THE CORRELATION OF MICROSTRUCTURE – SURFACE ROUGHNESS EFFECT ON FRICTION STIR WELDING LAP JOINT USING AA6061 ALUMINIUM ALLOY

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BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY (PROCESS AND TECHNOLOGY) WITH HONOURS

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Faculty of Mechanical and Manufacturing Engineering Technology

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A thesis submitted
in fulfillment of the requirements for the degree of
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2022

DECLARATION

I declare that this Choose an item. entitled " THE CORRECLATION OF MICROSTRUCTURE – SURFACE ROUGHNESS EFFECT ON FRICTION STIR WELDING LAP JOINT USING AA6061 ALUMINIUM ALLOY" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : *Indah Siti Shoufea binti Naharanuar*

Date : 18 January 2022

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 Manufacturing Engineering Technology (Process and Technology) with Honours.

Signature :

Supervisor Name : *Ts. Mohd Hairizal Bin Osman*

Date : 18 January 2022

DEDICATION

This research is dedicated to almighty God to Giving me strenght thru this journey. A special appreciation, I dedicated this thesis to my beloved husband and my parents, Mohammad Syafiq bin Mohd Sarif, Naharanuar bin Ayob and Azimah binti Ariffin. As well to my superior Ts. Mohd Hairizal Bin Osman, a lot of thanks for guidance and advices in completing this thesis.

ABSTRACT

Friction Stir Welding (FSW) is advance method in joining two parts by heat that been produced from friction between the stir head and the base metal. Generally, FSW rarely used in industry because of this is new technology and a lot of limitation into apply this technology in industries. Because of that, this study has been conducted to find solution for the limitation to gain new knowledge about FSW. Purpose of this study is to find out The Correlation of Microstructure versus Surface Roughness Effects on Friction Stir Welding for Lap Joint Using Aluminum Alloy 6061. Studies will be conducted in three phases which is it start with journal review, design the tool, followed by fabricate the tool. Second phase, run the friction stir welding using conventional milling machine with 9 differences parameter and surface roughness testing. Last but not list, phase three consist of cutting the part to get specimen that will be used for microstructure testing. At the end of this studies, should be able to determine the microstructure of the specimen either in Dry Friction Stir Welding or Underwater Friction Stir Welding.

ABSTRAK

Friction Stir Welding (FSW) adalah kaedah terkini dalam menyambung 2 bahan melalui haba yang dihasilkan daripada geseran antara pusingan mataalat dan logam asas. Secara amnya, FSW jarang digunakan dalam industri kerana ini adalah teknologi baharu dan banyak halangan untuk menggunakan teknologi ini dalam industri. Oleh sebab itu, kajian ini telah dijalankan untuk mencari penyelesaian bagi halangan yang ada untuk mendapatkan pengetahuan baharu tentang FSW. Tujuan kajian ini adalah untuk mengetahui Korelasi Struktur Mikro berbanding Kesan Kekasaran Permukaan terhadap Pusingan Geseran Kimpalan untuk Sambungan Lap Menggunakan Aloi Aluminium 6061. Kajian akan dijalankan dalam tiga fasa iaitu bermula dengan pembacaan jurnal, reka bentuk mataalat, diikuti dengan pembuatan mataalat. Fasa kedua, menjalankan FSW menggunakan mesin pengilingan konvensional dengan 9 perbezaan parameter dan ujian kekasaran permukaan. Bagi fasa ketiga, terdiri daripada memotong bahagian yang dikimpal untuk mendapatkan spesimen yang akan digunakan untuk ujian mikrostruktur. Di akhir kajian ini, keputusan yang dia harapkan adalah dapat menentukan struktur mikro spesimen sama ada dalam FSW keadaan kering, atau FSW keadaan dalam air.

ACKNOWLEDGEMENTS

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

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

My utmost appreciation goes to my supervisor, Ts. Mohd Hairizal bin Osman for all his supports, advice, and inspirations. He consistently patience for guidance and providing priceless insights will forever be remembered.

