

## EFFECT OF PULSE ON THE SURFACE PROPERTIES OF MILD STEEL USING TIG TORCH PROCESS



# BACHELOR OF MECHANICAL AND MANUFACTURING ENGINEERING TECHNOLOGY WITH HONOURS

2023



Faculty of Mechanical and Manufacturing Engineering Technology



Muhammad Abu Huzaifah Bin Ahmad Zubir

**Bachelor of Mechanical And Manufacturing Engineering Technology with Honours** 

2023

## EFFECT OF PULSE ON THE SURFACE PROPERTIES OF MILD STEEL USING TIG TORCH PROCESS

## MUHAMMAD ABU HUZAIFAH BIN AHMAD ZUBIR





Faculty of Mechanical and Manufacturing Engineering Technology

## UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

#### **DECLARATION**

I declare that this Choose an item. entitled "Effects Of Pulse On The Surface Properties Of Mild Steel Using TIG Torch Process" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



#### 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 with Honours.



#### DEDICATION

This research project is decided to all my family members and friends. To my beloved parents, Ahmad Zubir Bin Hanafi and Zarina Binti Kassim, thank you for all the affection, trust and moral support whenever any challenges get tougher. Their unconditional love makes me trying the best for this research project. All my fellow friends are deserved to be partnership in my success of the project. They have provided me a lot of miscellaneous aids when things go wrong. To my honor supervisor, Ir. Ts. Dr. Lailatul Harina Binti Paijan, thank you for willing to teach and assist me with with the problems I faced throughout my

project.

اونيۈم سيتي تيڪنيڪل مليسيا ملاك UNIVERSITI TEKNIKAL MALAYSIA MELAKA

#### ABSTRACT

Mild steel is a type of steel that is low in carbon content and has a relatively low tensile strength. It is also known as low-carbon steel or plain-carbon steel. This steel is widely used in various industries such as production of buildings, bridges, and other infrastructure. It is also used in the manufacturing of machinery and equipment, as well as in the automotive and aerospace industries. However, this material experienced wear and hardness failure during service. Therefore, a new development of surface modification has been introduced in this work by depositing the alumina powder into mild steel via TIG torch melting techniques. The process parameter for this works consists of pulse in the range from 1 to 10 pulse per second (PPS) and current from 80 A to 100 A. The hard surface layer produced from the surface modification was characterized using optical microscope, scanning electron microscopy (SEM), hardness tester, X-ray diffraction (XRD) and surface roughness tester. Based on the experimental results, it was found that the hard surface layer produced maximum hardness of 95.63 HRB with melt layer of 4.1 mm in sample processed under pulse of 1 PPS. The development of martensite structure contributes to the increment of hardness properties. It was found that the intermetallic compound of FeAl and FeO<sub>3</sub> were detected from XRD result which indicating the existence of alumina particles in the hard surface layer. In overall, it can be demonstrated that this surface modification is capable to produce hard surface layer on mild steel with higher hardness and better surface roughness properties which can be used for wear application in various industries.

رسيتي تيكنيكل مليسيا ملا UNIVERSITI TEKNIKAL MALAYSIA MELAKA

#### ABSTRAK

Keluli lembut ialah sejenis keluli yang rendah kandungan karbon dan mempunyai kekuatan tegangan yang agak rendah. Ia juga dikenali sebagai keluli karbon rendah atau keluli karbon biasa. Keluli ini digunakan secara meluas dalam pelbagai industri seperti pengeluaran bangunan, jambatan, dan infrastruktur lain. Ia juga digunakan dalam pembuatan mesin dan peralatan, serta dalam industri automotif dan aeroangkasa. Walau bagaimanapun, bahan ini mengalami kegagalan haus dan kekerasan semasa perkhidmatan. Oleh itu, satu perkembangan baru pengubahsuaian permukaan telah diperkenalkan dalam kerja ini dengan mendepositkan serbuk alumina ke dalam keluli lembut melalui teknik peleburan obor TIG. Parameter proses untuk kerja-kerja ini terdiri daripada nadi dalam julat 1 hingga 10 nadi sesaat (PPS) dan arus dari 80 A hingga 100 A. Lapisan permukaan keras yang dihasilkan daripada pengubahsuaian permukaan telah dicirikan menggunakan mikroskop optik, mikroskop elektron pengimbasan (SEM), penguji kekerasan, pembelauan sinar-X (XRD) dan penguji kekasaran permukaan. Berdasarkan keputusan eksperimen, didapati lapisan permukaan keras menghasilkan kekerasan maksimum 95.63 HRB dengan lapisan leburan 4.1 mm dalam sampel yang diproses di bawah nadi 1 PPS. Perkembangan struktur martensit menyumbang kepada peningkatan sifat kekerasan. Didapati sebatian antara logam FeAl dan FeO<sub>3</sub> dikesan daripada keputusan XRD yang menunjukkan kewujudan zarah alumina dalam lapisan permukaan keras. Secara keseluruhannya, boleh ditunjukkan bahawa pengubahsuaian permukaan ini mampu menghasilkan lapisan permukaan keras pada keluli lembut dengan kekerasan yang lebih tinggi dan sifat kekasaran permukaan yang lebih baik yang boleh digunakan untuk aplikasi haus dalam pelbagai industri. a. Su Solumi all au a

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

#### 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 giving me the chance to complete my research project "EEFECT OF PULSE ON THE SURFACE PROPERIES OF MILD STEEL USING TIG TORCH PROCESS".

Completing any sort of project successfully necessitates the assistance of a lot of individuals. I also got assistance in the development of this study from a variety of sources. There is now a little effort to express my heartfelt thanks to that wonderful individual.

I would like to express my heartfelt thanks to my supervisor at Universiti Teknikal Malaysia Melaka (UTeM), Ir Ts Dr Lailatul Harina Binti Paijan. This research would have been less effective if it hadn't been for his kind supervision and excellent instruction. His supervision and direction were vital in ensuring that this report was produced flawlessly at every stage of the project.

My deepest gratitude is expressed to my beloved mother, Zarina Binti Kassim and my belovedfather, Ahmad Zubir Bin Hanafi and my family members and friends.

a.

Thank you very much.

## TABLE OF CONTENTS

DEC	LARATION	
APP	ROVAL	
DED	ICATION	
ABS'	TRACT	i
ABS'	TRAK	ii
ACK	NOWLEDGEMENTS	iii
ТАВ	LE OF CONTENTS	iv
LIST	T OF TABLES	vi
LIST	T OF FIGURES	vii
LIST	TOF SYMBOLS AND ABBREVIATIONS	iv
1 161	CLARATION PROVAL PROVAL DICATION STRACT i STRACT i STRAK ii KNOWLEDGEMENTS ii BLE OF CONTENTS iv T OF TABLES vi T OF FIGURES vi T OF FIGURES vi T OF SYMBOLS AND ABBREVIATIONS vii T OF APPENDICES x APTER 1 INTRODUCTION 11 Background study Problem Statement Research Objective ITTENNIKAL MALAY SIA MELAKA 12 Scope of Research 13 APTER 2 LITERATURE REVIEW 14 Steel 14 Types of steel 14 2.2.1 Carbon steel 14 2.3.2 Laser cladding 114 Surface modification using melting techniques 17 2.3.1 TIG torch 18 2.3.2 Laser cladding 19 Electrical arc welding (SMAW) 21 2.4.3 Metal inert gas (MIG) 22 TIG torch process with pulse per second (PPS) 23 2.5.1 Advantages and disadvantages 24 Ceramic powder preplacement for surface modification 25 2.6.1 Silicon carbide 25	
	OF APPENDICES	X
СНА	PTER 1 INTRODUCTION	11
1.1	Background study	11
1.2	Problem Statement	12
1.3	Research Objective TI TEKNIKAL MALAYSIA MELAKA	12
1.4	Scope of Research	13
CHA	APTER 2 LITERATURE REVIEW	14
2.1	Steel	14
2.2	Types of steel	14
• •	2.2.1 Carbon steel	14
2.3	Surface modification using melting techniques	17
	2.3.1 TIG torch	18
	2.3.2 Laser cladding	18
	2.3.3 Ion implanting	18
2.4	2.3.4 Thermal spraying	19
2.4	Electrical arc welding	20
	2.4.1  IIG torch	20
	2.4.2 Shielded metal arc weiding (SMAW)	21
25	2.4.5 INITIAL INERT GAS (MIG)	22
2.3	2.5.1 Advantages and disc desertages	23
26	2.5.1 Advantages and disadvantages	24
2.6	Ceramic powder preplacement for surface modification	25
	2.0.1 Silicon carbide	25

	2.6.2 Alumina powder	26	
	2.6.3 Titanium carbide	27	
	2.6.4 Tungsten carbide	28	
2.7	Characterization of surface modified steel	29	
	2.7.1 Rockwell hardness test	29	
	2.7.2 Microstructural and morphological characterization	30	
	2.7.3 X-ray diffraction (XRD) analysis	31	
	2.7.4 Surface profilometer	31	
CHAI	PTER 3	33	
3.1	Introduction	33	
3.2	Flow chart of the project	33	
3.3	Sample preparation	35	
3.4	Alumina powder preplacement		
	3.4.1 Sample and powder preparation	36	
	3.4.2 Alumina powder preplacement on the surface specimen	37	
3.5	Surface modification by TIG torch	37	
3.6	Sample preparation for metallography and Rockwell hardness measurement	39	
3.7	Optical microscope (OM)	41	
3.8	X-ray Diffraction	41	
3.9	Microstructure examination	42	
3.10	Rockwell hardness measurement	43	
3.11	Surface roughness measurement	44	
CHAF	PTER 4	45	
4.1	Introduction	45	
4.2	Microstructure on mild steel before coating with alumina powder		
4.3	Optical microscope		
4.4	Scanning electron microscopy (SEM) MALAYSIA MELAKA		
4.5	X-ray Difrraction		
4.6	Rockwell hardness test before coating 5		
	4.6.1 Rockwell hardness test after coating	56	
4.7	Profilometer	60	
4.8	Melt depth	63	
CHAI	PTER 5	65	
5.1	Conclusion	65	
5.2	Recommendation	66	
5.3	Project potential	67	
REFERENCES			
APPE	NDICES	72	

