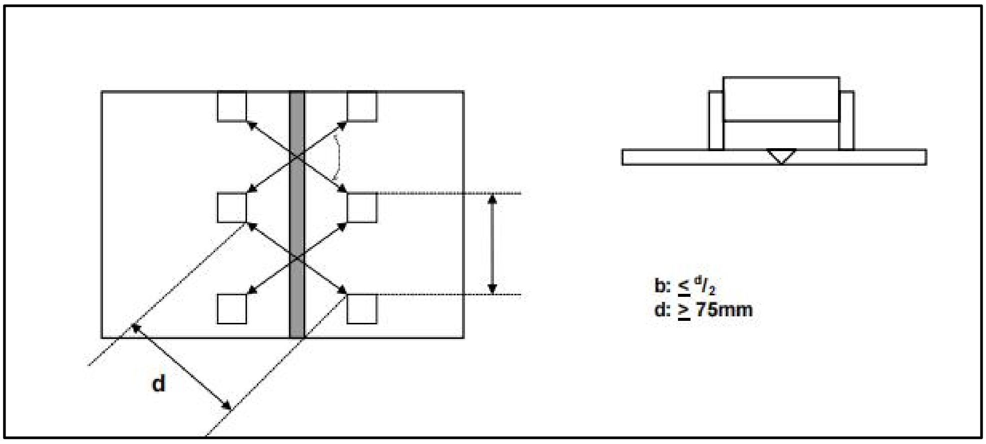


Figure 2.24: Typical Magnetization Techniques (Electromagnetic yokes)

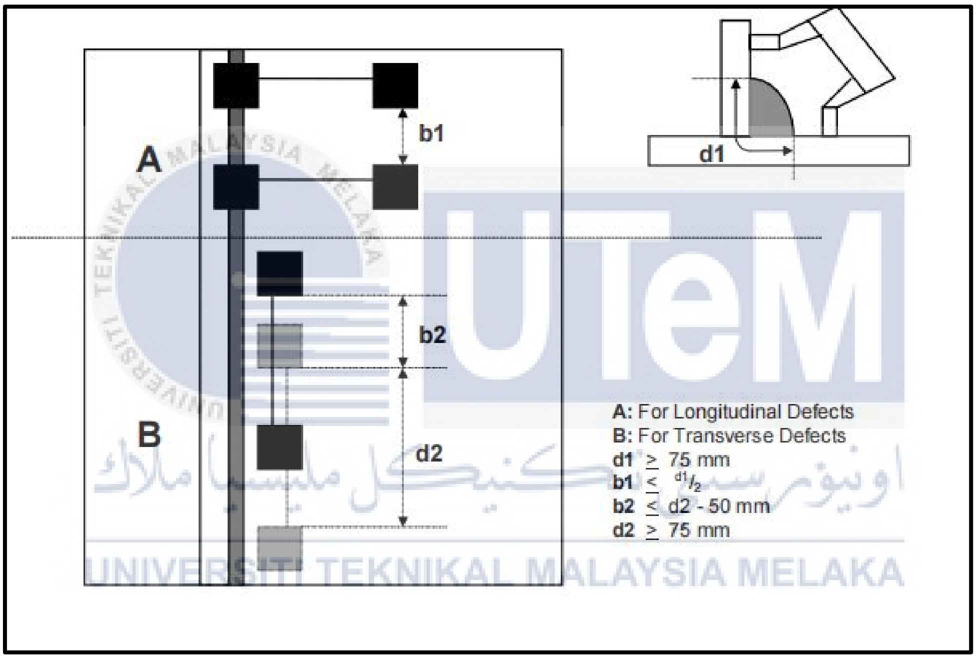


Figure 2.25:Typical Magnetization Techniques (Electromagnetic yokes)

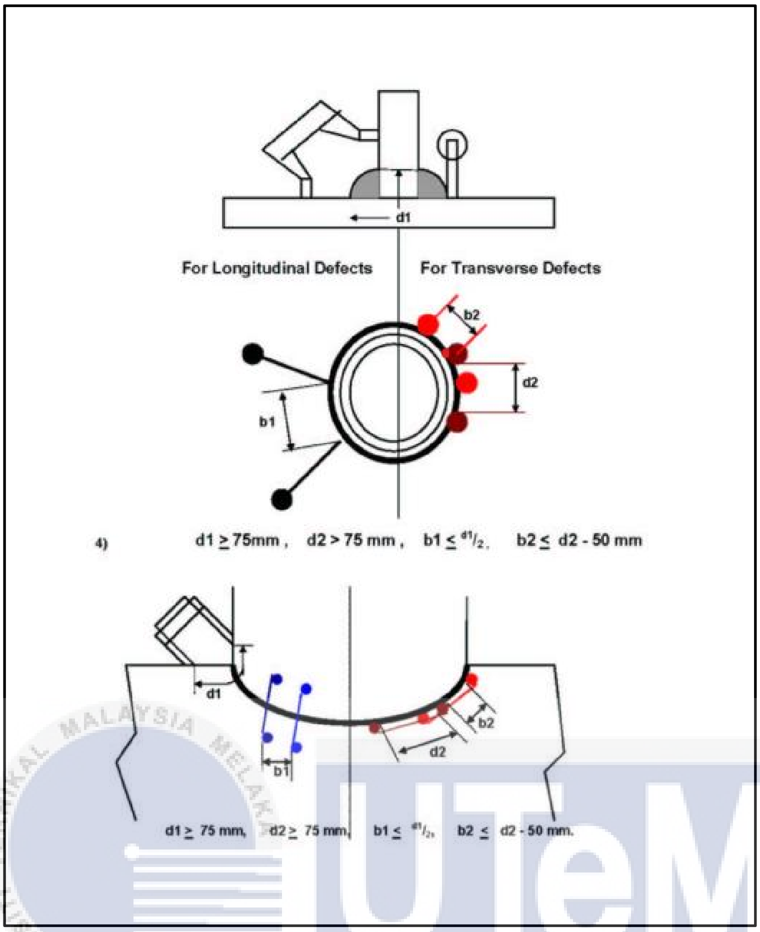


Figure 2.25: Typical Magnetization Techniques (Electromagnetic yokes)

2.8 Summary

This chapter is all about the researches that made to gain more information on non-destructive test, type of non-destructive test, welding, type of welding and type of welding cracks. So many important information was gathered which was helpful to finish this project. Firstly, the type of NDT is the main part of this project together with the type of welding crack. “A review on Non-destructive testing (NDT) techniques for low carbon steel welded joints” and “Type of welding Crack” are the two articles used to study the use of MPT to detect defects in welds made with different types of welding processes. The researcher studies the Non-Destructive Testing (NDT) methods utilized in the inspection of weld joints in low carbon steel, presenting case studies highlighting different welding defects.

Additionally, it explores welding techniques like GTAW, GMAW, and LBW, providing information on their respective parameters. Furthermore, the article delves into the topic of visual inspection testing as an economical approach to material inspection. Next, researcher also studies the various types of cracks that may arise in the welding process, specifically focusing on hot and cold cracks. Hot cracks are formed during the cooling and solidification phase of welding, resulting from reduced malleability at higher temperatures.

2.9 Summary Table

Table 2.2 Summary of previous researches findings

No.	Author	Title Project	Case Study	Advantage	Disadvantage
1	J Deepak, V Bupesh Raja, D Srikanth, H Surendran, and M Nickolas. 2020	Non-destructive testing (NDT) techniques for low carbon steel welded joints: A review and experimental study	Study on Magnetic Particle Testing	Rapid NDT method	-
2	Seyed Saman Khedmatgozar Dolati 1, Nerma Caluk 1, Armin Mehrabi 1 and Seyed Sasan Khedmatgozar Dolati (: 19 October 2021)	Non-Destructive Testing Applications for Steel Bridges	Testing on steel Bridge by using magnetic particle test	Requiring little or no surface preparation	-
3	Sandeep Kumar Dwivedia , Manish Vishwakarmab , Prof.Akhilesh Sonic	Advances and Researches on Non Destructive Testing: A Review	Method using magnetic particle test	Easier to see than the actual crack	-

4	Magdalena Rucka 6 November 2020	Special Issue: “Non-Destructive Testing of Structures”	diagnostics of structural materials and components in civil and mechanical engineering.	-	-
5	Bibby, H; Hinsley, J	Magnetic particle inspection and EMF Directive 2013/35/EU	Understanding the implications of the new EMF regulations for magnetic particle inspection	-	-
6	David Lovejoy	Methods of magnetizing components and materials for magnetic particle inspection	Electric current passes directly from its source to the tested material there is always the danger of poor contact leading to arcing and burning.		