Last but not list, from the bottom of my heart a gratitude to my beloved husband, Mohammad Syafiq bin Mohd Sarif, for his encouragements and who have been the pillar of strength in all my endeavors. My eternal love also to my son, Haris Nawfal bin Mohammad Syafiq, for their patience and understanding. I would also like to thank to my beloved parents Naharanuar bin Ayob and Azimah bin Ariffin for their endless supports, loves and prayers. Finally, thank you to all the individual who had provided me the assistances, supports and inspirations to embark on my study.

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LIST OF SYMBOLS AND ABBREVIATIONS

FSW	-	Friction Stir Welding
etc	-	And the other things
Kg	-	kilogram
FRW	-	Friction Welding
PP	-	Polypropylene
g	-	gram
°	-	Degree
Rpm	-	Rotation per minute
HAZ	-	Heat Affected Zone
HRB/HRC0	-	Value hardness in Rockwell
Kw	-	Kilowatt
Kg/mm3	-	Kilogram per cubic milimeter
UV	-	Ultraviolet
Mm	-	Milimeter
V	-	Voltage
AC	-	Altenative current
DC	-	Direct Current
HP	-	Host Power
AA6061	-	Aluminium Alloy 6061
Mm/min	-	Milimeter per minute

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

In the machinery industry, joining two or more materials has become one of the most important procedures. These methods of combining materials have been used for centuries and decades to make a better and more flexible shape for easier use. One material can be joined with another that is comparable or distinct and suitable. The most basic instrument for combining materials is the nail and hammer, but it has a variety of drawbacks, including material hardness, accuracy, the number of products that may be made, and product durability.

The process of connecting two metals is known as metal fabrication. The diagram below displays the classification of joint processes, from permanent and nonpermanent categories to subcategories at a deeper level. One of the most often used processes in industry is solid state.