## LIST OF TABLES

TABLE	TITLE	PAGE
Table 2.1 properties of carb	oon steel by (Singh, 2020)	15
Table 3.1 Size of alumina p	oowder	36
Table 3.2 Parameter setup	for the current of 80 A	38
Table 3.3 Parameter setup	for the current of 100 A	38
Table 3.4 Size of sandpape	r (grit)	40
Table 4.1 Hardness value n	neasurement for mild steel	56
Table 4.2 Result hardness t	est after coating	57
Table 4.3 Surface roughness result after welding on the surface		
Table 4.4 Melt depth result		63
سيا ملاك	اونيۆمرسيتي تيڪنيڪل مليہ	
UNIVERSI	TI TEKNIKAL MALAYSIA MELAKA	

## LIST OF FIGURES

FIGURE	TITLE	PAGE
Figure 2.1 Microstructure on mild s	teel (Sekban et al., 2018)	16
Figure 2.2 Ion implanting process (	Susita & Siswanto, 2107)	19
Figure 2.3 Thermal spraying proces	s (Salmatonidis et al., 2019)	20
Figure 2.4 Setup of the TIG torch p	rocess (Azevedo & Alves De Resende, 2019)	21
Figure 2.5 Stick welding process (H	Iaider et al., 2019)	22
Figure 2.6 MIG welding process (Jo	ogi et al., 2018)	23
Figure 2.7 TIG torch process welding	ng (Baghel & Nagesh, 2018)	24
Figure 3.1 Flow chart		34
Figure 3.2 Sample surface after mil		35
Figure 3.3 Sample after grinding an	d polishing	40
Figure 3.4 Optical microscope in la	ويور سيبي بيه boratory	41
Figure 3.5 X-ray diffraction at XRI	laboratory MALAYSIA MELAKA	42
Figure 3.6 Rockwell hardness test n	neasurement	44
Figure 3.7 Surface roughness measured	arement apparatus	44
Figure 4.1 Microstructure before co	ating with alumina powder	45
Figure 4.2 Microstructure that reveal after using the current of 80 A		
Figure 4.3 Microstructure that revea	al after using the current of 100 A	48
Figure 4.4 Sample A with 1 PPS at	a current of 80 A (a) Microstructure	
magnification 3 k (b) M	licrostructure magnification 1 k	50
Figure 4.5 Sample H with 8 PPS at	a current of 80 A (a) Microstructure	
magnification 3 k (b) M	licrostructure magnification 1 k	51

Figure 4.6 Sample Q with 7 PPS at a current of 100 A (a) Microstructure with	
magnification 3 k (b) Microstructure with magnification 1k	52
Figure 4.7 Sample R with 8 PPS at a current of 100 A (a) Microstructure with	
magnification 3 k (b) Microstructure with magnification 1 k	53
Figure 4.8 XRD for four sample graph	
Figure 4.9 Graph of the Rockwell hardness test	
Figure 4.10 Surface roughness value graph	



## LIST OF SYMBOLS AND ABBREVIATIONS

D,d	-	Diameter
PVD	-	Physical Vapor Deposition
CVD	-	Chemical Vapor Deposition
TIG	-	Tungsten Inert Gas
SEM	-	Scanning Electron Microsopy
XRD	-	X-ray Diffraction
$Al_2O_3$	-	Alumina Powder
ASTM	-	American Society for Testing and Materials
MPa	- 14	Megapascal
GPa	and the second s	Gigapascal
GTAW	EK.	Gas Tungsten Arc Welding
GMAW	F S	Gas Metal Arc Welding
SMAW	E.	Shielded Metal Arc Welding
Al	- 1/	Aluminum
Zn	ملاك	اونور ست تكنك ملس
MAB	-	Manganese-Aluminium- Bronz
MIG	UNIVE	Metal Inert GasNIKAL MALAYSIA MELAKA
PAW	-	Plasma Arc Welding
WC	-	Tungsten Carbide
Ti	-	Titanium
Si	-	Silicon
С	-	Carbide
°C	-	Degree Celsius

## LIST OF APPENDICES

APPENDIX	TITLE	PAGE
APPENDIX A	GANT CHART PSM 2	72
APPENDIX B	GANT CHART PSM 2	73
APPENDIX C	TURNITIN	74



#### **CHAPTER 1**

#### **INTRODUCTION**

#### **1.1 Background study**

Accordingly, the present study attempts Balaram Naik & Chennakeshava Reddy, (2018) the most advanced production technology includes metal connectors, metal welding, material quality, and durability. Welding is the technique of connecting two metals using a combination of metal bases and filler material added to the surface of molten metal to create a strong bond between the metals. In tungsten arc welding, a tungsten electrode with a continuous welding power source is utilised to create an electric arc between the electrode and the workpiece, generating heat to form the weld.

Other studies by Jiang, P. et al. (2016) an arc welding process, Gas Tungsten Arc Welding (GTAW), also known as Tungsten Inert Gas Welding (TIG), uses non-weldable tungsten electrodes. The welding area and the electrode are both shielded from oxidation and any other impurities present in the environment by an inert shielding gas (argon or helium). Filler metals are utilized quite commonly, but there are types of welds known as autogenous welds or composite welding that do not require filler metals. The GTAW welding technique is often used to join relatively small pieces of stainless steel and non-ferrous metals, such as aluminium, magnesium, and copper alloys. This method gives the operator a more significant degree of control over the welding process than competing methods, such as shielded metal arc welding and gas metal arc welding. As a result, it is possible to produce welds of a more considerable quantity and a higher quality. The Gas Tungsten Arc Welding technique, generally known as GTAW, is significantly slower than the majority of other welding processes and more complicated (Jiang, P. et al. 2016).

In different study Yelamasetti & Rajyalakshmi, (2019) say that in the mode known as pulsed current, the welding current jumps back and forth between the two settings very quickly. The current condition at the upper level is referred to as the pulse current, while the current level at the lower level is referred to as the background current. The weld area is heated up, and fusion takes place during the interval that the pulse current is being applied. The weld region is allowed to cool down and become more solid when it falls into the background current. Pulsed current GTAW has many benefits, including a decreased heat input and, as a direct result, a reduction in distortion and buckling in thin workpieces. In addition to this, it grants a better degree of control over the welding pool and has the potential to enhance weld penetration, welding speed, and welding quality.

#### **1.2 Problem Statement**

Mild steels are widely used in various industrial sectors due to their excellent strength, low-cost materials and ease of fabrication. However, this material suffers from hardness and wear resistance properties. Therefore, surface modification is required on this material by using a mixture of alumina powder as a coating on the mild steel surface because alumina powder has high hardness, excellent corrosion resistance and high melting point. A common problem encountered on the surface during welding is the lack of fusion at the root. Therefore, by using the pulsed method to find the effect that can melt the rod on the surface is able to harden the layer on the surface.

#### **1.3** Research Objective

- a) To develop a new hard surface layer on mild steel using alumina powder preplacement and TIG torch process.
- b) To evaluate the effect of pulsed-TIG welding on mild steel in terms of hardness, microstructural, and surface roughness.

## 1.4 Scope of Research

- The process parameters used in this project is pulse from 1 10 PPS, current (80 100 A) and constant gas flow rate 15 L/min.
- The development of hard surface layer is examined and characterized using Optical microstructure (OM), Scanning Electron Microscopy (SEM), Rockwell hardness test, X-ray diffraction and surface roughness.



#### **CHAPTER 2**

#### LITERATURE REVIEW

#### 2.1 Steel

Researchers have studied about steel Islam & Rashed, (2019) say steel is a generally acknowledged, iron-rich ore-derived, versatile, complex metal substance. The infinite diversity of microstructures for allotropy, availability, abundance, and characteristics achieved by solid-state transformation and straightforward processing procedures have given steel a competitive advantage over other materials. Iron ore is abundant in the earth's crust and is easily reduced by heated carbon to produce iron, with a melting point of approximately 15431°C. Ordinary carbon steel comprises 80% of all metallic materials and is the most extensively used iron in the industrialised world. It can also be cast and heated to provide a range of mechanical qualities, beginning with modest yield strengths (200–300 MPa or 30–40 KSI). Ductility to yield strengths over 1400 MPa (200 KSI) with fracture toughness levels as high as 110 MPa (100 KSI), allowing it to be utilised in a vast array of applications.

#### 2.2 Types of steel

There are four main types of steel, carbon steel, alloy steel, stainless steel, and tool steel. Each type of steel has unique characteristics that lead it to be used in its respected fields. In this project, the steel used is a mild steel.

#### 2.2.1 Carbon steel

Previous studies have primarily concentrated on carbon steel Singh, (2020) say carbon steel, an iron-carbon alloy, is the least expensive metal for pipes and valves. This substance is classed as a non-corrosive alloy that is susceptible to carbon dioxide and hydrogen sulphide corrosion. Carbon steel can be alloyed with silicon, copper, and manganese. Carbon steels can be classified as low carbon with a carbon content below 0.25%, medium carbon with a carbon content between 0.25% and 0.5%, and high carbon with a carbon content between 0.5% and 1.25%. If the iron-carbon alloy has more than 2% carbon, the substance is called cast iron. Before the invention of plastic pipes, cast the iron was frequently used for sewage and water pipes. Table 2.1 show the properties inside carbon steel.

Property	Carbon Steel
Density (1000 kg/m <sup>3</sup> )	7.85
Elastic Modulus (GPa)	190 - 210
Poisson's Ratio	0.27 – 0.3
Thermal Expansion (10 <sup>-6</sup> /K)	11 – 16.6
Thermal Conductivity (W/m-K)	24.3 - 65.2
Specific Heat (J/kg-K)	MALAYSIA 450-2081A
Tensile Strength (MPa)	276 - 1882
Yield Strength (MPa)	186 - 758

Table 2.1 properties of carbon steel by (Singh, 2020)

#### 2.2.1.1 Low carbon steel

Other name for the low carbon steel is known as mild steel. In recent years, several studies have focused on low carbon steel of mild steel Singh, (2020) according to reports, low carbon steel is the most commonly utilised type of carbon steel. These steels typically have a carbon content of less than 0.25 wt.%, cannot be toughened by heat treatment (to

generate martensite). Hence hard work is typically required. Carbon steels are often soft and possess poor strength. However, their high ductility makes them excellent for machining and welding and inexpensive. For example, Rajendran et al., (2020) has described the usage Low carbon steel is frequently used for automobile body parts, structural shapes (I-beams, channels, and angle irons), pipes, construction and bridge components, and food cans. Figure 2.1 shows microstructure on mild steel with the label of pearlite (P) and ferrite ( $\alpha$ ).