7	Malesexdoll	Magnetic particle testing on student welding practice results based on AWS and ASME standards	Analyze the level of test clearance, the number of welding indications, and the cause of indications from the results of welding students using magnetic particle test methods based on AWS and ASME standards .	-	-
8	Aan Ardian, Khusni Syauqi, Putut Hargiyarto, Sugiyono	Analysis of student welding results with liquid penetrant and magnetic particle testing	the welding results of students in the Diploma IV Mechanical Engineering Study Program.	-	-
9	Kim Jong Duck	Magnetic Particle Spray For Magnetic Particle Testing	Analysis of student welding results with liquid penetrant and	-	-

			magnetic particle testing		
10	Kim Tae Hoo, Hong Joo Youl, Lee Su Hyun	Magnetic particle testing device	The Magnetic Particle Testing device accuracy	-	-

CHAPTER 3

METHODOLOGY

3.1 Introduction

This thesis was focused on how magnetic particle testing detect the defect on carbon steel weld. The presence of discontinuities at surface or near the surface (sub-surface) of ferromagnetic materials to be measure. The Magnetic particle testing was done on student sample by using magnetic yoke. This was done to determine and detect the defect on low carbon steel weld. This test was carried out through the magnetic yoke on low carbon steel weld sample produced by student

3.2 Flow Chart of Magnetic Particle Testing

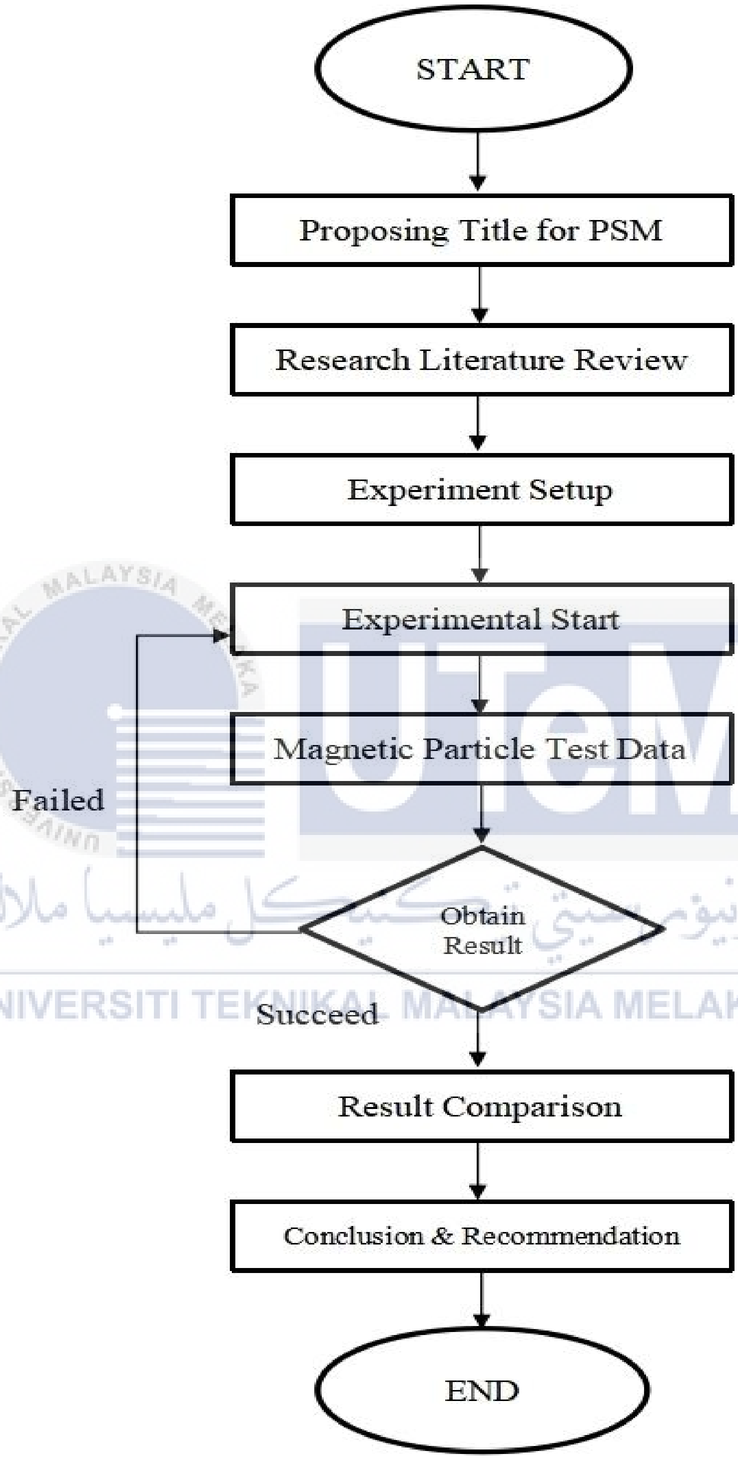


Figure 3.1: Flow Chart of Magnetic Particle Test

3.3 Research Design

This project focuses on monitoring the defect check on carbon steel weld standard block by using Magnetic Particle Testing. The experiment was carried out by measuring the length of defect from 0 as a datum and length of flaw. The magnetic particle testing was carried out to identify the relationship between magnetic particle test and crack on student welding.

3.4 Proposed Methodology

Firstly, to begin the magnetic particle testing it is crucial to determine the composition of the material and ensure that it consist of ferromagnetic element because magnetic particle testing is specifically designed for magnetic material. Once material has been identified as ferromagnetic, the next step is to apply the magnetizing technique to the material. In this project the magnetic yoke has been used.

Next, select the appropriate magnetic particle based on the type of defect. Different type of magnetic particle are available including dry particle, wet particle or fluorescent particles. The selection based on factor as example defect type, surface condition and desired visibility of indication. Lastly, evaluate and interpretation the data. The data evaluated based on their size and location.

3.5 Experimental Setup

Figure 3.2: Experimental Setup

The experimental setup for magnetic particle testing involves the arrangement of equipment, material and procedures necessary to conduct the testing process effective and efficiently. The first step in MPT is to prepare the work pieces by cleaning its surface to remove any contaminants. This is essential because MPT relies on the presence of magnetic fields, and contaminants can interfere with the magnetic field.

Once the work piece has been clean, before start the experiment the yoke must be checked by using pie gauge. The purpose to check yoke by using pie gauge is to make sure that magnetic flux were in good condition. Then, check the presence of magnetic flux on the specimen of the study material by using Magnetic field indicator meter. Following the Magnetic Particle Inspection (MPI) process, it is imperative to subject the inspected component to a demagnetization procedure. To ensure that no undesirable particles are attracted to the area or interfere with subsequent processes, it is imperative to remove any leftover magnetism that may have been created during the MPI. To guarantee the component's integrity and avoid any unintentional magnetic impacts, demagnetization is an essential post-inspection procedure. If there is a reading on study material specimen, the specimen must be demagnetized by using magnetic yoke. After that, experiment can be run by magnetized by using electromagnetic yoke. The type of magnetization used depends on the desired inspection technique. For example, longitudinal magnetization is used to detect surface flaws, while circular magnetization is used to detect subsurface flaws.

After the work piece was magnetized, a magnetic particle medium is applied to its surface. The medium contains tiny magnetic particles that are either dry or suspended in a liquid carrier. The particles are often coloured to make them stand out against the background. The magnetic particles align themselves along the magnetic field lines created by defects in the material, forming indications at the defect locations. These indications are then visible for inspection. The inspection is conducted by examining the workpiece's surface under the right lighting conditions. The indications' interpretations are essential in determining whether they represent flaws or acceptable conditions. Applicable standards or acceptance criteria are used to assess characteristics such as size, shape, and location. After the inspection, the magnetic particle medium is removed from the workpiece, and the surface is thoroughly cleaned to remove any residue or excess particles.

3.6 Equipment of Testing

The setup for magnetic particle testing involves several steps. First, identifying the material to be tested and ensuring its ferromagnetic nature, cleaning the surface to remove contaminants, determining the appropriate magnetization method, selecting the magnetizing technique and verifying magnetization, selecting and applying magnetic particles, conducting the inspection under suitable conditions, interpreting and evaluating the indications, and classifying the material based on acceptability or the need for further action. By following this comprehensive setup, effective detection of defects or indications on ferromagnetic materials can be achieved.

3.6.1 Magnetizing Equipment

The magnetizing equipment are important in creating the magnetic necessary for detection the flaws. There are two types of magnetizing component such as permanent magnet and electromagnet. Permanent magnet is a magnetic material that possesses its magnetic properties and does not required an external powered source to generate a magnetic field. Permanent magnetic are suitable for small scale inspection, spot check and situation where the power supply was limited.

Next equipment is electromagnet. Electromagnet is a magnet that created by passing the electric current through the coil or wire. Unlike a permanent magnet, an electromagnet's magnetic properties can be controlled and manipulated by varying the amount of current flowing through the coil. Electromagnets offer advantages in terms of their ability to generate stronger magnetic fields compared to permanent magnets. This attribute allows for enhanced detection capabilities, particularly for smaller or deeper defects. The adjustable magnetic field strength also facilitates the inspection of different types of materials with varying magnetic properties. electromagnets provide greater control over the magnetic field strength and direction, offering versatility in magnetic particle testing. It particularly advantageous for larger-scale applications and inspections of heavy or complex structures.