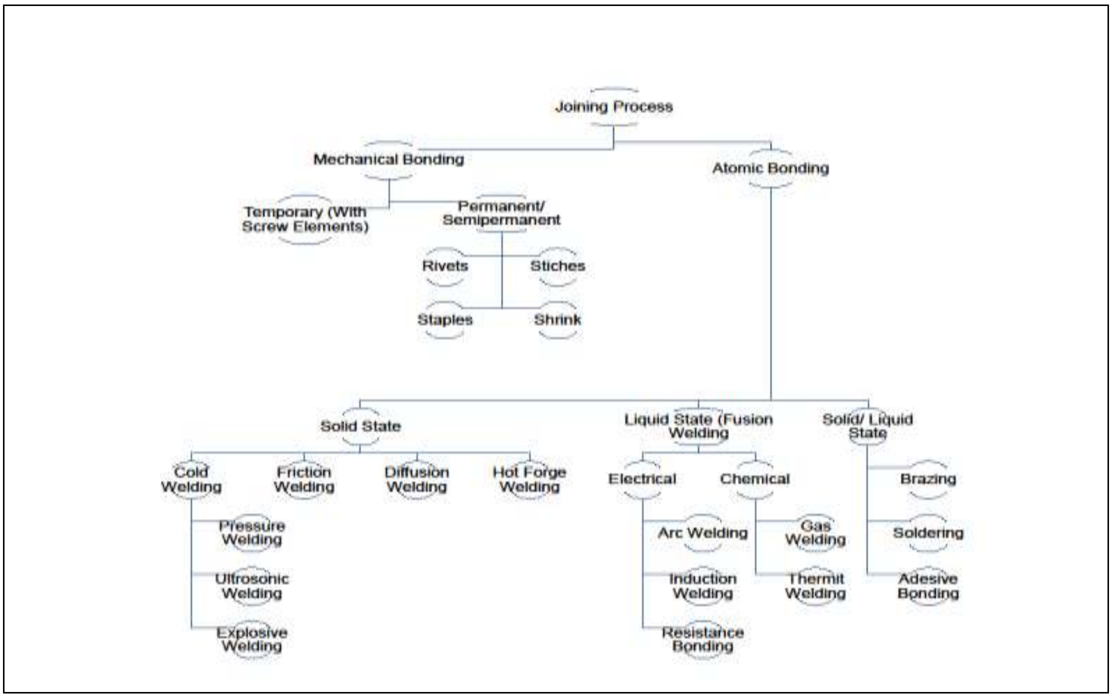


Figure 1.1 Chart Tree Joining Process

Welding is a technique for joining two or more materials. Welding is a fabrication or sculptural technique that uses coalescence to join materials, most commonly metals or thermoplastics. This is frequently accomplished by melting the workpieces and adding a filler material to form a pool of molten material (the weld pool) that cools to form a strong joint, with pressure being used in conjunction with heat or alone to achieve the weld. The welding process is descended from several processes, each with its own set of characteristics. Friction welding, for example, melts the filler material using the heat generated by friction.

Friction Stir Welding (FSW) is a solid-state welding process that uses mechanical friction to generate heat between workpieces in relative motion, as well as a lateral force called "upset" to plastically displace and fuse the materials. Friction Stir Welding is a forging technique rather than a welding procedure in the usual sense because no melt occurs. The name has gained popular due of the similarities between these procedures and classical welding. Friction Stir Welding is used in a range of aviation and automotive applications using metals and thermoplastics.

Friction Stir Welding (FSW) is a solid-state joining technology that uses frictional heat generated by a revolving tool to fuse materials (the metal is not melted). The non-consumable tool is rotated and plunged between two workpieces into the interface using a profiled probe and shoulder. It then moves along the joint axis, causing the material to heat up and soften. The shoulder is also contained in this plasticized material, which is manually mixed to make a solid phase weld.

In the last two decades, several variations of Friction Stir Welding (FSW) have gained popularity. For classical FSW, several researchers enhanced auxiliary energy sources to obtain better welding speeds and tool life at a lower cost. FSW has an edge over other welding procedures when it comes to connecting dissimilar materials like aluminum and steel. Friction stir welding (FSW) is widely used in a variety of sectors due to its high performance and long-term durability. This approach is widely used in the automotive, aerospace, shipbuilding, and railway industries.

When compared to traditional welding methods, the FSW has a significant advantage in that it reduces the number of process factors that must be managed. Travel speed, rotation speed, and pressure are the only three process parameters that must be monitored in FSW. This complicates the welding process even more, potentially increasing manufacturing costs. Furthermore, welds made with FSW have shown to have good mechanical qualities and the capacity to weld materials that were previously thought to be "un-weldable."

1.2 Problem Statement

Friction Stir Welding rarely used in industry because of it is new technology. Several studies have been done to understand and improve the process in this technology. Geometrical parameters of the tool bit play very important roles because it is resulting on metal flow and heat generation. Both factors also might cause defects during welding operations. By studying the effects of different geometry of the tool bit types on microstructure, good tool can be designed, and the process can be improved.

1.3 Research Objective

The objectives of this project shown as below:

a) To design and fabricate tool for Friction Stir Welding.
b) To study the weldability of Aluminium Alloy 6061.
c) To study effects on different geometry of tool bit types on surface roughness and microstucture of Friction Stir Welding Plate.

1.4 Scope of Research

The scope of this research are as follows:

1. To carry out in depth study on the friction stir welding process – step, parameters, machines, and application.
2. To fabricate several design tool types for Friction Stir Welding (FSW) by using Conventinal Lathe and CNC Milling Machine.
3. To study surface roughness value and grain boundries of the microstructure.