Figure 2.1 Microstructure on mild steel (Sekban et al., 2018)

#### 2.2.1.2 Medium carbon steel

#### UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Previous studies have primarily concentrated on carbon steel Singh, (2020) suppose medium carbon steel has a carbon concentration between 0.25% and 0.60% weight and a manganese level between 0.60% and 1.65% weight. This steel's mechanical characteristics are improved by a heat treatment involving austenitization, quenching, and tempering, which results in a martensitic microstructure. However, additional alloying elements, such as chromium, molybdenum, and nickel, can be added to the steel to increase its ability to be heat treated and, therefore, harden. Medium-carbon steels that have been hardened have greater strength than low-carbon steels but at the sacrifice of ductility and toughness. Medium-carbon steels are frequently used for railway tracks, train wheels, crankshafts, gears, and equipment components requiring this mix of qualities due to their high strength, resistance to wear, and tensile strength.

#### 2.2.1.3 High carbon steel

In recent years, several studies have focused on low carbon steel of mild steel Singh, (2020) according to reports, high carbon steel has a carbon content between 0.60% and 1.25% weight and a manganese value between 0.30% and 0.90% weight. It has higher hardness and tensile strength than carbon steel but lower ductility. Because it is virtually always hardened and tempered, high carbon steel is highly wear-resistant. Statement Singh, (2016) due to its extreme hardness and wear resistance, high carbon steel is commonly used for cutting tools that maintain sharp edges and stone nails that can be pushed into concrete or brick blocks without bending, however, due to its brittleness, it tends to break when subjected to excessive stress.

#### 2.3 Surface modification using melting techniques

Researchers have studied about surface modification using melting techniques Amanov, A. and Sasaki, S. (2013) according to the author, the surface hard coating approach has been widely implemented in numerous industries, including automotive, aerospace, and medicinal. In these sectors, engineering components generally function under harsh conditions involving heat, friction, and dynamic motion. As a result, the materials will degrade rapidly, and the component's lifespan will be reduced. A surface coating can enhance a material's tribological qualities by increasing its near-surface hardness, wear resistance, and lowering its coefficient of friction. Surface melting techniques such as laser surface melting and Inert Tungsten Gas (TIG) torch surface melting can be used to apply composite coatings.

#### 2.3.1 TIG torch

Previous studies have primarily concentrated on TIG torch Kumar Das, (2022) it has been stated that tungsten inert gas emission coating is one of the most used methods for coating surfaces. It is often used in coating processes due to its superior metallurgical compatibility between the coating and substrate material, ease of operation, and lower cost than laser-assisted and electron beam assisted coating. Wire feed, powder injection, and precoating powder processes are the three methods for putting coating material onto a surface substrate. The feed wire feed process takes the stock material or material to be coated in the forming wire. The wire is delivered to the melting pool through the sidewalls at various angles while the TIG flame remains vertical. After producing coated layer wire smelting onsite, surface materials with strong metallurgical adhesion are used.

#### 2.3.2 Laser cladding

Researchers have studied the laser cladding Zhu et al., (2021) is a procedure that employs manufacturing processes like coating, prototyping, and repair with the production of metallurgical solids can be observed using this method. Liu et al., (2021) summarized that laser cladding is similar to arc welding in that the laser will melt the surface and add material to the surface in the form of a wire, strip, or powder. Frequently, laser cladding can boost the corrosion resistance to the material.

#### 2.3.3 Ion implanting

Previous studies have primarily concentrated on ion implantation Susita & Siswanto, (2107) is a low-temperature technique in which ions from one element are propelled into a dense target, therefore modifying the target's physical, chemical, or electrical properties. If ions halt and remain in the target, they can alter the element's composition if their composition differs from the target's. Ion implants also induce chemical and physical changes when ions with high energy obstruct targets. The Cascades of energetic collisions can damage or even destroy the crystal structure of the target, and ions with sufficient energy (10s MeV) can cause nuclear transmutation. In addition to materials science research, ion implantation is utilised to manufacture semiconductor devices and metal finishes. Figure 2.2 shows ion planting system design and the name of the component of the process.



#### 2.3.4 Thermal spraying

In recent years, several studies have focused on thermal spraying Salmatonidis et al., (2019) thermal spraying can protect a substrate, enhance its surface qualities, and meet the surface requirements for a particular service environment. In this technique, the feedstock material is heated to a molten or semi-molten state, accelerated by an intense flow, and sprayed onto a prepared substrate. Figure 2.3 shows thermal spraying process technique that used in industry.



Figure 2.3 Thermal spraying process (Salmatonidis et al., 2019)

# 2.4 Electrical arc welding

Electric arc welding is a type of welding in which an electric arc generates heat to unite metal components. Electric arc welding is a type of welding that uses a welding power supply to generate an electric arc between an electrode and the workpiece in order to melt the metals at the point of contact. Welding using an electric arc can utilize either a DC or AC supply and a consumable or non-consumable electrode.

# 2.4.1 TIG torch

Researchers have studied of Tungsten Inert Gas (TIG) welding Azevedo & Alves De Resende, (2019) TIG welding is widely employed in the industry due to its higher weld quality, arc stability, smooth head appearances, and lower pollution in weld zones. TIG welding is autogenous without filler metal procedure widely utilised for thin welding components. As opposed to MIG/MAG, heat input in this technique is independent of filler metal rate. As a result, the technique enables precise control of heat input and the manufacture of high-quality welds with little distortion and no spattering. Figure 2.4 shows the TIG torch process, where the two plate need to joint together using the rod and melting together at the surface plate.



Figure 2.4 Setup of the TIG torch process (Azevedo & Alves De Resende, 2019)

#### 2.4.2 Shielded metal arc welding (SMAW)

ARLAYSIA

Researcher have studied the Shielded Metal Arc Welding (SMAW) Haider et al., (2019) say that the shielded metal arc welding (SMAW) is also known as Manual Metal Arc Welding (MMA or MMAW) and stick welding, which is frequently employed in the construction and repair industries due to its greater portability and flexibility. This welding stick has electrodes protected by a substance known as flux. When utilising this welding rod, the flux coating on the electrode begins to burn, releasing a protective gas that shields the base metal and the weld from environmental contamination. Hydrogen and oxygen are the most prevalent air pollutants, creating issues such as cracks and porosity in welding. It is a standard welding method due to its ease of use and low cost of maintenance. Figure 2.5 shows the process of the SMAW, where electrode holder needs to hold the electrode that used to joint the plate.



Figure 2.5 Stick welding process (Haider et al., 2019)

#### 2.4.3 Metal inert gas (MIG)

In recent years, several studies on Metal Inert Gas (MIG) or Gas Metal Arc Welding (GMAW) Jogi et al., (2018) say that MIG or GMAW is among the most commonly utilized welding methods in production environments for ferrous metals such as mild steel, stainless steel, and non-ferrous metals aluminum, magnesium, nickel, and its alloys. MIG or GMAW is among the most commonly utilized welding methods in production environments for ferrous metals aluminum, magnesium, nickel, and its alloys. MIG or GMAW is among the most commonly utilized welding methods in production environments for ferrous metals such as mild steel, stainless steel, and non-ferrous metals aluminum, magnesium, nickel, and its alloys. MIG welding is the formation of a welding arc by manipulating the metal from a wire electrode. In terms of bead-weld geometry and mechanical properties, the welding process parameters have a significant influence in determining the quality of the weld connection. Figure 6 shows demonstrates how the MIG welding procedure is carried out. Figure 2.6 demonstrates the MIG welding procedure is carried out during the process.



Figure 2.6 MIG welding process (Jogi et al., 2018)

#### **2.5** TIG torch process with pulse per second (PPS)

In recent years, several studies have focused on Pulsed-TIG welding Baghel & Nagesh, (2018) pulsed-TIG welding is a modified kind of TIG welding in which the pulse current oscillates between low and high levels. This current pulsing causes periodic melting along the joint seam, resulting in a succession of separate melt sites that overlap. Pulse controls modify the number of pulses per second and the proportion of time spent at the peak amperage level, regulating heat input. The welding speed is also an essential factor in determining the features of the weld bead. The most excellent tensile characteristics are achieved when the welding speed, cooling rate, and grain size are maximised. Figure 2.7 shows the example of the pulsed-TIG torch process during welding process of plate.



Figure 2.7 TIG torch process welding (Baghel & Nagesh, 2018)

#### 2.5.1 Advantages and disadvantages

Previous studies have primarily concentrated on advantages pulse welding Wang et al., (2020) pulse welding also reduces spatter, which reduces the requirement for subsequent operations and rework. The majority of the cost savings achievable by pulse welding are attributable to spatter reduction. Additionally, this reduces the time necessary for clean-up after the weld has been completed. Pulse welding boosts productivity by boosting deposition rates outside of the weld zone. In addition, pulse welding is more straightforward than other transfer methods, which boosts productivity. Pulse welding can provide a steadier arc and a higher-quality finish than other transfer methods; this is the ultimate objective of any welding technique.

In other study Khan et al., (2021) has talked about the disadvantage of TIG pulse. It has been discovered that increasing the pulse frequency refines the grain structure of the welded metal, especially when welding is performed with a short pulse length. Long pulse length decreases the pulse frequency at which refining of weld metal components occurs. Pulse duration was discovered to determine the effect of pulse frequency on grain structure. A long pulse duration resulted in a coarser structure for a given pulse frequency than a short pulse duration. An increase in the peak current coarsened the grain structure.

#### 2.6 Ceramic powder preplacement for surface modification

Researchers have studied about of ceramic powder preplacement for surface modification Amanov, A. and Sasaki, S. (2013) say that the surface morphology of solid materials is an important feature. Morphology dictates the effective surface area, always more significant than the macroscopic geometric area. Most procedures utilised in the mass production of materials, including casting, injection moulding, extrusion, and rolling, are limited in their ability to increase the surface area beyond the geometric one. Frequently, solid materials are created from liquids whose surface energy encourages the formation of smooth surfaces. Such a smooth surface is frequently kept even after solidification. Numerous applications, however, prefer a solid material with an enormous surface area (far greater than the geometric one). Frequently, a rough surface improves the adherence of a coating and is essential for many applications. The surface area is typically augmented much beyond its geometric value by etching or depositing.