3.6.1.1 Magnetic Yoke

In this project, the type of electromagnetic magnet has been used to conduct this research. The equipment to carry out this study is the magnetic yoke. A yoke refers to the device and system that utilizes magnetic field and it consist the magnetic core and coils of wire wound around to create an electromagnet. The yoke is constructed using a ferromagnetic which help in concentrating the magnetic field. The coils of wire around the yoke are connected to a circuit that supplies the current to create magnetic field.

Figure 3.3: Magnetic Yoke

3.6.1.2 Pie Gauge

The Pie Gauge is a tool for quickly verifying the direction of magnetic flux on a surface. It is made from eight ferrous segments. The divisions serve as artificial defects that radiate out in different directions from the centre. The diameter of the gage is 3/4 to 1 inch. The divisions between the low carbon steel pie sections are to be no greater than 1/32 inch.

Figure 3.4: Pie Gauge

3.6.1.3 Magnetic Field Indicator Meter

Field indicators meter, also known as a magnetic field strength meter or gauss meter. It a device used to measure the strength and direction of magnetic field.

Figure 3.5: Gauss Meter

3.6.2 Cleaning Equipment

Cleaning equipment is a broad term that encompasses all the tools, machines, and devices used to clean surfaces. This equipment are specifically designed to remove dirt, dust, stains, debris, and other contaminants from surfaces quickly and efficiently.

3.6.2.1 FLUXO S 190

The cleaning procedure in magnetic particle testing (MPT) involves by removing contaminants from the test piece's surface to get the accurate results. It begins by preparing a clean and well-ventilated area with the necessary cleaning materials. Cleaning agent that has been used in this study is FLUXO S 190. This product acts as cleaning of penetrant excess and degreasing before start the test.

Then, dry the surface to remove moisture. Verify cleanliness by visually inspecting for any remaining contaminants. Finally, proceed with the magnetic particle testing according to the applicable procedure or standard. Remember to consult specific requirements outlined in relevant specifications or industry standards for cleaning in MPT.

Figure 3.6: FLUXO S190

3.6.2.2 Wire Brush

In this test, wire brush has been used as a cleaning medium. A wire brush is a handheld tool that uses stiff metal bristles to clean the surface. The bristles can be made of various metal, such as steel, brass or stainless steel. Wire brush are used to remove rust, paint, dirt, scale and other surface contaminants. The stiff bristles allow for use in aggressive scrubbing and scraping.

Figure 3.7: Wire Brush

3.6.3 Equipment of testing

For start the magnetic particle testing on specimen, the dry magnetic particle medium must be applied on specimen. The magnetic particle medium helps to enhance the visibility of defect or discontinuities present on the surface. The dry particle medium is applied in a powder form directly onto surface of the specimen for being inspected. In this study, a product name FLUXO 4 (white contrast) in Figure 25 has been used as dry particle.

Figure 3.8: FLUXO 4 (White Contrast)

When dry magnetic particle was applied, the liquid magnetic particle medium was sprayed on test specimen. Liquid magnetic particle is a medium that has liquid carrier, which can be either water based or liquid based. In a liquid suspension, the magnetic particles are finely divided and dispersed in the liquid carrier and creating mixture. The liquid carrier act as a vehicle for the particle and allowing them to be applied to the specimen surface more easily and uniformly. The product that has been used to run this experiment is FLUXO 3.

Figure 3.9: FLUXO 3 (Black Magnetic Ink)

3.7 Measurement

Figure 3.10: Measurement Setup

The measurement step in Magnetic Particle Testing (MPT) involves quantifying the size and distribution of defect indications formed by the magnetic particles. This step is crucial for evaluating the severity of the defect and making informed decisions. The goal is to identify and pinpoint areas on the test object where magnetic particles have gathered, revealing a potential defect. The inspection process involves a meticulous examination of the test object under suitable lighting conditions, often utilizing backlight. The presence of accumulated magnetic particles serves as a visual indicator, guiding inspectors to the specific regions of interest where defects may be present. This careful scrutiny ensures that potential flaws are identified accurately and that the inspection process is effective in revealing areas of concern.

Once a defect indication is identified, the next step involves specifying the measurement area based on the type and shape of the detected defect. The measurement area is the portion of the test object that will be assessed for the characteristics of the indication. Depending on the nature of the defect, it need to define specific parameters for measurement. This could entail considering the entire area covered by the indication, measuring a certain length or width along the defect, or assessing a specific depth if there are suspicions of subsurface defects. By defining the measurement area, inspectors ensure a focused and systematic approach to quantifying the dimensions and characteristics of the detected indications, contributing to a thorough and accurate evaluation of the test object's integrity.

When determining the most effective way to measure the dimensions of defect indications, various methods can be employed based on the characteristics of the flaw. The choice of measurement method depends on factors such as the complexity and clarity of the indications. There are two types of method in measurement which is direct measurement and image analysis. Direct measurement was the method that involve by using physical tools such as calipers, rulers and others to directly measure the length, width and depth of the defect indication. It was a straight forward approach that is particularly suitable for simple and well-defined indications. Inspectors can directly assess and quantify the dimensions of the flaw using traditional measuring instruments, ensuring a precise and tangible evaluation. Next, if cases where defect indications are complex or intricate, employing image analysis can be advantageous. This method involves capturing images of the indications under appropriate lighting conditions and magnification. Once the images are obtained, specialized software is utilized to analyze them and extract measurements such as area, perimeter, or defect depth. The analysis may be based on 3D reconstruction, providing a more comprehensive understanding of the indication's geometry. Image analysis is particularly valuable when dealing with intricate flaws that may be challenging to measure directly. In this testing session direct measurement was used for check length of defect.

Figure 3.11: Length Of Defect

After that, the meticulous recording of the specific dimensions associated with the defect indication and note down key measurements, which may include length, width, depth, area, or other relevant parameters, depending on the nature of the flaw. The measured values should be recorded with precision and clarity to ensure that the documentation provides an accurate representation of the defect's physical characteristics. This meticulous recording is crucial for establishing a reliable record of the inspection results and facilitating subsequent analyses or comparisons.

3.8 Summary

This conclusion of the methodology is it focuses on the importance of implementing the proper methods of analysis and regulatory planning in the process of materializing as efficiently. In this chapter, it is also discussed the platform of tool to be used to obtain the data which is important to the objective of executing this PSM title. This chapter presents the proposed methodology of magnetic particle testing on low carbon steel welding by student.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

After conducting a thorough examination and measurement process, the focus shifts to presenting and analyzing the findings. This crucial phase involves the interpretation of the gathered data, drawing meaningful insights, and considering the implications of the results within the broader context of the study. The results and discussion section serve as a platform to communicate the outcome of the investigation and delve into the significance of the observed outcomes. This experiment's anticipated results will be covered in this chapter, which is based on the suggested technique. The result will discuss the number of white contrast layers and defect length.

4.2 Magnetic Flux Reading

Before starting magnetic particle inspection (MPI), it's crucial to take a magnet reading. This involves using a gaussmeter or teslameter to measure the residual magnetism in the test object. An essential step in ensuring accurate and trustworthy results is taking a magnet reading prior to starting a Magnetic Particle Inspection (MPI) examination. Even in the absence of applied magnetization, residual magnetism in the material might attract magnetic particles, creating the possibility of erroneous fault indicators. The baseline magnetic state of the material can be determined by taking a magnet reading, and then modifying the inspection settings accordingly. To increase the accuracy of defect identification, this step is crucial for differentiating between real faults and residual magnetism.

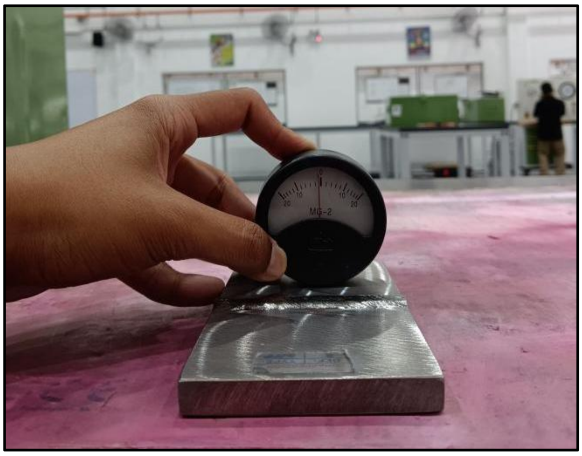


Figure 4.1: Magnetic Flux Reading on Sample

Table 4.1: Magnet Reading

Sample	Magnet Reading
Block 1	0.02
Block 2	0.05
Block 4	0.01
Block 1A	0.02
Block 1B	0.01
Block 14	0.03

The overall findings from magnet reading before do Magnetic Particle Inspection (MPI) are consistently low, ranging from 0.01 to 0.05. These values are generally within acceptable limits for most MPI applications, showing that there is very little residual magnetism within the tested blocks. Block 2 has the highest reading at 0.05, while Block 4 has the lowest reading at 0.01. Although the values are within acceptable limits, the observed variances between blocks indicate that further investigation is required. Significant discrepancies in magnetic readings between blocks may indicate material characteristics differences or divergent magnetization histories. Understanding and correcting these variances is critical to assuring the inspection process's dependability. The consistency of results across multiple blocks is critical in Magnetic Particle Inspection for reliable defect detection, and any notable differences warrant careful consideration to maintain the integrity of the inspection results.