1.5 Thesis Outline

The structure of this thesis is based on the publications of this research and follows the thesis format of Universiti Teknikal Malaysia Melaka (UTeM). An introduction, literature review, methodology, findings and comments, and conclusions are included in each report chapter. The following are the specifics of the arrangement:

i) Chapter 1: The concerns exist from this study, and the research goals were mentioned clearly in this chapter. The importance of this study, as well as the extent of the examination, have been clearly stated.

ii) Chapter 2: This chapter provides an overview of previous research on topics such as tool, jig & fixture, parameter, and materials that are linked to friction stir welding. In addition, the research gap discovered in prior studies was explained in this chapter.

iii) Chapter 3: The research methodologies used in this study are explained in this chapter, with an emphasis on material preparation, machine equipment, and testing settings.

iv) Chapter 4: This chapter presents the result data of the hardness for nine different parameters of each condition within Rockwell Hardness Testing Machine. Besides that, the result was also discussed in this chapter and related to this study's objective.

v) Chapter 5: This chapter gives the project's conclusion based on the study and findings. Aside from that, a suggestion for this study project will be offered.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will define the scope of the literature review as it relates to prior research on friction stir welding in dry and underwater environments. Apart from that, this chapter will highlight the numerous trials and jobs successfully completed by various analysts and professionals in the field of research. Additionally, it illustrates the associated tool materials and various jig and fixture designs utilised in the manufacturing business. This chapter will help with the project's research. Additionally, this chapter was written with the goal of enhancing research and avoiding excessive duplication of the study's issue area. This chapter will describe how data is gathered. The data will be utilized to steer the research project's completion. As a primary source of information, the following were identified:

1. Book
2. Journals

2.2 Friction Stir Welding (FSW)

The Welding Institute (TWI) conducted the first FSW experiment in the United Kingdom in December 1991, with the first phase consisting entirely of laboratory work (Santosh K. Sahu., 2017). Friction Stir Welding (FSW) is a non-consumable joining process that uses an inert tool to connect two workpieces without melting the workpiece's material or adding electrical energy or heat from other workpiece sources (Padmanav Dash., 2017). The friction between the revolving tool and the workpiece material creates heat, which contributes to the softening of the region around the FSW tool (Dawood et al., 2015). The procedure includes mechanically combining the edge zones of two clamped metal species using a spinning tool. To obtain a defect-free welding region, the material structure must spin in lockstep with the tool's rotational speed and move in lockstep with the tool's travel speed (Ilangovan et al., 2015).

FSW is being developed in a variety of industries and research facilities worldwide. Numerous research has been conducted to better understand and expand the FSW process since its inception in 1991. Most of them address challenges such as temperature deformation distribution and heat transmission, mostly via the use of numerical methods such as finite element and finite difference approaches. It is a solid-state joining technology for producing high-quality aluminum alloy welds (Choudhary et al., 2019). FSW has been regarded acceptable for combining various materials such as magnesium, steel, titanium, copper, and composites since that time (Krishna et al., 2014). Friction stir welding has been identified as an ideal solution for enhancing the joining of different materials (Helal et al., 2019). According to (Malopheyev et al., 2016), to fabricate high-strength welds in 6061 Aluminum Alloys, the dissolving process must be accelerated while coarsening is minimized.

2.2.1 Dry Friction Stir Welding (FSW)

According to Narges Dialami et al (2019), Friction Stir Welding (FSW) is a solid-state welding technology that has been extensively used in shipbuilding, railways, and aerospace sectors since its inception because to its low defect and absence of melting. Because FSW is a solid-state joining method, it avoids flaws like hot cracking and porosity. It's used to join a variety of metals, including aluminum, stainless steel, and magnesium, that are difficult to fuse using traditional welding methods.

FSW is a linked thermomechanical process in which heat, and mass transfer alter weld characteristics and microstructure. Base material is heated by the frictional heat generated by the shoulder and agitated by the spinning pin as it passes along the weld line, according to previous research conducted by Hamid Reza Ghazvinloo and Nasim Shadfar in the year 2020. As a result, this method resembles extrusion. Because the temperatures are well below the melting point, problems associated with the liquid/solid phase transition are avoided in this procedure. Figure 2.1 shows a schematic representation of the Friction Stir Welding (FSW) technique, which will be used in this final year project.