## UNIVERSITI TEKNIKAL MALAYSIA MELAKA

#### 2.6.1 Silicon carbide

In recent years, several studies have focused on Silicon Carbide Katoh & Snead, (2019) according to experts, silicon carbide (SiC) is a ceramic with a wide range of applications, including electronics, jewellery, heat management, heating components, releasing materials, brake linings, and other structural forms. Along with carborundum, this material possesses a high decomposition temperature 2,830°C and excellent oxidation resistance. Silicon carbide (SiC) is primarily used for thermal and abrasive applications, with industrial demand tripling and its penetration expanding dramatically. From D. Sharma et al. (2019) found that by using silicon carbide as a coating on the surface of alloy steel and TIG

welding, the surface hardness of micro-alloy steel was significantly increased by 2.9 times. TIG arcing was found to be effective on flux-coated substrates containing SiC, and the development of SiC-reinforced composite surfaces significantly increased surface hardness compared to TIG surface hardening without flux coating. Analysis using optical microscopy, EDS, XRD, and FESEM revealed that the surface hardness was mainly due to martensitic ferrite production in the matrix, and the presence of approximately 1.6 vol.% of oxides and SiC reinforcement further increased it to the maximum observed.

#### 2.6.2 Alumina powder

Alumina powder offers several advantages in today's industry, but its poor strength, plastic deformation, and fracture toughness come with disadvantages. Less than 98% of alumina is currently commercially available Grossin et al., (2021). There are numerous composites with alumina, such as alumina-titanium carbide, alumina-silicon carbide, alumina-zirconia, and alumina-alumina.

The previous researcher by Eray (2020) found that the alumina-zirconia composites combine the hardness of alumina with the fracture toughness of zirconia. Composites are utilised as load-bearing materials in arthroplasties, such as hip and knee prostheses. Biocompatibility and improved mechanical and tribological properties of Al<sub>2</sub>O<sub>3</sub> - ZrO<sub>2</sub> composites enable long-lasting prostheses, the composites micro graphed via SEM. The matrix might be alumina or zirconium, while the matrix of Alumina-toughened zirconia implants is ZrO<sub>2</sub>. The Al<sub>2</sub>O<sub>3</sub> - ZrO<sub>2</sub> composites are used in cutting tools. In cutting tools, SiC disperses in steels and other ferrous alloys, SiC cannot coexist with iron. In order to address this issue, zirconia-reinforced alumina was developed. Zirconia may serve as the matrix material, whereas alumina may serve as the reinforcing.

Also, that alumina-fiber reinforced alumina, or simply alumina-alumina composites, are lightweight high-temperature materials with strong thermal shock resistance and adequate stability in oxidising atmospheres (their densities are roughly one-third that of high-temperature steel alloys). These composites are employed in high-temperature (up to 1150°C) applications such as flame tubes, hot gas distributors, and furnace components process extracts alumina by distilling the chemical component Al<sub>2</sub>O<sub>3</sub> (alumina powder) from the bauxite mineral combination.

#### 2.6.3 Titanium carbide

Gupta et al., (2019) have studied about titanium carbide according to research, titanium carbide (TiC) is a refractory ceramic material with a comparable hardness to tungsten carbide. Sodium chloride is a dark powder with a crystalline appearance. It is a naturally occurring kind of the mineral khamrabaevite. It was discovered in 1984 near the Uzbek border on Mount Arashan in Chatkal District. The mineral is named after Ibragim Khamrabaevich Khamrabaev, the director of Geology and Geophysics in Tashkent, Uzbekistan. The size of crystals in nature ranges between 0.1 and 0.3 mm.

#### UNIVERSITI TEKNIKAL MALAYSIA MELAKA

In a different study, Yao et al (2020) have undertaken Titanium carbide experiments. Titanium lacks mechanical qualities, including low hardness and wears resistance. On titanium (Ti) samples, laser synthesis of titanium carbide (TiC) structures has been accomplished. To evaluate the mechanical characteristics and corrosion of the samples, Vickers hardness indenters, wear tests, impedance spectroscopy, and polarisation studies were conducted. The adhesion between Ti and the final TiC structure is a property that promotes this technique. The results indicate that the TiC coating improves the mechanical hardness of the Ti substrate. In addition, the friction coefficient value of laser-treated Ti samples was dramatically decreased. As laser treatment time increases, the surface roughness of laser-treated Ti approaches its minimal value. Even though Ti laser surface treatment had no discernible influence on Ti corrosion resistance in Hank physiological solution relative to Ti reference, the increase in Ti hardness with laser treatment duration is an exemplary aspect of this technology.

#### 2.6.4 Tungsten carbide

Previous studies have primarily concentrated on tungsten carbide Omole et al., (2022) has informed that tungsten has the highest melting point of all metals and is resistant to corrosion, contributing to its durability and thermal conductivity. Tungsten is, therefore, a good material for use in welding. Compared to tungsten and tungsten carbide, tungsten carbide has more excellent durability. Tungsten carbide is a compound with the formula WC with the formula indicates that the compound is composed of equal parts of tungsten and carbon. It has a molar mass of 195.86 grams per mole (g/mol).

The previous researcher by Sabzi et al., (2018) these experiments proved the qualities of tungsten carbide Nickel single component coating and Ni-W<sub>2</sub>C nanocomposite coating on St37 steel present a dendritic structure free of pores, as shown by optical and scanning electron microscopy images and EDS analysis results. In addition, microscopic examination revealed that the tungsten carbide nanoparticles contained inside the Ni-tungsten carbide nanocomposite coating did not dissolve. The dendritic structure of Ni-tungsten carbide nanocomposite coatings becomes more refined as the number of tungsten carbide nanoparticles increases.

The micro-hardness test findings (hardness profile from the coating surface to the steel substrate) demonstrated a hardness range of 300 to 1000 Vickers for the precipitated coating on St37 steel. Uncoated St37 steel has a hardness of around 180 Vickers. This increase in hardness suggests that the Ni-tungsten carbide nanocomposite coating has a

relatively high hardness due to the tungsten carbide reinforcement nanoparticles and rapid solidification conditions in TIG welding, which can contribute to the coating's abrasion resistance in various environments. The hardness profile indicates that Ni-tungsten carbide nanocomposite coatings are much more complex than nickel coatings. This hardness profile reveals that the Ni-tungsten carbide nanocomposite coating containing 20% tungsten carbide is more complex than the coating containing 5% tungsten carbide due to the relatively high hardness of the tungsten carbide phase. The hardness profile of this sedimented coating demonstrates that the coating's surface layer has the highest hardness, whereas the coating/substrate contact has the lowest hardness. The substrate medium's melting is responsible for the interface's softness and close closeness.

#### 2.7 Characterization of surface modified steel

Fracture toughness is a material property that characterizes a material's resistance to crack propagation. It is used to evaluate the structural integrity of materials, predict the remaining life of equipment, guide safe equipment design, and ensure the safety of equipment in service.

# 2.7.1 Rockwell hardness test

The Rockwell and Vickers hardness tests are both methods for measuring the hardness of a material. The main difference between them is the way in which the hardness is determined. In the Vickers test, the hardness is determined by the diagonal length of an indentation left by a diamond indenter in the shape of a pyramid with a 136 degree angle between opposite sides. In contrast, the Rockwell test measures the hardness by the depth of penetration of an indenter under a heavy load compared to a preload. The Rockwell test is faster and less expensive than the Vickers test and it does not require any material preparation, and the hardness result is immediately visible. Vickers test also known as

microhardness test, is used for small shapes and thin sections, where as Rockwell is widely used for large sections.

According to a study by Mohazzab et al., (2020) to improve the accuracy of the hardness, the hardness tester should be well-maintained and calibrated regularly, the specimen surface should be smooth and clean with a maximum roughness of Ra1.6µm, and the specimen thickness should be at least ten times the residual indentation depth when using a diamond taper presser. It is also essential to compare the test results to a standard Rockwell hardness block before evaluating the hardness, clean the test bench, pressure plug, inspection surface, and support surface of the specimens, and securely position the samples to prevent movement or distortion during testing. It should be noted that even if the hardness testers are calibrated and certified, the results may not be consistent as the hardness of the same specimen in different locations may vary, and using different hardness test methods on the same specimen may also yield inconsistent results.

#### 2.7.2 Microstructural and morphological characterization

Microstructure and morphology are closely related concepts in materials science. Microstructure refers to the internal structure of a material, such as the arrangement and size of the individual crystals or grains that make up a metal or polymer, while morphology refers to the shape and form of these microstructural elements. The relationship between these two concepts is such that the microstructure of a material determines its properties, and properties can be predicted by observing the morphology. A microscope is often used to observe the microstructure and morphology of a material. A microscope can magnify the structure of an object or material by more than 25 times, which allows for detailed observations of the internal structure and external form of a material.
#### 2.7.3 X-ray diffraction (XRD) analysis

X-ray diffraction is a technique used to analyze the crystal structure of materials at the nano-scale. The basic principle of XRD is that when X-rays are directed at a crystalline material, the atoms in the crystal cause the X-rays to diffract or scatter in different directions. The resulting diffraction pattern can be analyzed to determine the crystal structure of the material.

To perform an XRD experiment, a sample of the material is placed in the center of an XRD instrument. X-rays are then directed at the sample, and a detector is used to measure the diffracted X-rays. The diffraction pattern is then recorded and graphed, with peaks appearing at specific angles corresponding to the distances between atoms in the crystal.

X-rays are high-energy electromagnetic waves with a short wavelength similar to the distances between atoms in a crystal. This allows X-ray diffraction to be used as a powerful tool to analyze the atomic arrangement and structural properties of materials. It is used to identify unknown materials and quantitatively determine the purity, crystallinity and phase identification of the material.

# 2.7.4 Surface profilometer

A profilometer is a measuring instrument used to assess surface characteristics of a material. It works by contacting a sharp stylus with a small measuring force to a sample surface. This allows it to detect surface roughness, texture, waviness, step heights, and even thin film thickness.

A profilometer typically has two main components: the sample stage and the detection stage. The sample stage is responsible for holding the sample in place, while the detection stage is used to locate the point on the sample being measured. Some profilometer

systems have the sample stage move to facilitate measurement, while others have the detection stage move.

The measurement process typically involves using a stylus to scan over the surface of the sample. The tip of the stylus is sensitive to touch and moves over the surface, collecting data on the height of the surface. This data is then processed and analyzed to determine the surface characteristics of the material.



#### **CHAPTER 3**

### METHODOLOGY

# 3.1 Introduction

This chapter discusses the project material and equipment, as well as the processes and strategies used to ensure that the project objectives are met. This chapter will detail the use of every material and equipment. This chapter is essential for understanding the process flowchart and ensuring that it operates smoothly to meet the final expected result. Furthermore, proper project planning is necessary to ensure that the part and system are appropriate and capable of performing properly. The methodology for the project serves as a flow of process that allows the project to run smoothly.