4.3 Result

Table 4.2 Block Sample 1

Layer	Actual Length (mm)	Measurement Length (mm)	visual
1	25	28	Unclear
2	25	26	Clear
3	25	27	Very Clear

Table 4.3 Block Sample 2

Layer	Actual Length (mm)	Measurement Length (mm)	visual
1	25	26	Unclear
2	25	27	Clear
3	25	29	Very Clear

Table 4.4 Block Sample 4

Layer	Actual Length (mm)	Measurement Length (mm)	visual
1	25	27	Unclear
2	25	26	Clear
3	25	25	Very Clear

Table 4.5 Block Sample 1A

Layer	Actual Length (mm)	Measurement Length (mm)	visual
1	25	35	Unclear
2	25	33	Clear
3	25	31	Very Clear

Table 4.6 Block Sample 1B

Layer	Actual Length (mm)	Measurement Length (mm)	visual
1	25	35	Unclear
2	25	31	Clear
3	25	31	Very Clear

Table 4.7 Block Sample 14

Layer	Actual Length (mm)	Measurement Length (mm)	visual
1	25	24	Unclear
2	25	26	Clear
3	25	31	Very Clear

4.4 Graph

This graph summaries the key findings from the inspection procedure, providing a visual picture of the material's response to the applied magnetic field. crucial aspects like the shape of the graph, the use of the layer of white contrast spray, and the indications of faults as through the details.

The values on the X-axis has been measured in millimetres, for example. This axis to construct a horizontal bar graph that details the length of flaws within the block. The horizontal axis of the graph represents the length or location along the examined surface of the sample block. Moving along this axis provides a visual depiction of the material being examined, which aids in the exact length of defect. The Y-axis of the graph represents the number of layers of magnetic particle testing white-contrast spray applied during the inspection process. This value indicates the extent to which the material has been inspected for flaws and represents the depth or coverage of the inspection. Every white-contrast spray layer increases the test's sensitivity and improves its ability to identify flaws. Changes in the number of layers are visible as we proceed along the Y-axis, and these changes shed light on how comprehensive the inspection was at various points across the material.

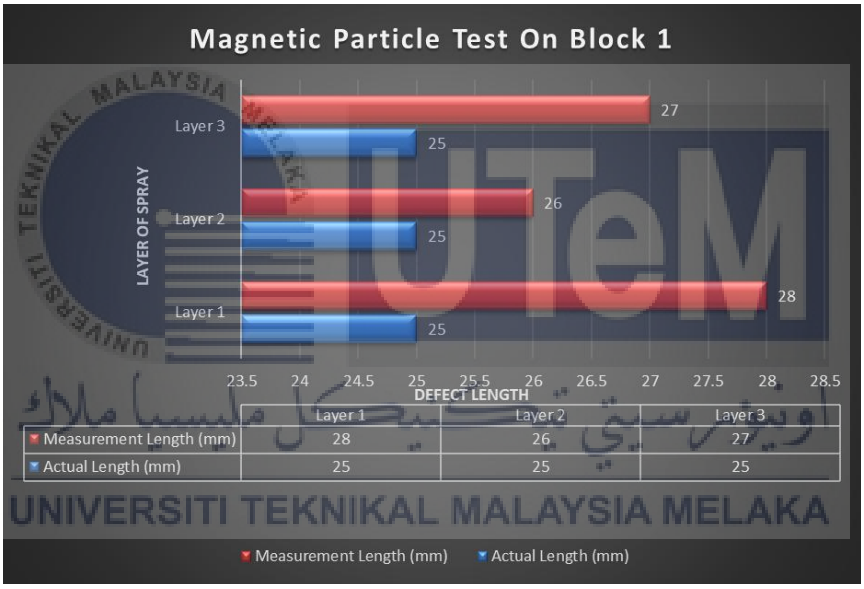
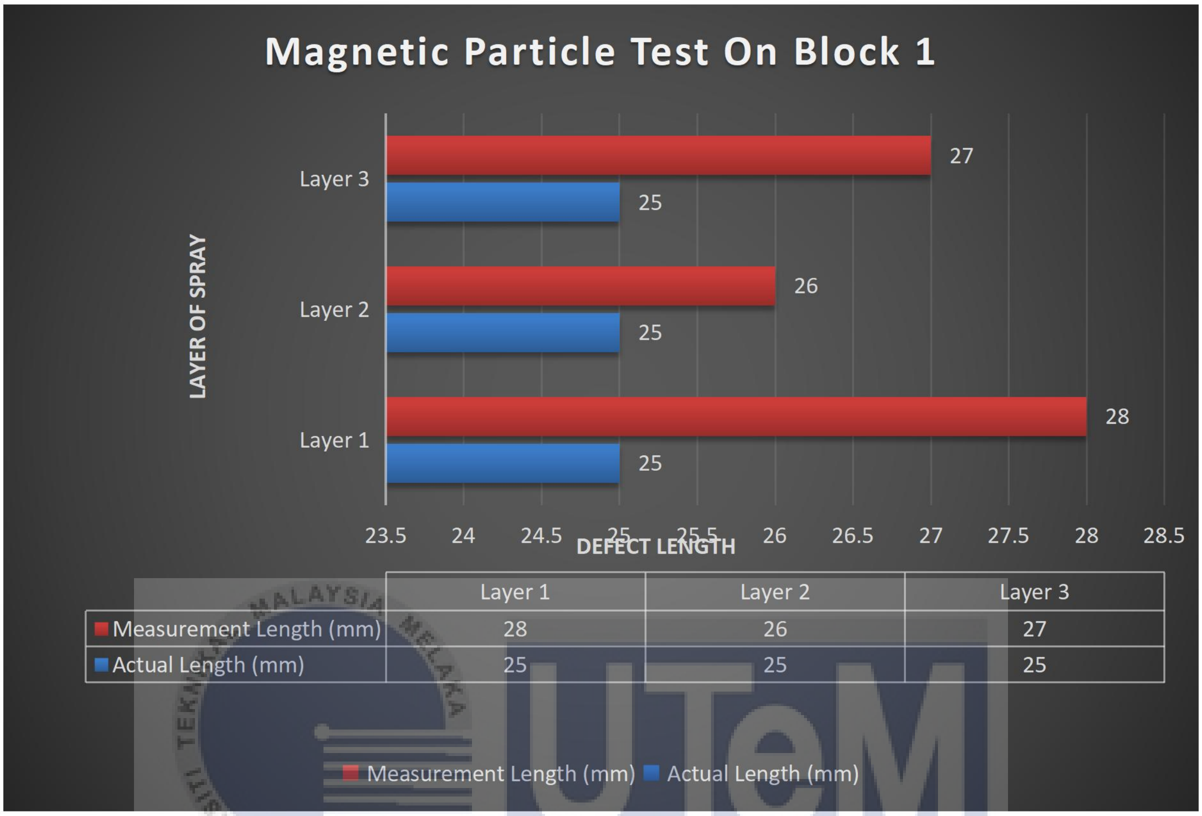