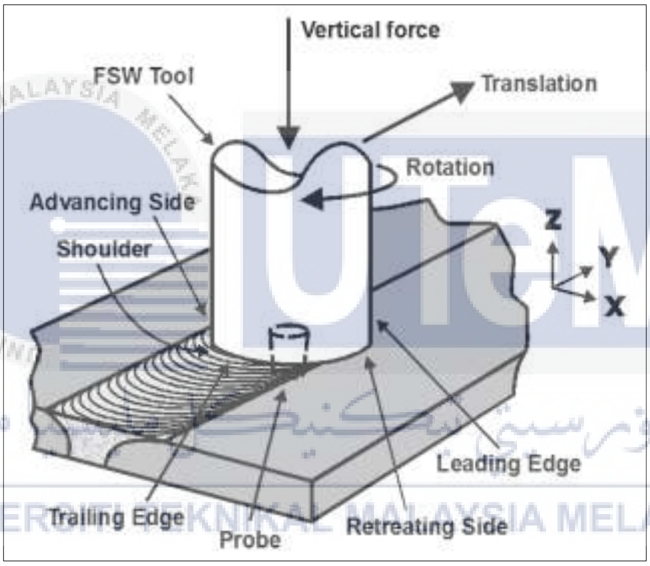


Figure 2.1 The Dry Friction Stir Welding (FSW) Process is illustrated schematically

FSW has several advantages over traditional welding procedures. It creates no noxious gases or toxic fumes, uses significantly less energy, and requires no flux, filler metal, or shielding gas, making it an environmentally benign and energy efficient material joining method. Weld flaws can be extremely problematic. For example, they degrade the quality and strength of welding joints, causing them to fail prematurely. As a result, research into the incidence of weld faults in friction stir welded joints is critical.

2.2.2 Underwater Friction Stir welding (UFSW)

In recent years, research has become the primary focus in almost every discipline. Underwater Friction Stir Welding (UFSW) is one of the advanced welding processes; formerly, Friction Stir Welding (FSW) was performed in a dry environment. Indeed, it is a dynamic and growing technology. It is a kind of solid-state welding. A non-consumable tool is used to run over the substrates in this welding technique, which produces no fumes. It uses less energy and has improved mechanical qualities (Garg et al., 2014). It significantly improves the utility of the weld junction. There has been relatively little research in the field of UFSW. Researchers and academicians in this field may benefit from research. The average grain size of the stir zone was significantly finer than ordinary FSW because to the enhanced cooling rate (Jialiang Dong., 2020).

According to (P. Mahto, 2019), experimental study was conducted on friction stir welding in dry and wet circumstances using the L9 Taguchi technique on AA6061-T6 and AISI-304 (thin sheet) to get the best results. This finding demonstrates that UFSW is superior to FSW. In UFSW, water absorbed frictional heat, resulting in a reduction in frictional heat as compared to FSW. Aside from that, UFSW provides superior weld strength than FSW and has a smaller welding cavity than FSW. Finally, the fact that UFSW has a larger response force (F2) than FSW implies that the tool will interact better with welding materials. The influence of tool rotation and welding speed on joint quality in terms of microstructures, hardness, and tensile characteristics was investigated in this study using a 6061-T6 aluminum alloy welded in USFW. In other words, no published research has taken into consideration the influence of water cooling on the distribution of residual stress (Fathi et al., 2019).

According to (Mabuwa & Msomi, 2020), the researchers discovered that the joints produced by underwater friction stir welding were more ductile than those processed in a dry environment. Aside from that, the researchers said that when compared to the FSW process, which is connected to the cooling rate provided by water, the UFSW process contributed significantly to grain refining. In comparison to FSW, the UFSW technique generated joints with improved tensile characteristics. It's also been discovered that UFSW may be employed to boost the joint's Ultimate Tensile Strength (UTS) and % elongation (Mabuwa & Msomi, 2020).