# **3.2** Flow chart of the project

The flow chart summarises and presents the significant activities of the research approach. The initial stage of this research was to prepare the samples. The specimen was downsized to more manageable proportions during this procedure stage. The milling method was utilised to cut the specimen for the dimensions of mild steel 33mm x 50mm x 8mm. Alumina powder will be manufactured once the necessary sample dimensions have been achieved. This process was designed to pre-place the alumina powder ceramic particles on the specimen prior to welding. The third step in embedding alumina powder into mild steel was the welding operation employing the TIG torch procedure for surface modification. Multiple track types of welds were performed on the object for the experiment. Before performing metallography and Rockwell micro hardness testing on multiple track samples, sample preparation will be performed. Figure 3.1 shows the flow chart of this project from the start until the end.



Figure 3.1 Flow chart

# **3.3** Sample preparation

The sample selected for this project is mild steel. This mild was cut using a machine (gate PR-250V) to a size of 33mm x 50mm x 8mm of the original size was 1220mm x 50mm x 8 mm. this machine automatically cuts the mild steel plate setting up the value to be cut. The coolant water is always opened while cutting the mild steel sample to avoid broken saw blades. After finishing cutting the mild steel sample. The following process is the milling machine (FM-16VS). This process is to level the sample's surface by controlling the axis of the milling machine. Figure 3.2 shows sample surface after milling process that used in laboratory.



Figure 3.2 Sample surface after milling

#### 3.4 Alumina powder preplacement

Then, alumina powder was applied to the surfaces of the samples cut to the correct dimensions. The alumina powder was placed at 0.5, 1.0, and 1.0 mg per square meter  $(mg/m^2)$ . In all instances, a small amount of polyvinyl acetate (PVA) binder was combined with the powder formulations before application to the specimens' surfaces. The thickness of the pre-applied layers was kept between 0.2 and 0.3 millimetres (mm). Prior to the welding

process, the goal of this method was to apply alumina powder particles to the surface of samples. This method includes two steps, first is the sample and second is the powder preparation and prepositioning.

# 3.4.1 Sample and powder preparation

The purpose of sample preparation is to ensure that the surface to be coated with alumina powder particles is free of any dust or other particles that could inhibit alumina powder particles from sticking to the surface. Initially, sandpaper was used to polish the sample's surface. The specimens will next be polished to improve the mild steel's surface quality.

Due to the absence of wetting of the ceramic particles by the liquid metal, the formation of a composite coating with a uniform distribution of ceramic particles, such as alumina powder, in the melting zone may be hindered. Alumina powder particles were placed at 0.5g/mm2 with varying particle sizes shown in Table 3.1. PVA and methanol are used as binders in the pre-placement process. According to the formula, this is the total amount of alumina powder and actual PVA that used in this step.

Reading	Sizes Of Alumina Powder
1	24.96
1	24.86 μm
2	23.17 µm
3	28.77 μm
4	29.6 µm
5	32.69 µm
6	37.01 µm
Average	29.35 μm

Table 3.1 Size of alumina powder

# 3.4.2 Alumina powder preplacement on the surface specimen

Before applying powdered alumina to the sample, powdered alumina will be combined with distilled water, polyvinyl acetate (PVA), and methanol to create a coating mixture for the sample surface. After coating the sample surface with an alumina powder combination, the sample was placed in an oven at 80°C for one hour to dry the alumina powder mixture coated on the sample surface.

# **3.5** Surface modification by TIG torch

After the coating process has been completed on the mild steel surface, the TIG Torch is used to perform multiple track welding on the sample surface. This welding technique uses argon gas at a rate of 15 L/min, and the value of this gas remains constant. The current is then divided into two portions, 80A and 100A. For current 80A, ten types of welding tracks are performed according to the pulsed given, and for current 100A, ten types of welding tracks are performed according to the pulsed given. Up to four samples are required to execute these multiple welds. There are only five weld tracks per sample. This experiment aimed to examine the pulsed effect on the changed surface. Table 3.2 and 3.3 shows the parameter setup for the experiment TIG torch welding to melt the alumina powder together with the sample.

Material	Argon gas flow rate	Current	Pulsed	
		(A)	(Pulsed per second-PPS)	
			1	
			2	
			3	
			4	
Mild steel	151 /min	80	5	
wind steel		00	6	
			7	
			8	
	ALAYSIA		9	
4			10	
Table 3.3 Parameter setup for the current of 100 A				

Table 3.2 Parameter setup for the current of 80 A

Table 3.3 Parameter setup for the current of 100 A

Material	Argon gas flow rate	Current (A)	Pulsed (Pulsed per second-PPS)
٤	No lundo IC		1
			2
UN	IIVERSITI TEKNIK	AL MALAYSIA	MELAKA
			4
Mild staal	151 /min	100	5
wind steel	151/11111		6
			7
			8
			9
			10

#### 3.6 Sample preparation for metallography and Rockwell hardness measurement

After milling the sample's surface, grinding and polishing are the subsequent stage. A Presi Mecapol P320 machine is utilized during the grinding and polishing procedure. This procedure eliminates the grinding effect and smooths the sample's surface. The first procedure done on this material is grinding. Distilled water is utilised throughout this procedure to prevent scorching effects on the sample. After cleaning the sample's surface with distilled water, it is dried with a blow dryer. Table 3.4 shows size of sandpaper that used in this process.

The polishing process is the following phase. The polishing procedure involves utilizing a wool pad as a liner and spraying 6-micron diamond, 3-micron diamond, and 1-micron diamond on the wool pad to remove any scratches from the sample's surface by drying the sample using a blower. For microscopy investigation, the samples were etched using nital solution reagent (95 - 99 ml ethanol and 1 – 5 ml nitric acid) to reveal the microstructure of the samples. The samples are etched for 10 seconds and after that washed thoroughly with running water immediately. Then the samples are dried using hot dryer for 1 minute. The microstructure of the samples is observed and examined under scanning electron microscopy with magnification ranging from 1000X. SEM is a technique that utilises a focused beam of high-energy electrons to generate various signals at the surface of solid materials. Figure 3.4 shows sample after grinding and polish with Presi Mecapol P320 machine.

Table 3.4 Size of sandpaper (grit)

Size Of Sandpaper
(grit)
80
180
320
600
800
1000
1000
1200



Figure 3.3 Sample after grinding and polishing

# **3.7 Optical microscope (OM)**

The optical microscope is one of the microscopes used to observe the surface microstructure of a material. This microscope model is a German-made Zeiss Axioscope A1 model, producing optical systems and optoelectronic products and the monitor and central processing unit (CPU) used is a Dell brand, the monitor is used to see the microstructure more clearly and easily while the CPU is used to store data. Before examining the sample's microstructure with an optical microscope, the sample must first be etched. The acid used to create etching is nitric acid; then, immerse a sample in nitric acid for 5 seconds and rinse it with distilled water to obtain the optimal microstructure under 20X magnification. The microstructure will be viewed on a monitor connected to an optical microscope. Figure 3.4 depicts an optical microscope of the Zeiss type.



Figure 3.4 Optical microscope in laboratory

# 3.8 X-ray Diffraction

X-ray diffraction (XRD) is a technique used to analyze the crystal structure, composition, and physical properties of materials. It works by shining X-rays onto a sample and measuring the diffraction patterns. This model is Zeiss EVO 50 Series. The diffraction

patterns contain information about the arrangement of atoms in the sample and the crystals' size, shape, and orientation.

XRD is a non-destructive technique that analyses various materials, including metals, ceramics, polymers, and minerals. It is commonly used in materials science, pharmaceuticals, geology, and engineering to study materials' properties and develop new materials with specific properties.

XRD can be used to determine the crystal structure of a material, identify unknown materials, and quantify the amount of each component in a sample. It is also helpful for studying the effects of temperature, pressure, and other external factors on the structure and properties of materials. Figure 3.5 shows X-ray diffraction that used in the XRD laboratory.



Figure 3.5 X-ray diffraction at XRD laboratory

# 3.9 Microstructure examination

A scanning electron microscopy (SEM) can be used to analyze the microstructure of mild steel, a low-carbon steel type. SEM works by focusing a beam of high-energy electrons onto the sample's surface and measuring the electrons that are emitted or scattered back. These emitted or scattered electrons can provide information about the surface and

subsurface structure of the sample, including its composition, morphology, and crystalline structure.

Using SEM, it is possible to obtain high-resolution images of the microstructure of mild steel at various magnifications. These images can reveal the size, shape, and distribution of the grains and the presence of any defects or inclusions. SEM can also be used to analyze mild steel's surface roughness and topography and to measure the thickness and composition of thin films or coatings on the surface.

SEM is a powerful tool for studying the microstructure of mild steel and other materials and is widely used in research and industrial applications. It provides detailed information about the microstructure that can help understand the material's properties and performance and optimize its processing and use.

# 3.10 Rockwell hardness measurement

The weld sample is subjected to the hardness test. Each multi-track weld that has been coated with alumina powder will be subjected to a hardness test in order to collect hardness data. This data is used to determine the data value before sample prepositioning and for the sample that has been pre-welded and coated with alumina powder. By using the Rockwell hardness test, the three readings are the average of the HRB value that performed for measure the hardness with the brand Mitutoyo HR-400. This machine will employ a ballindenter to apply pressure to the welding surface to measure the sample's hardness. Figure 3.6 shows Rockwell hardness test machine from Mitutoyo company.



Figure 3.6 Rockwell hardness test measurement

# 3.11 Surface roughness measurement

The Mitutoyo SJ-410 model will assess the surface quality of samples coated with an alumina powder mixture. The objective is to determine the surface roughness of the specimen. A graph reading is displayed on the monitor after the sample is introduced into the Mitutoyo SJ-410 model to determine the surface roughness of the sample. Figure 3.7 show surface roughness measurement that used inside laboratory.



Figure 3.7 Surface roughness measurement apparatus

# **CHAPTER 4**

#### **RESULT AND DISCUSSION**

#### 4.1 Introduction

For this chapter's results and discussion, the data obtained via optical microscope, SEM, X-ray diffraction, Rockwell hardness test, surface roughness, and melt depth will be described. This chapter's primary objective is to examine the evolution of light hardness. After coating steel with alumina powder and searching for a PPS that satisfies the established specifications, the steel is scanned.



4.2 Microstructure on mild steel before coating with alumina powder

Figure 4.1 Microstructure before coating with alumina powder

Figure 4.1 shows the microstructure that has not been coated with alumina powder, this show the two structures in mild steel which is pearlite and ferrite. (Aghogho et al., 2015) says that pearlite is a microstructural phase consisting of alternating layers of ferrite and cementite. It forms when steel is slowly cooled from the austenite phase, which is the phase

that exists at high temperatures. Pearlite has relatively low hardness and tensile strength but good ductility, which means it can easily deform without breaking.