Figure 4.2: Layer of Spray vs Defect of Length Graph

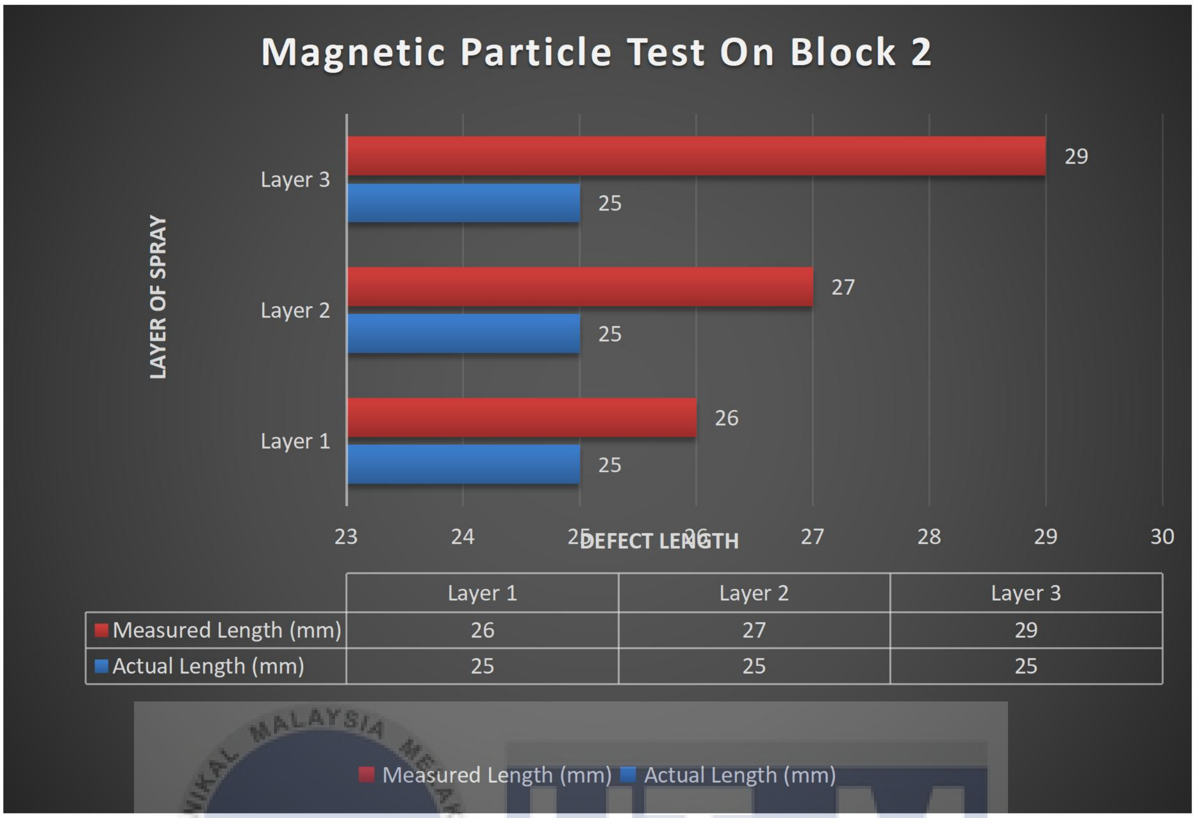
This graph with the designated axes enables us to clearly correlate the application of magnetic particle testing white-contrast spray layers with the length of flaws. It offers a thorough depiction of the inspection's depth and spatial dispersion, which helps with the analysis and interpretation of the Magnetic Particle Test findings.

4.5 Data Analysis



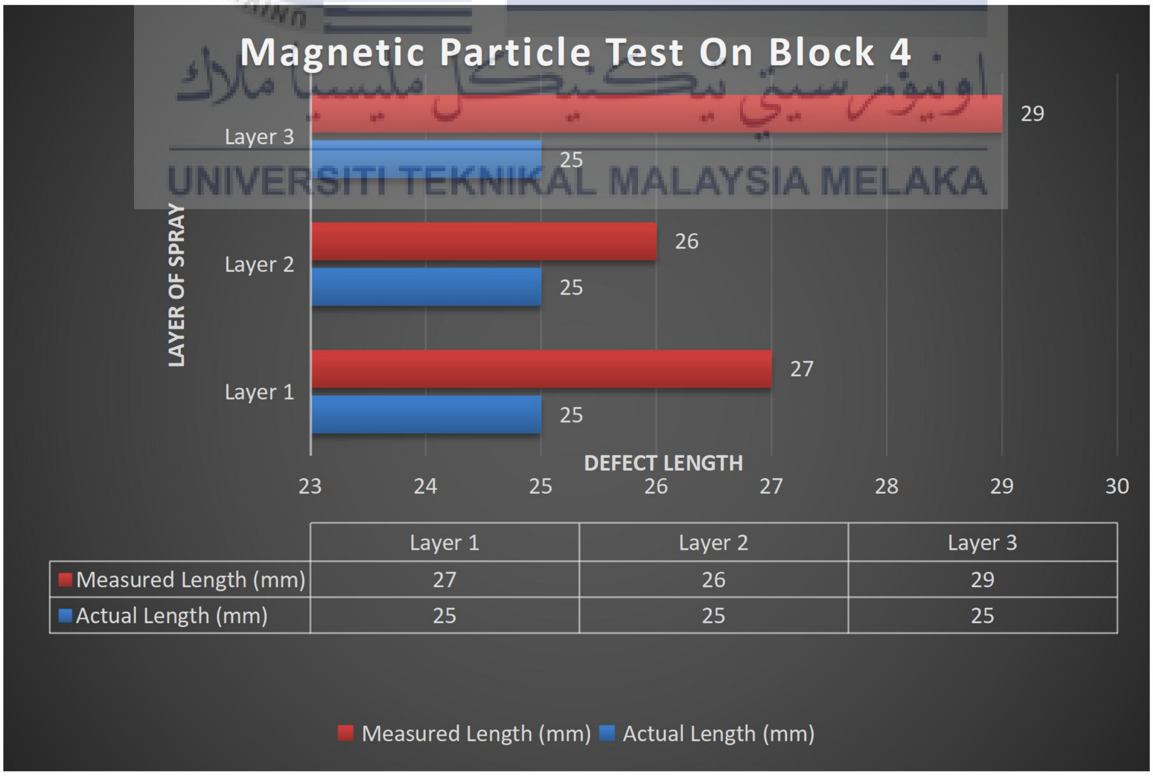
	Layer 1	Layer 2	Layer 3
🟥 Measurement Length (mm)	28	26	27
🟦 Actual Length (mm)	25	25	25

Figure 4.3: Magnetic Particle Test on Block 1



	Layer 1	Layer 2	Layer 3
🟥 Measured Length (mm)	26	27	29
🟦 Actual Length (mm)	25	25	25

Figure 4.4: Magnetic Particle Test on Block 2



	Layer 1	Layer 2	Layer 3
🟥 Measured Length (mm)	27	26	29
🟦 Actual Length (mm)	25	25	25

Figure 4.5: Magnetic Particle Test on Block 4

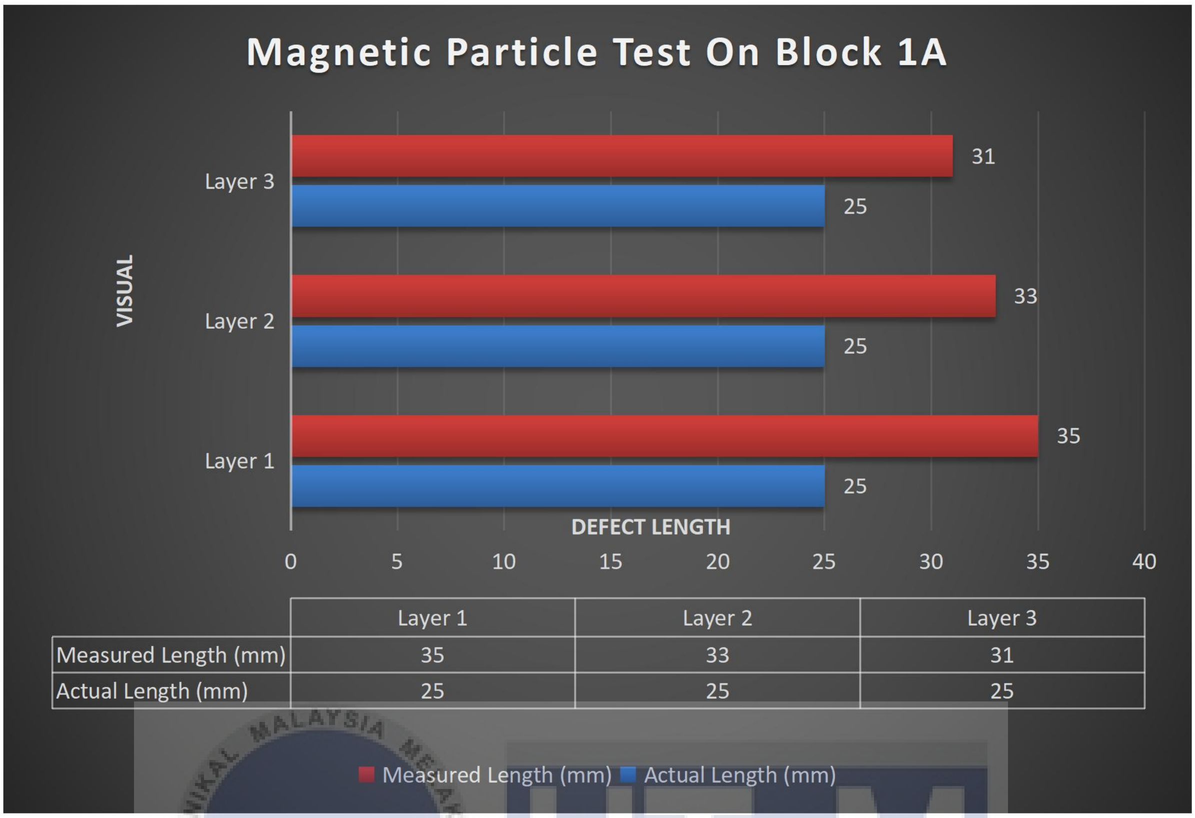
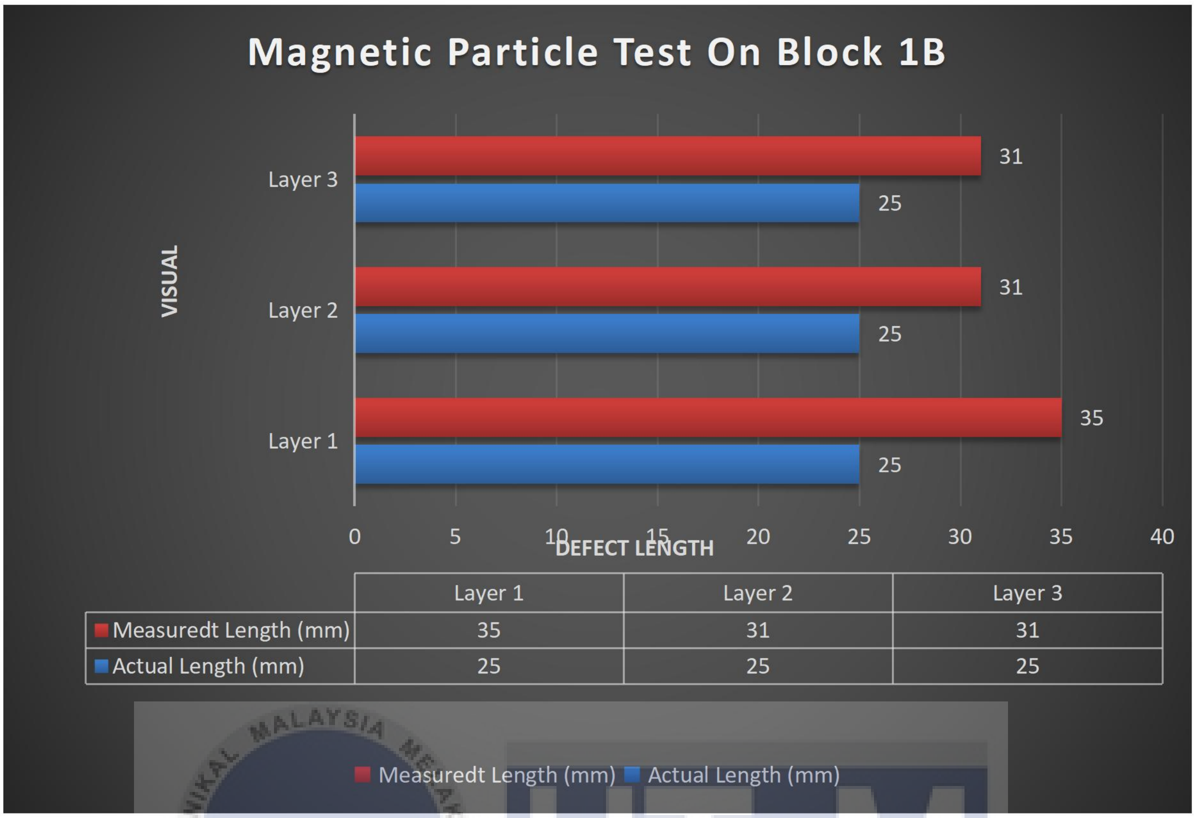