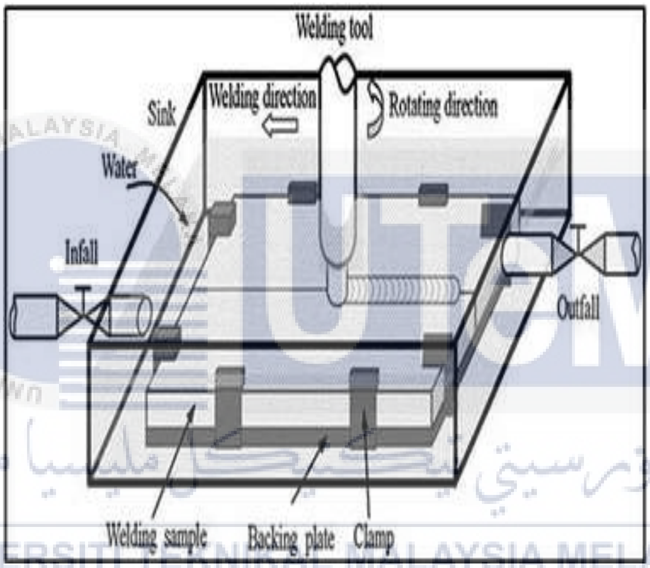


Figure 2.2 Schematic diagram of Underwater FSW

2.3 Welding Tools

The introduction of new welding tools has enabled many of the advancements gained in friction stir welding. The design of the welding tool, particularly its shape and the material from which it is manufactured, is important to the process's success.

2.3.1 Introduction Of Friction Stir Welding Tools

FSW is a solid-state joining process that involves combining two faying weld parts with a non-consuming tool. The tool's movement is a combination of translational and rotational movement, and it must fulfill two main functions. To form a junction, frictional heating of the workpieces and material stirring are used. (P. Podrzaj et al, 2014)

The heating of the workpiece is caused by the related friction between the tool and the workpiece, as well as the plastic deformation of the workpiece material, due to the axial (vertical) force acting on the tool. The two major parameters determine the rate of energy input due to friction. The first is the tool's rotating speed, while the second is the tool's translational speed. The material, heat treatment, and geometry of the FSW tool are also critical. Figure 2.4, for example, depicts various shoulder forms.

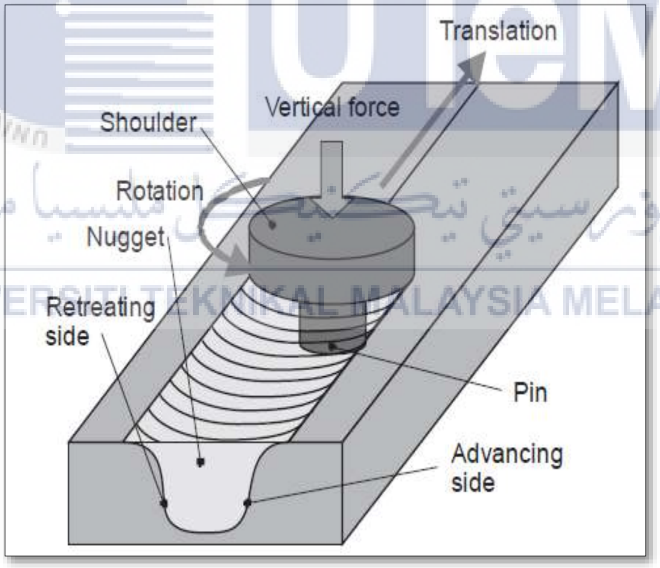


Figure 2.3 A Friction Stir Welding Schematic is depicted in this diagram (FSW)

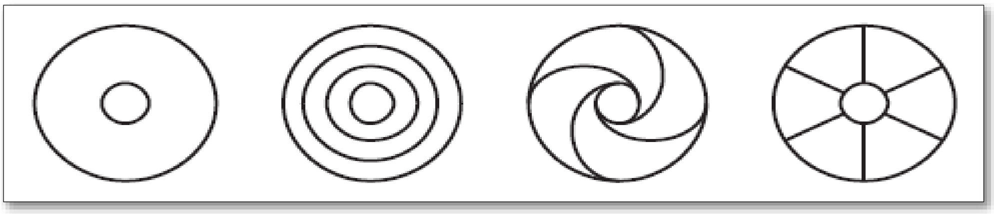


Figure 2.4 Various forms of shoulders (shown from underneath)