Adetunji (2013) stated that ferrite is a microstructural phase consisting of pure iron. It forms when steel is cooled rapidly from the austenite phase. Ferrite has relatively low hardness and tensile strength but excellent ductility and toughness, which means it can absorb much energy without breaking.

One advantage of pearlite is its good ductility, which makes it useful for applications where steel needs to be formed or formed into a specific shape. It is also relatively cheap to produce. One advantage of ferrite is that it has excellent ductility and toughness, making it useful for applications where the steel needs to absorb much energy without breaking. It is also relatively cheap to produce.

# 4.3 Optical microscope

Figure 4.2 shows the microstructure of the surface of welded mild steel under a 20x magnification optical microscope. Each sample uses a variable pulse per second (PPS) and a current of up to 80 A, while the argon gas flow rate remains constant at 15 L/min. Figure 11 illustrates the distinction in microstructure between samples with varying PPS.



Figure 4.2 Microstructure that reveal after using the current of 80 A





Figure 4.3 Microstructure that reveal after using the current of 100 A

Based on Figures 4.2 and Figure 4.3 show pearlite structures more than ferrite. In the case of ferrite and pearlite microstructure, PPS may be necessary because it can affect the microstructure of the welded material.

Aghogho (2015) mentioned that ferrite and pearlite are two microstructural phases in steel and other iron alloys. Ferrite is a body-centred cubic (BCC) lattice structure with high electrical resistance and low thermal conductivity. At the same time, pearlite is a mixture of ferrite and cementite, meaning that it has a rugged, brittle iron carbide that forms a lamellar structure. The microstructure of a material can significantly affects its mechanical properties, such as its strength and ductility.

Mondal (2019) demonstrated that the PPS setting in welding can affect the microstructure of the welded material because it controls the heat input into the material. A higher PPS setting may result in a higher heat input, which may cause the material to reach a higher temperature and produce a different microstructure than a lower PPS setting. For example, a higher PPS setting can result in the formation of more ferrite in the welded material, while a lower PPS setting can result in the formation of more pearlite. In summary, the PPS setting in the weld can be necessary for the microstructure of ferrite and pearlite because it can affect the heat input into the material and, therefore, the micro-phase structure that is formed.

# Kumar (2021) have reported that the current in TIG welding can also be adjusted to

control the heat input into mild steel. A higher current will result in higher heat input, while a lower current will result in lower heat input. Heat input can affect the microstructure of welded mild steel because it can cause the material to reach different temperatures and cause different microstructural phases to form.

Higher currents can result in the formation of more ferrite in the welded material, while lower currents can result in the formation of more pearlite. The microstructure of a material can significantly affects its mechanical properties, such as its strength and ductility. In summary, the current in TIG welding can affect the microstructure of mild steel because it controls the heat input into the material and can influence the microphase of the structure formed.

# 4.4 Scanning electron microscopy (SEM)

After the sample has been coated with alumina powder particles, this microstructure can be observed through a SEM, which was used to investigate the structure of the mild steel in greater detail.



magnification 3 k (b) Microstructure magnification 1 k

Figure 4.4 shows sample A (1 PPS), which uses 1 PPS for current, 80 A, and up to 15 L/min of argon gas. Using a SEM, the microstructure of Figure 4.4 reveals martensite, pearlite, and ferrite microstructures. The microstructure of martensite with needle-like materials is a hard structure. This martensite structure is the result of deposition alumina powder with mild steel during TIG torch welding.

Sample A shows the best microstructure among the other samples as a result of using the correct current. In addition, this sample has a high hardness value because it controls the manual movement throughout the welding process of the sample, and the A PPS sample uses the correct current and pulses per second. The 1 PPS sample has a hardness value of 95.63 HRB, the highest value among other samples. besides that, PPS is also important to determine the hardness of the sample because the appropriate PPS and current can melt the sample well and produce a martensite structure in the sample. pearlite and ferrite structure will be more produced compared to martensite structure if the PPS used is high and does not melt in the welding track well. The difference between (a) and (b) in figure 4.4 is the difference in magnification settings, due to that martensite structure will reveal more detail in different areas.



Figure 4.5 Sample H with 8 PPS at a current of 80 A (a) Microstructure magnification 3 k UNIVERSITE TEKNIKAL MALAYSIA MELAKA (b) Microstructure magnification 1 k

Figure 4.5 shows sample H using a current as high as 80 A, pulse per second as high as 8 PPS and argon gas as high as 15L/min. Figure 4.5 shows the microstructure containing martensite pearlite, ferrite and hole structure. Based on sample H, the hardness value is low only 82.67 HRB, because, as seen in the SEM structure, pearlite ferrite and holes are more than martensite.

Aghogho, (2015) found that pearlite is a microstructure that forms in mild steel when cooled slowly at a high temperature. It consists of alternating ferrite and cementite layers, a rigid and brittle form of iron carbide. This microstructure is relatively soft and has a low hardness compared to other microstructures due to the presence of a relatively soft ferrite phase and the relatively brittle nature of cementite. This causes the hardness of the welding track to decrease compared to other samples. In the microstructure, there is a hole. This happens because the pulse per second is too high, and the manual movement during the welding process is slow. In addition, the current is also an essential factor in the welding process because if the current is too high, the welding track will become a hole in each welding track. Based on Figure 4.5, the microstructure became a hole because the pulse per second and current did not match and caused the value from the hardness test to decrease from the other samples.



Figure 4.6 Sample Q with 7 PPS at a current of 100 A (a) Microstructure with magnification 3 k (b) Microstructure with magnification 1k

Figure 4.6 shows the sample Q microstructure (7 PPS). This sample requires up to 100 A of current, 15 L/min of argon gas, and 7 PPS. Figure 4.6 demonstrates that the structure created on the sample's surface is a pearlite and martensite, indicating that alumina powder has entered the sample since the microstructure has changed from its original form. The needle shape in Figure 4.6 indicates that sample Q (7 PPS) is hard because, as seen in the microstructure, nearly all of the martensite-shaped areas are present, and the current, argon gas, and pulses per second utilized are appropriate and correct. The pearlite structure

has been seen in this microstructure, maybe because the TIG torch's heat did not reach the area or the alumina powder did not penetrate the area. Given that the hardness value of the 7 PPS sample is 89.60 HRB, this sample has a high hardness value for a 100 A.



Figure 4.7 Sample R with 8 PPS at a current of 100 A (a) Microstructure with magnification 3 k (b) Microstructure with magnification 1 k

Figure 4.7 shows sample R (8 PPS), which uses a current as high as 100 A, an argon gas as high as 15 L/min and a pulse per second as high as 8 PPS. There are more holes in this microstructure than in the other microstructure samples due to excessive current or heat causing holes in this microstructure. With this hole's presence, the welding track's hardness will decrease because the hole creates an area of weakness in the material that is more prone to deformation or failure under load. When a material is subjected to a hardness test, the load applied to it is transmitted through the microstructure. Any holes present in the microstructure can result in a lower hardness value.

In addition, manual speed during the welding process is also one of the factors in the occurrence of holes because too fast-manual speed during welding can cause holes in mild steel structures because the metal material that is exposed to heat does not have time to flow properly before hardening. This can cause metal material to concentrate in one place and

form holes. If the heat produced is insufficient to flow the metal material well, there will be a hole or a small gap on the side affected by the heat. The resistance value for sample R is 83.16 HRB. This value is the lowest value among other samples.

# 4.5 X-ray Difrraction

After the surface modification process on mild steel, the highest and lowest peaks will be observed using X-ray diffraction in addition to observing the intermetallic compounds in each peak. Figure 4.8 depicts the collection of four samples for analysis. These four samples were selected because, based on the findings of the optical microscope, SEM, Rockwell hardness test, surface roughness, and melt depth, they obtained the lowest and highest values while using different currents and PPS.

The highest peaks for this sample are Fe (Iron) and Al (Aluminum) because all of these samples include a mixture of alumina powder and iron. Based on the graph in Figure 4.8, this peak is characterised by intensity because, as seen in this graph, the intensity of FeAl is greater than that of FeO<sub>3</sub>, which has contributed to the high hardness of samples A and sample Q. Figure 4.8 shows the low peak graph combines together with Fe (Iron) and O<sub>3</sub> (Oxide), due to that the presence of oxide, FeO<sub>3</sub> forms and reduces the sample's hardness.

Pulse per second is significant in this modification process because it can alter the structure's shape and the sample's hardness. If the PPS is too high and the current is too low, the welding track will not melt, and if the current and PPS are too high, the welding track will melt excessively, reducing the sample's hardness.



Figure 4.8 XRD for four sample graph

Based on graph 1 of PPS, which uses a current of 80 A, and graph 7 of PPS, which uses a current of 100 amperes, the peak that has been seen is FeAl which is Fe (Iron) and Al (Aluminum) because from the hardness test this sample got a high hardness. FeAl refers to a material consisting of a mixed Fe and Al composition. FeAI has unique properties compared to separate Fe or Al, with this FeAI has high strength and high hardness.

Based on graph 8, PPS uses a current of 80 A, and in graph 8, which uses a current of 100 A, the resulting peak is FeO<sub>3</sub>. FeO<sub>3</sub> refers to Fe metal oxide (Iron), which consists of three oxygen molecules bound to one Fe molecule. FeO<sub>3</sub> is usually formed through an oxide process, where Fe is exposed to oxygen in the air or an oxygen-containing atmosphere. FeO<sub>3</sub> has different properties compared to raw Fe. It has lower strength and lower ability because this sample got the lowest score on the hardness test.

#### 4.6 Rockwell hardness test before coating

The sample's surface was tested using a Rockwell hardness test by taking the data five times over the sample's surface in different places. This data acquisition is due to evaluating the strength samples before coating with alumina and after welding. Table 4.1 shows the data for hardness measurement for mild steel as substrate material before coating process.



Table 4.1 Hardness value measurement for mild steel

#### 4.6.1 Rockwell hardness test after coating

The sample data coated with a combination of alumina powder and welded, and tested for hardness using the Vickers hardness test, are presented in Table 4.2. (Mitutoyo HR-400). The force that only uses is 100 N for this experiment. In this experiment, the data acquired after coating a sample of mild steel with alumina powder are superior to those

obtained beforehand, indicating that the coating of alumina powder on the surface of the mild steel has increased its hardness.