Figure 4.6: Magnetic Particle Test on Block 1A



	Layer 1	Layer 2	Layer 3
🟥 Measuredt Length (mm)	35	31	31
🟦 Actual Length (mm)	25	25	25

Figure 4.7: Magnetic Particle Test on Block 1B

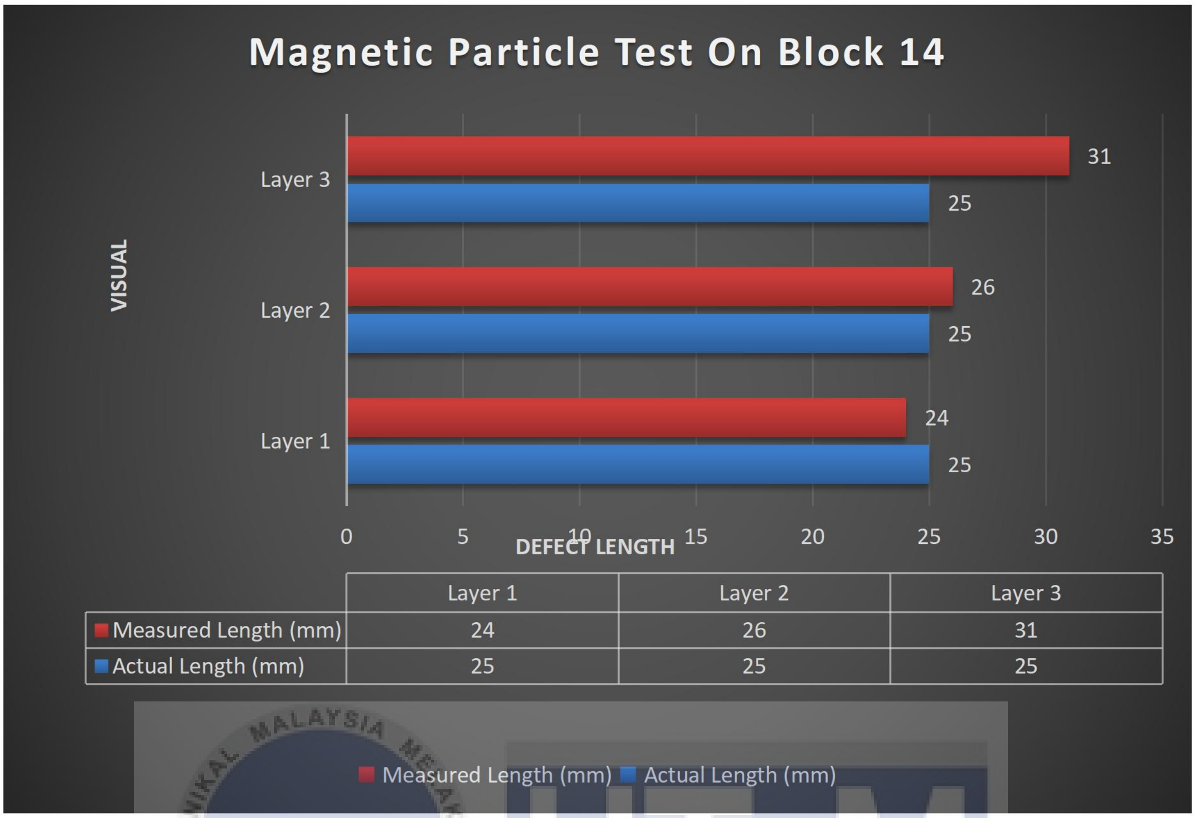


Figure 4.8: Magnetic Particle Test on Block 14

The Magnetic Particle Test results on Sample Block are displayed in the graph. The graph shows a comparison between the measured and actual lengths of flaws under three different visual clarity conditions: Very Clear, Clear, and Unclear. The blue bars show the actual lengths, and the red bars represent the measured lengths. Like an example, Figure 36 above display in all three categories, there's a slight difference between measured length and actual length. For "Very Clear," measured length is 31 mm while actual length is 25 mm. For "Clear," both measured and actual lengths are equal at 26 mm. For "Unclear," measured length is shorter at 24 mm compared to an actual length of 25 mm. That's graph shows that relationship between the length of defect and the layer of white contrast spray in MPT. The application multiple layer of white contrast spray proves advantageous. This technique offers a dual benefit by providing a thicker target for magnetic particles to accumulate and enhancing the contrast between the defect and the background material.

4.6 Defect Visibility

In nondestructive testing, such magnetic particle testing (MPT), defect visibility describes how easily flaws or discontinuities become visible and observable throughout the inspection procedure. It is concerned with the nature and specificity of signals that arise from the accumulation of magnetic particles at fault locations on a magnetized component. A component is magnetized and magnetic particles are applied to its surface during the magnetic particle testing process. These particles are drawn to regions where the material has defects or flaws that produce magnetic flux leakage.

4.6.1 Factor Affecting Visibility

In Magnetic Particle Inspection (MPI), several factors can affect the appearance of indicators. MPI is a non-destructive testing technique that is used to detect surface and near-surface flaws in ferromagnetic materials. Indication visibility is critical for proper defect identification and assessment. Some of the factors that can influence visibility in MPI are as follows:

a) The Concentration of Magnetic particle

The concentration of magnetic particles is a critical factor influencing the visibility of indications in Magnetic Particle Inspection (MPI). This parameter refers to the density of magnetic particles within the inspection material and directly affects the effectiveness of defect detection. When the particle concentration is insufficient, the resulting indications may be weak and challenging to discern, particularly in the case of smaller or subtle defects. Inadequate particle density can lead to a less pronounced response to the magnetic field, making it difficult for inspectors to identify and accurately assess the presence of defects.

Conversely, an optimal concentration of magnetic particles enhances the sensitivity of the inspection process, ensuring that indications are more distinct and clearly visible against the background material. Achieving the right balance in magnetic particle concentration is essential for maximizing the efficacy of MPI and facilitating the accurate detection of defects, thereby contributing to the overall reliability of non-destructive testing results

b) Surface Finish

One of the factors affecting the visibility of indicators in Magnetic Particle Inspection (MPI) is the surface finish of the material being examined. The surface condition is critical in determining how well magnetic particles stick to the material and travel across its surface throughout the examination process. Irregular or rough surfaces create issues in terms of particle mobility and adhesion, potentially making uniform particle dispersion problematic. Such unequal distribution may result in fewer obvious and visible signs, making it more difficult for inspectors to precisely identify faults.

Smoother surfaces create a better setting for magnetic particles to spread evenly. The enhanced particle distribution on smooth surfaces improves the clarity of indications, ensuring that flaws stand out more against the background material. In essence, the surface finish of the investigated material is critical in improving particle mobility and adhesion, directly impacting the overall visibility and efficiency of Magnetic Particle Inspection. Surface conditions must be consider during the testing process to improve the reliability of flaw detection and the quality of non-destructive testing outcomes.

c) Magnetic Field Strength

The strength of the magnetic field is a fundamental factor that exerts a significant impact on the outcomes of Magnetic Particle Inspection (MPI). This parameter directly affects the mobility and alignment of magnetic particles within the inspected material. A higher magnetic field strength has the effect of enhancing the response of magnetic particles, compelling them to accumulate more prominently around areas with defects. This increased accumulation results in clearer and more distinct indications, making the presence of defects more evident during the inspection process.

A higher magnetic field allows for a more pronounced interaction between the magnetic particles and the material, resulting in increased sensitivity to potential flaws. As a result, modifying and optimising magnetic field intensity is an important part of MPI, allowing inspectors to strike a balance that provides both successful detection and clear sight of indications. This precise control over magnetic field strength is critical for improving the accuracy and reliability of non-destructive testing results in the identification and characterization of surface and near-surface defects

4.7 Measurement Error

Measurement error refers to the discrepancy between the observed or measured value of a quantity and its true or actual value. It is a natural and inherent aspect of any measurement process and arises from various sources, leading to uncertainties in the recorded data. Measurement error can impact the accuracy and reliability of experimental results, observations, or any form of quantitative assessment. Measurement error, also known as observational error, refers to the difference between a measured quantity and its true value. It includes random errors that occur naturally during the measurement process.

Measurement error can affect the accuracy and precision of measurements. Accuracy refers to how close a measured value is to the true value, while precision relates to the consistency and reproducibility of repeated measurements. Measurement errors can lead to inaccuracies in data analysis and interpretation if not properly accounted for

Table 4.8 Measurement Error Sample 1

Layer	Actual Length (mm)	Measurement Length (mm)	Error (%)	visual
1	25	28	12	Unclear
2	25	26	4	Clear
3	25	27	8	Very Clear

The analysis begins with a layer-by-layer examination of the measurement inaccuracies. Layer 1 has a 12% inaccuracy, meaning that the measured length differs from the actual length by 12%. Layer 2 has a 4% error, whereas Layer 3 has an 8% error. These figures show the degree of error in the measurements for every layer. The analysis should take into consideration the impact of these inaccuracies on the overall correctness of the examination. A 12% mistake in Layer 1 indicates a comparatively larger discrepancy, which could indicate obstacles or issues unique to that layer. Meanwhile, the lesser inaccuracies in Layers 2 and 3 show that those layers have more precise data.

Table 4.9 Measurement Error Sample 2

Layer	Actual Length (mm)	Measurement Length (mm)	Error (%)	visual
1	25	26	4	Unclear
2	25	27	8	Clear
3	25	29	16	Very Clear

The search begins with a layer-by-layer inspection of the measurement errors. Layer 1 has a low error around 4%, indicating that there is little difference between measured and actual lengths. Layer 2 has an error around 8%, while Layer 3 has the highest error of 16%. These values provide a quantitative assessment of measurement inaccuracy for every stratum. The magnitude of the errors is essential in understanding the extent of the discrepancies. Layer 1, with a 4% error, suggests a relatively small deviation from the actual length, implying a higher level of accuracy. In contrast, the 16% error in Layer 3 signifies a more substantial difference,

Table 4.10 Measurement Error Sample 4

Layer	Actual Length (mm)	Measurement Length (mm)	Error (%)	visual
1	25	27	8	Unclear
2	25	26	4	Clear
3	25	25	0	Very Clear

The column "Error (%)" shows the percentage difference between the actual and measured lengths for each layer. Layer 1 has an 8% mistake, Layer 2 has a 4% error, and Layer 3 has a 0% error. These inaccuracies show the degree of measurement inaccuracy when compared to the real lengths. Layer 1 has an 8% error on a layer-by-layer basis, indicating a considerable departure from the actual length. Layer 2 has a 4% error, indicating a smaller discrepancy, and Layer 3 has a 0% error, showing that the measured length precisely matches the actual length.

Table 4.11 Measurement Error Sample 1A

Layer	Actual Length (mm)	Measurement Length (mm)	Error (%)	visual
1	25	35	40	Unclear
2	25	33	32	Clear
3	25	31	24	Very Clear

Layer 1 has a 40% error, Layer 2 has a 32% error, and Layer 3 has a 24% error. These errors deLayer 1 has a 40% error, meaning a large differences from the actual length. Layer 2 has a 32% error, indicating a significant difference, while Layer 3 has a 24% error, indicating less deviation.monstrate the degree of measurement inaccuracy when compared to the actual lengths.

Table 4.12 Measurement Error Sample 1B

Layer	Actual Length (mm)	Measurement Length (mm)	Error (%)	visual
1	25	35	40	Unclear
2	25	31	24	Clear
3	25	31	24	Very Clear

Layer 1 has a 40% an error, Layer 2 has a 24% error, while Layer 3 has a 24% error. These errors show the degree of measurement inaccuracy when compared to the actual lengths. Layer 1 has a 40% error, suggesting a large differences from the actual length. Layers 2 and 3 both show a 24% error, indicating a significant yet consistent variance. Although errors are the same percentage-wise for Layers 2 and 3, the absolute numbers may differ, which should be taken into consideration in the analysis.

Table 4.13 Measurement Error Sample 14

Layer	Actual Length (mm)	Measurement Length (mm)	Error (%)	visual
1	25	24	4	Unclear
2	25	26	4	Clear
3	25	31	24	Very Clear

The error for Layer 1 is shown as "N/A," indicating that the measurement error could not be determined. Layer 2 has a 4% error, and Layer 3 contains a 24% error. These errors show the degree of measurement inaccuracy when compared to the real lengths. Layer 1 shows a "N/A" error, indicating that the calculation was unable to be completed. This could be because of a lack of data or a problem with the measurement method. Layer 2 has a 4% mistake, indicating a minor difference, while Layer 3 has a 24% error, indicating a more significant difference.

As Conclusion, Table 1 shows varying errors across layers (4%, 8%, 16%), with a notable correlation between visual clarity and error magnitude. To enhance accuracy, potential causes and quality control measures need consideration. Table 2 displays decreasing errors from Layer 1 to Layer 3 (40%, 32%, 24%) with a consistent correlation between visual clarity and error. In-depth investigation into potential causes, quality control, and tolerances is crucial. Table 3 exhibits decreasing errors (8%, 4%, 0%) alongside a clear correlation with visual clarity. Consideration of potential causes, quality control measures, and tolerances is highlighted. Table 4 demonstrates varying errors (40%, 24%, 24%) with a visual clarity correlation. Thorough investigation into potential causes, quality control, and tolerances is warranted. Table 5 introduces uncertainty in Layer 1 (N/A error), emphasizing the need for exploration of potential causes, quality control, and tolerances.

4.8 Field Testing

Field testing, in the context of Magnetic Particle Inspection (MPI), refers to the use of this non-destructive testing technology in real-world settings or conditions. After the test on the sample block is done, there are some inputs that can be used for the test on the student sample. Among the inputs that can be used for student samples are the amount of white contrast layer, magnetic particle concentration and orientation between magnetic field.

Based on figure 4.9 below, that is welding sample student that has been inspect by using Magnetic Particle Inspection (MPI). The purpose of this project is mainly to confirm the quality of the product because the previous record activities prepared by student there is no quality performance regarding the welded part. Outcomes from this research has been presented. Some of the student samples inspected appear to be many defect which can be concluded the quality of the product not in a good specification.

Figure 4.9: Welding Sample Student

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

Magnetic Particle Inspection (MPI) is an important non-destructive testing technique for detecting surface and near-surface flaws in ferromagnetic materials. Several significant aspects influence the success of an MPI inspection, each of which contributes to the overall conclusion drawn from the research. Another important consideration is the application of a white contrast spray. This layer improves defect visibility by providing a contrast to the magnetic particles. Regularity and thickness of the contrast layer had a major impact on the quality of the inspection. For maximum defect visibility, a consistent correct application of the white contrast spray, combined with proper surface preparation, is required to get the best result.The precision of an MPI inspection depends on accurate measurement of defect size and depth. Significant measurement errors could compromise the trustworthiness of inspection results, emphasizing the significance of regular calibration of equipment as well as thorough training for inspection personnel.The magnetic flux reading, indicating the strength and distribution of the magnetic field, was a valuable parameter in MPI .