Current	Argon gas	Sample	Pulse Per Second	Rockwell hardness (HRB)
		Α	1 PPS	95.63 HRB
		В	2 PPS	93.96 HRB
		С	3 PPS	92.73 HRB
		D	4 PPS	93.43 HRB
80.4	15 T /m.i.	Е	5 PPS	85.80 HRB
80 A	IS L/min	F	6 PPS	91.23 HRB
ST.	ALC: NO.	G	7 PPS	90.57 HRB
EKN	KA	н	8 PPS	82.67 HRB
TH	L. L. S. S. S.	I	9 PPS	84.57 HRB
943)		J	10 PPS	89.47 HRB
et al	كل مليسيا ملاك	K	1 PPS	86.93 HRB
<u>بر</u> ت		L L	2 PPS	86.07 HRB
UNIV	ERSITI TEKN	IKAL MALAY	SIA 3 PPSAKA	86.77 HRB
	100 A 15 L/min	Ν	4 PPS	89.03 HRB
100 A		0	5 PPS	83.23 HRB
100 11		Р	6 PPS	83.93 HRB
		Q	7 PPS	89.60 HRB
		R	8 PPS	83.16 HRB
		S	9 PPS	87.60 HRB
		Т	10 PPS	87.57 HRB

Table 4.2 Result hardness test after coating



Figure 4.9 Graph of the Rockwell hardness test

The graph from Figure 4.9 shows hardness values for all mild steel samples that have been coated with alumina powder. This value has been differentiated with different parameters, which are for current using 80 A and 100 A for pulses per second using 1 PPS up to 10 PPS, and argon gas is constant, which is 15 L/min. The data in the graph shows that most samples from 80 A have higher values than 100A.

From Figure 4.9, it has been proved that this experiment was successful because the hardness value increased by 20% from the value of the sample that was before coated and after coated with alumina powder. The highest sample recorded for this experiment is sample A (1 PPS), using a current as high as 80 A. The hardness value for sample A (1 PPS) is 95.63 HRB, while the lowest hardness is sample H (8 PPS) which is 82.67 HRB using the same current.

This proves that the alumina powder has melted and successfully entered the sample A 1 PPS sample during the welding process. Referring to the SEM for sample A with 1 PPS structure which is in this sample more like martensite. Referring to the XRD graph, sample A has this high FeAl peak because alumina entered sample A during the welding process. To get the best welding track to control manual movement during welding. Based on previous journals saying that (Kumar et al., 2021), correct manual movement is essential to get the best welding results because it affects the effectiveness and quality of welding results. Accurate movement helps ensure that the electrode is placed correctly and pressed with the appropriate force on the part to be welded. This helps to guarantee that the welding results will be of high quality and meet the specified specifications.

Manual movement is one of the essential factors in welding because if the movement is unstable, porosity will occur on the surface that has been welded; this will cause the welding track to be contaminated by air and reduce its hardness. In addition, the parameters are also the main factor in obtaining a sound welding track. If the parameters are not appropriate, the welding track will become cracked, porous and melt excessively. In addition, if the current is insufficient to melt the mild steel, the hardness of the welding track will decrease.

# Sample H (8PPS) got the lowest hardness value, and it is possible that alumina

powder did not enter the sample during the welding process. From the XRD graph, sample H (8 PPS) has a high FeO<sub>3</sub> peak, which causes the hardness of sample H to decrease compared to sample A. In addition, this sample may also have been contaminated by air due to the presence of poles in the welding track. In addition, the pearlite structure is seen more in sample H compared to the martensite structure.

Sample Q (7PPS) has the highest hardness value for samples that use a current as high as 100 A because a scanning electron microscopy (SEM) reveals a martensite structure in sample Q (7PPS), and this demonstrates that sample 7 PPS has a high hardness for samples that use a current as high as 100 A due to the abrasive nature of the martensite structure. Sample R (8 PPS) has a hardness value of 83.16 HRB, which is low. Sample R has the lowest hardness value because the used parameters are incompatible with its characteristics. In addition, the welding mould contains poles, which impacts the hardness test.

# 4.7 Profilometer

Used a stylus profiler, and the surface roughness of each melted sample was assessed. The surface roughness of molten samples substantially affects their tribological behaviour. Greater surface roughness results in an increased coefficient of friction, which accelerates the wear rate. Thus, it is better to have samples with a reduced surface roughness, which results in a lower friction coefficient and wear rate. The unit for the surface roughness that measure is micrometer ( $\mu$ m). Table 4.3 shows the result of the 10 sample using the parameter that has been applied on the mild steel

Current	Argon Gas	Sample	Pulse Per	Surface
			Second	roughness
UNIV	ERSITI TEK	NIKAL MAL	AYSIA MELA	KA
	Α	1 PPS	0.383 µm	
		В	2 PPS	2.532 µm
		С	3 PPS	0.634 µm
		D	4 PPS	0.592 µm
80 A	15 I /min	E	5 PPS	5.289 µm
00 A	1 <i>3 L/</i> IIIII	F	6 PPS	8.730 µm
		G	7 PPS	9.900 µm
	Н	8 PPS	10.411 µm	
		Ι	9 PPS	0.512 µm
	J	10 PPS	1.161 µm	

Table 4.3 Surface roughness result after welding on the surface

		K	1 PPS	0.452 µm
		L	2 PPS	9.500 µm
		М	3 PPS	0.517 µm
		Ν	4 PPS	0.378 µm
100 A 15 L/min	15 I /min	0	5 PPS	3.154 µm
	1 <i>3</i> L/IIIII	Р	6 PPS	0.761 µm
	Q	7 PPS	0.322 μm	
		R	8 PPS	11.469 µm
		S	9 PPS	9.247 µm
		Т	10 PPS	0.412 μm



Figure 4.10 Surface roughness value graph

Using a Mitutoyo SJ-400 machine, the roughness of the welded sample was measured. Figure 4.10 shows that for a sample that uses a current as high as 80 A, Argon gas as high as 15 L/min, and a pulse per second as high as 1 PPS, sample A receives a low value of 0.383  $\mu$ m from the surface roughness test. This demonstrates that, the sample A of

1 PPS is the best because the welded surface is uniform. This is because manual movement can be precisely regulated throughout the welding process to produce an even and hole-free welding track. In addition, sample A has a measured melt depth of 4.1 mm, demonstrating that the welding track's surface is smooth and flat since if the melt depth is not that deep, the welding track will be uneven and rough.

The surface roughness value for sample H of 8PPS gets a high value of 10.411  $\mu$ m because the manual movement during the welding process is unstable and results in the welding track becoming uneven. For the melting depth of sample H, this value was 3.2 mm deep because the current was not enough to melt the sample and caused the surface of the welding track to become rough and uneven.

In this experiment, sample Q of 7 PPS obtained a high value for the current 100 A, which is  $0.322 \ \mu$ m. Therefore, this sample has a high surface roughness value because the surface on the welding track is even and the welding track that has been produced is not high; furthermore, the parameters used for this sample are suitable. The melt depth test yielded a value of 3.9 mm, indicating that sample Q has a smooth and uniform welding track surface.

The sample R of 8 PPS has the lowest surface roughness value. This sample receives a high score because the parameters utilised are insufficient, and the surface of sample R is roughened by manual movement speed during welding. The fact that the melting depth for sample R is 3.2 mm demonstrates that the welding track for sample R is not smooth and even because the settings utilised are insufficient to melt the welding track for sample R, resulting in an uneven welding track.

This surface roughness test is comparable to the hardness and melts depth tests. If the surface roughness value is high, hardness is low because FeO<sub>3</sub> has entered the welding track during the welding process, thereby reducing the hardness of the welding track. This also causes the surface to become rough, increasing the surface roughness value.

According to a previous study (Nazrin Md Idriss et al., 2021), the surface roughness of the weld track on mild steel may be correlated with the melt depth attained during the welding process. If the melt depth is insufficient, the surface of the weld may be rough and uneven. In contrast, a weld with a deep melt depth could have a smoother finish. The roughness of the weld track's surface can affect its appearance, strength, and hardness.

#### 4.8 Melt depth

Argon Gas	Larain Ma		Pulse per	Melt depth
flow rate	Current	Sample	second	( <b>mm</b> )
LISS ST	80 A	A	1 PPS	4.1 mm
15 L/min	كل مليسياً	H	و م مسبق ن	3.2 mm
UNIVE	RSI100 AEKN	Q IIKAL MALA	7 PPS	3.9 mm KA
		R	8 PPS	3.0 mm

Table 4.4 Melt depth result

Based on the information in Table 4.4, the melt depth of the TIG-welded sample has been determined. Table 4.4 reveals that samples A and sample Q have a deeper melt depth, proving that this sample has a high hardness value since a deeper melt depth typically results in a stronger and more durable weld. In addition, welds with fewer flaws, such as porosity, incomplete fusion, and cracks, are typically produced by welds with a greater melt depth. This can aid in life extension. This parameter is suitable for these two samples, as it yielded low surface roughness values of  $0.383 \,\mu\text{m}$  for sample A and  $0.322 \,\mu\text{m}$  for sample Q. This demonstrates that a low surface roughness value suggests a smoother surface, which can improve quality, strength, and longevity. Based on the XRD graph, these two samples contain FeAl in the welding track, indicating that this sample has a more excellent hardness rating than the other samples.

This indicates that the melt depth is low for samples H and sample R since the current and PPS employed are insufficient to melt the material. This will result in a decline in the quality or performance of the welds, such as a loss of strength or corrosion resistance. Sample A low current can cause insufficient heat input to produce a sufficiently high melt depth, resulting in a low melt depth, while a high PPS will cause the hand to move faster and the sample to melt less. The surface roughness values for these two samples are also reasonably high, sample H is 10.411  $\mu$ m and sample R is 11.469  $\mu$ m is indicating that the sample's track welding is rough compared to the other samples. The hardness test on this sample yielded a low value of 83.16 HRB for the sample H and 82.67 HRB for the sample R due to the presence of a high level of FeO<sub>3</sub> in the welding track, as observed by XRD, which reduces the welding track's endurance in comparison to samples A and sample Q.

#### **CHAPTER 5**

#### CONCLUSION AND RECOMMENDATION

#### 5.1 Conclusion

The main of this experiment was to determine the effect of pulse on the surface properties of mild steel using TIG torch process. With the development of experiment for this project, this research objective which are to develop a new hard surface layer on mild steel using alumina powder preplacement and TIG torch process also to evaluate the effect of pulsed TIG welding on mild steel in terms of hardness, microstructural, and surface roughness have been met.