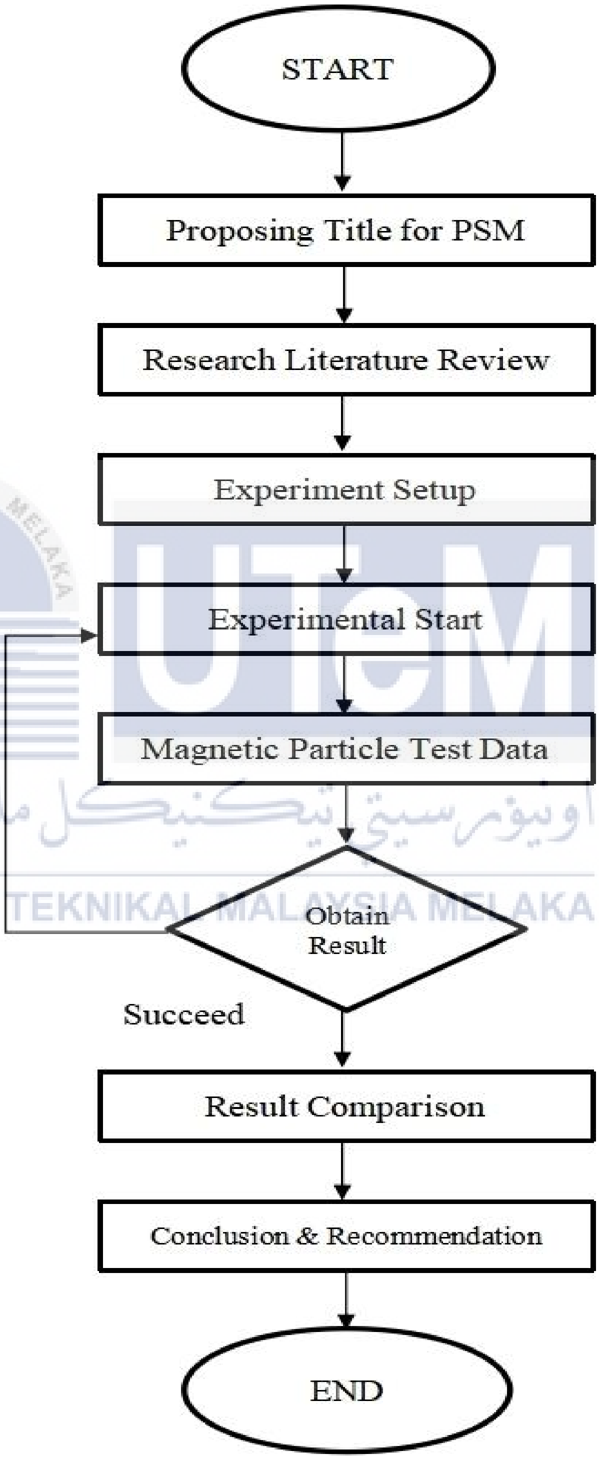
Magnetic flux values must be calibrated and monitored on a regular basis to maintain consistency and reliability. For a complete assessment of the material's integrity, these readings should be interpreted in conjunction with visual checks.Defect visibility, which is affected by factors such as defect size, shape, orientation, and surface conditions, is an important consideration. Some defects may be inherently more difficult to detect than others. A thorough examination, incorporating multiple angles and orientations, is recommended to improve the likelihood of detecting various defect types. It is important to understand the method's limitations for specific defect characteristics.

5.2 Recommendation

For recommendation for this project is conduct the MPI in controlled environments whenever possible. The ambient conditions, including harsh weather, excessive humidity, or extreme temperatures, can significantly impact the inspection process. In such conditions, the application of contrast agents may be compromised, leading to uneven coverage and reduced defect visibility. Beside that, the behaviour of magnetic particles can be influenced by environmental factors too. To improve this Magnetic Particle Inspection outcomes, it recommend to implement control measures such as temperature regulation and protection from environmental elements.Conducting inspections in controlled environments helps maintain consistent inspection conditions, improves the accuracy of defect identification, and contributes to the overall quality and reliability of the inspection process.

APPENDICES

APPENDIX A Flow Chart of the Project



APPENDIX B Gantt Chart of PSM 1

Activities	Status	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Supervisor and Title Registration	Plan	🟩	🟩	🟩											
	Actual	🟦	🟦	🟦											
Project Explanation and Briefing by Supervisor	Plan	🟩	🟩	🟩											
	Actual		🟦	🟦	🟦										
Defining Problem Statement, Objective and Project Scope	Plan			🟩	🟩										
	Actual			🟦	🟦										
Drafting and Writing Chapter 1	Plan	🟩	🟩	🟩	🟩										
	Actual			🟦	🟦	🟦	🟦								
Defining and Finding Source for Literature Review	Plan			🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
	Actual				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Drafting and Writing Chapter 2	Plan					🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩		
	Actual				🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦			
Defining Methodology on How to Conduct the MPI Test	Plan							🟩	🟩						
	Actual							🟦	🟦	🟦					
Drafting and Writing Chapter 3	Plan							🟩	🟩	🟩	🟩	🟩	🟩		
	Actual								🟦	🟦	🟦	🟦	🟦	🟦	
Revising Report Chapter 1,2 and 3 before Submission	Plan													🟩	🟩
	Actual													🟦	🟦

APPENDIX C Gantt Chart of PSM 1

Activities	Status	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Briefing with Supervisor	Plan	🟩	🟩	🟩											
	Actual		🟦	🟦	🟦										
Run Test on Carbon Steel Weld sample Block	Plan					🟩	🟩	🟩	🟩	🟩					
	Actual								🟦	🟦	🟦				
Field Testing to the student sample	Plan									🟩	🟩				
	Actual									🟦	🟦				
Discussion with the Supervisor	Plan										🟩				
	Actual										🟦	🟦	🟦		
Report Writing and Submission	Plan	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩		
	Actual	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		
Poster Preparation and Presentation	Plan													🟩	🟩
	Actual													🟦	🟦

REFERENCE

ASNT (2009)

-Non Destructive Test Handbook, Volume 3: Magnetic particle Inspection

Aan Ardian, Khusni Syauqi, Putut Hargiyarto, Sugiyono

-Analysis of student welding results with liquid penetrant and magnetic particle testing

Bibby, H; Hinsley, J

-Magnetic particle inspection and EMF Directive 2013/35/EU

Charles J. Hellier (2009)

-Magnetic Particle and Liquid Penetrant Testing

Club Technical, "Casting Definition, Advantages, Limitations, Defects, Types," 2019.

David Lovejoy

-Methods of magnetizing components and materials for magnetic particle inspection

Gui Yun Tian

-Nondestructive Testing and Evaluation

https://www.twi-global.com/technical-knowledge/faqs/ultrasonic-testing

https://www.sciencedirect.com/science/article/pii/S2214785320392476

https://www.weldinghandbook.com/types-of-welding/

https://www.nationalboard.org/index.aspx?pageID=164&ID=377

https://www.flyability.com/magnetic-particle-inspection

https://www.thefabricator.com/thefabricator/article/testingmeasuring/how-to-prevent-delays-in-weld-nondestructive-testing-ndt

https://www.fushunspecialsteel.com/magnetic-particle-inspection-mpi/

J Deepak, V Bupesh Raja, D Srikanth, H Surendran, and M Nickolas. 2020.

- Non-destructive testing (NDT) techniques for low carbon steel welded joints: A review and experimental study

Kim Jong Duck

-Magnetic Particle Spray For Magnetic Particle Testing

Kim Tae Hoo, Hong Joo Youl, Lee Su Hyun

-Magnetic particle testing device

M. P. Blodgett, P. Nagy *(2019)*

-"Review of Magnetic Particle Inspection Research for Quantitative Reliability"

Magdalena Rucka (6 November 2020)

-Special Issue: "Non-Destructive Testing of Structures"

Ma, Tao; Sun, Zhenguo; Chen, Qiang (September 2018)

-Study on crack features in images of fluorescent magnetic particle inspection for railway wheelsets

Malesexdoll
Magnetic particle testing on student welding practice results based on AWS and ASME standards
Seyed Saman Khedmatgozar Dolati 1, Nerma Caluk 1, Armin Mehrabi 1 and Seyed Sasan Khedmatgozar Dolati (19 October 2021)

-Non-Destructive Testing Applications for Steel Bridges

Sandeep Kumar Dwivedia , Manish Vishwakarmab , Prof.Akhilesh Sonic

-Advances and Researches on Non Destructive Testing: A Review

Zhang Shuting, Long Huijin, Jiang Bin, Lu Guojiang, Jiang Kecheng, Zhong Zhiyong, Ruan Chenqing, Wang Cuiping
-Magnetic particle detection method