From the analysis of result using hardness test, it shows that the sample with the highest hardness for current 80 A is sample A, which uses 1 PPS and find that the hardness value is 95.63 HRB. For the current 100 A PPS, the sample with the highest hardness is sample Q, which uses 7 PPS while the hardness value is 89.60 HRB. The sample with the lowest hardness for current 80 A is sample H, which uses 8 PPS with the hardness value is 82.67 HRB, and for the sample R, found that the hardness is 83.16 HRB by using the 100 A. This is the prove that by adding the correct value mixture of alumina powder that melted and successfully entered the sample during welding and PPS can make the surface harder.

Apart from that, the result analysis surface of roughness using Mitutoyo SJ-400 machine shows that sample H, which uses 8 PPS, has the highest surface roughness for current 80 A, at 10.411  $\mu$ m, while the sample R, has the highest surface roughness by using 8 PPS for current 100 A, at 11.469  $\mu$ m. For the sample A, which uses 1 PPS, has the lowest surface roughness for current 80 A, at 0.383  $\mu$ m, while the sample Q has the lowest surface roughness for current 100 A, at 0.322  $\mu$ m. From the result, it can be concluded that manual

movement speed during welding process is the main character to make the track surface is smooth and flat in order to achieve the deep melt depth to avoid the welding track to be uneven and rough. As shows in the melt depth result, for a current of 80 A, the highest melt depth is 4.1 mm for sample A with 1 PPS, and for a current of 100 A, the highest melt depth is 3.9 mm for sample Q with 7 PPS. For a current of 80 A, sample H with 8 PPS has the lowest melt depth at 3.2 mm, while sample R with 100 A has the lowest melt depth at 3.0 mm. This is the prove that the deeper the melt depth, the lower the surface roughness can be obtained by the sample.

Lastly, by using SEM machine, it can investigate the structure of mild steel in detail with the suitable magnification. This SEM machine can reveal the presence of martensite in a sample. Martensite is the result of deposition alumina structure. A high concentration of martensite in a microstructure could contribute to an increase in hardness. It is characterized by a distinct microstructure that is made up of very fine, needle-like grains. The hard, sharp edges of these grains give martensite its high hardness and strength. If a material has a high concentration of martensite in its microstructure, it may have an increased hardness as a result. However, if the microstructure of a material lacks martensite, it may be softer and less resistant to deformation than materials with a higher martensite content. This can be caused by various factors, including the composition and processing of the material.

# 5.2 Recommendation

In this experiment there are several recommendations to improve the hard surface layer:

 Using automatic TIG welding equipment, it is possible to get a precise weld with reasonable control over the shape and size of the weld, producing high-quality welds with good penetration and few defects and doing so in a relatively short amount of time.
2. Perform a surface topography test to obtain a more precise surface roughness value

## 5.3 **Project potential**

The PPS used is able to change the shape of the structure on mild steel, the change occurs as a result of the placement of alumina powder. Many advantages in terms of application and benefit for the material are had by doing surface modification. The hardness, roughness, and melt depth is able to provide an impact suitable for its application is found by the experiment that has been done. The potential in this project, the hard surface layer can be used in automotive and agriculture industries. In the automotive industry, it could be used on cylinder liners and piston rings for its wear resistance properties and for the agriculture industry, it could be used on palm oil cutters and plungers for its ability to resist cracking and withstand strong impact on joint of the welding.



## REFERENCES

Amanov, A. and Sasaki, S., 2013. A study on the tribological characteristics of Duplextreated TI–6AL–4V alloy under oil-lubricated sliding conditions. *Tribology International*, 64, pp. 155–163.

Azevedo, S. C., & Resende, A. A., 2021. Effect of angle, distance between electrodes and TIG current on the weld bead geometry in TIG-MIG/MAG welding process. *The International Journal of Advanced Manufacturing Technology*, *114*(5-6), 1505–1515.

Baghel, P. K., & Nagesh, D. S., 2017. Pulse TIG welding: Process, automation and Control. *Journal of Welding and Joining*, *35*(1), 43–48.

Balaram Naik, A. and Chennakeshava Reddy, A., 2018. Optimization of tensile strength in TIG welding using the taguchi method and analysis of variance (ANOVA). *Thermal Science and Engineering Progress*, 8, pp. 327–339.

Gupta, P., Fang, F., Rubanov, S., Loho, T., Koo, A., Swift, N., Fiedler, H., Leveneur, J., Murmu, P. P., Markwitz, A., & Kennedy, J., 2019. Decorative black coatings on titanium surfaces based on hard bi-layered carbon coatings synthesized by carbon implantation. *Surface and Coatings Technology*, 358, 386–393.

Haider, S.F. et al., 2019. Effect of shielded metal arc welding (SMAW) parameters on mechanical properties of low-carbon, mild and stainless-steel welded joints: A Review. *Journal of Advances in Technology and Engineering Research*, *5*(5).

Islam, T. and Rashed, H.M.M.A., 2019. Classification and application of Plain Carbon Steels. *Reference Module in Materials Science and Materials Engineering*. Elseveir.

Jiang, P. et al., 2016. Optimization of laser welding process parameters of stainless steel 316l using FEM, Kriging and NSGA-II. *Advances in Engineering Software*, 99, pp. 147–160.

Jogi, B.F. et al., 2018. Metal Inert Gas (MIG) welding process optimization using teachinglearning based optimization (TLBO) algorithm. *Materials Today: Proceedings*, *5*(2), pp. 7086–7095.

Katoh, Y. and Snead, L.L., 2019. Silicon Carbide and its composites for nuclear applications – historical overview. *Journal of Nuclear Materials*, *526*, p. 151849.

Khan, F. N., Junaid, M., Hassan, A. A., & Baig, M. N., 2021. Effect of pulsation in TIG welding on the microstructure, residual stresses, tensile and impact properties of Ti-5Al-2.5Sn alloy. *Proceedings of the Institution of Mechanical Engineers*.

AALAYSIA

Kumar Das, A., 2022. Recent developments in TIG Torch assisted coating on austenitic stainless steel: A critical review. *Materials Today: Proceedings*, 57, pp. 1846–1851.

Liu, Y. et al., 2021. Research and progress of laser cladding on Engineering Alloys: A Review. *Journal of Manufacturing Processes*, 66, pp. 341–363.

Mohazzab, B.F. et al., 2020. Laser surface treatment of pure titanium: Microstructural analysis, wear properties, and corrosion behavior of titanium carbide coatings in Hank's physiological solution. *Surfaces and Interfaces*, 20, p. 100597.

Omole, S. et al., 2022. Advanced processing and machining of Tungsten and its alloys. *Journal of Manufacturing and Materials Processing*, 6(1), p. 15.

Rajendran, T.P. et al., 2020. Influence of heat treatment on friction-welded joints made of high-carbon high-chromium tool steel/low-carbon steel for tooling applications. *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, 42(2).

Sabzi, M., Dezfuli, S.M. and Far, S.M., 2018. Deposition of Ni-tungsten carbide nanocomposite coating by TIG Welding: Characterization and control of microstructure and wear/corrosion responses. *Ceramics International*, 44(18), pp. 22816–22829.

Salmatonidis, A. et al., 2018. Workplace exposure to nanoparticles during thermal spraying of ceramic coatings. *Annals of Work Exposures and Health*, 63(1), pp. 91–106.

Sekban, D.M. et al., 2018. Formability of friction stir processed low carbon steels used in shipbuilding. *Journal of Materials Science & Technology*, 34(1), pp. 237–244.

Sharma, D. et al., 2018. Surface modification of microalloyed steel by silicon carbide reinforcement using tungsten inert gas arcing. *Materials Research Express*, 6(3), p. 036530.

Singh, R., 2016. Stresses, Shrinkage, and Distortion in Weldments. *In Applied Welding Engineering* (pp. 201–238). Elsevier.

Singh, R., 2020. Alloys. In Applied Welding Engineering (pp. 7–10). Elsevier.

Singh, R., 2020. Classification of steels. *In Applied Welding Engineering* (pp. 53–60). Elsevier.

Susita, L. R., & Siswanto, B., 2017. Corrosion resistance improvement of Aisi 316L stainless steel using Nitrogen Ion Implantation. *GANENDRA Majalah IPTEK Nuklir*, 16(2).

Wang, Y., Chen, M. and Wu, C., 2020. HF pulse effect on microstructure and properties of AC TIG Butt-welded joint of 6061al alloy. *Journal of Manufacturing Processes*, 56, pp. 878–886.

Yelamasetti, B. and Rajyalakshmi, G., 2019. Effect of TIG, pulsed TIG and Interpulse TIG welding techniques on weld strength of dissimilar joints between Monel 400 and AISI 316. *Materials Today: Proceedings*, 19, pp. 755–760.

Zhu, L. et al., 2021. Recent research and development status of Laser Cladding: A Review. *Optics & Laser Technology*, 138, p. 106915.



## APPENDICES

## **APPENDIX** : Gant Chart

		Semester 6 (2022)														
No.	Activities	Weeks														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	PSM 1 briefing								-							
2	Supervisor selection / Title release / 1 <sup>st</sup> meeting															
3	Meeting with supervisor															
3	Find article for literature review								1							
4	Chapter 1 : Introduction															
5	Problem statement	1				5										
6	Objective	1	1			-										
7	Scope of project															
9	Chapter 2 : Literature review															
10	Highlight issue		. /		- 10	-										
11	Past research background	R			3	m	ull,	10	13 9							
12	Sample preparation				. (	2.0		1	a -							
13	Chapter 3 : Methodology					**				-						
14	Flow chart	CAL	M	AL.	AV	AIS	MAG	1 A	KA							
15	Sample preparation	- M		n.	A. I.	JIM	IAIC		urv-							
16	Parameter setup															
17	Microstructure (microscope optic)															
18	Chapter 1,2, and 3 check by supervisor															

No.	Activities	Semester 6 (2022)													
								W	eeks						
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	PSM 2 implementation														
2	Discussion with supervisor:														
3	Method uses for experiment														
3	Experiment setup						-								
4	Identify the material use														
5	Selection equipment				1										
6	Experiment begins and testing								/						
7	S'ALWO								4						
9	Meeting with supervisor			/											
10	Writing chapter 4:	7	1		23	:2	w	1	su.	91					
11	Result and discussion					Ų.		-							
	Writing chapter 5: UNIVERSITITEKN	IK A	LI	IAI	.A`	SI/	A M	EL	AK	A					
13	Conclusion and recommendation														
14	Chapter 4 and 5 check by supervisor														