Figure 2.5, on the other hand, displays the most frequent types of tool pins in a cross section and side view, according to (S. Boopathi, 2017). The cross section can be shaped in a variety of ways. A pin with four flutes is seen in the last two instances in the upper row of Figure 2.5. Three-flute pins are also extremely frequent. These flutes frequently twist in a vertical direction. The tools that do not require a pin were also evaluated. It's also worth noting that the gadget is frequently slanted.

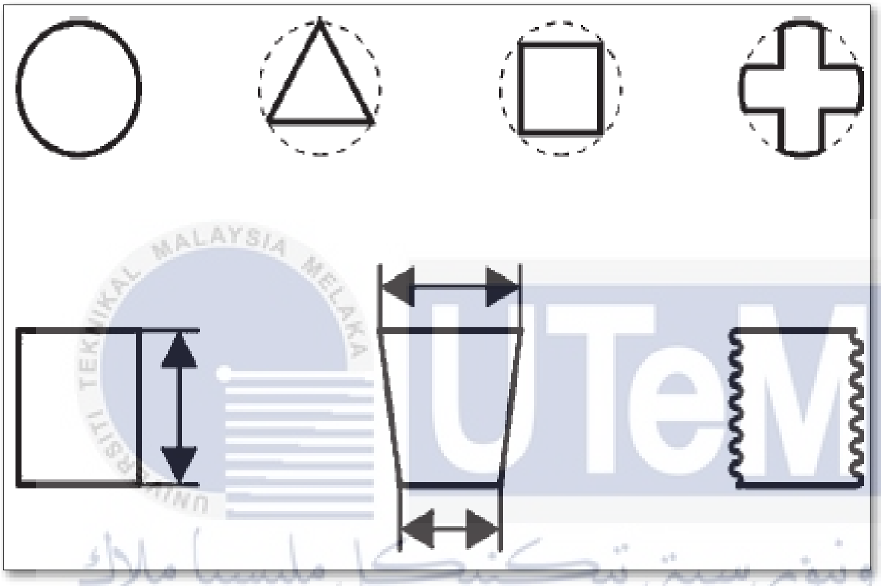


Figure 2.5 Tool pins come in a variety of shapes and sizes. (a cross section and side view)

2.3.1.1 Tool Steel as Friction Stir Welding

Cold work is commonly done with AISI D2, a high-carbon, high-chromium ledeburite tool steel. The breakdown of alloying elements and the precipitation of carbides give it its high strength, hardness, and wear resistance. The mechanical properties of AISI D2 steel are influenced by alloying components, austenite grain size, sub-grain size, martensite lath width, dislocation density, and precipitates. The number, kind, size distribution, form, stability, and geographical distribution of precipitates all have a role in the relationship between hardness and hardness. The size, shape, and distribution of the eutectic carbides, which are mostly determined by the hot working conditions, soaking temperature, and time between forging cycles, affect the steel's performance. Therefore, the production process parameters may be used to change the size and number of precipitates. (G. Sucharitha,2017)

2.3.2 AISI D2 Steel Tool Properties

AISI D2 steel is an air harden able high-carbon, high-chromium tool steel. It has a high level of wear and abrasion resistance. It has a hardness of 55-62 HRC and may be heat treated. In the annealed form, it is also machinable. AISI D2 steel has a minimal deformation when suitably hardened. When hardened, AISI D2 steel's high chromium content gives limited corrosion resistance.

2.3.2.1 AISI D2 Steel Tool Application

As Refer to website (steelexpress.co.uk) typical applications for AISI D2 steel are:

- Stamping or Forming Dies
- Punches
- Forming Rolls
- Knives, slitters, shear blades
- Tools
- Scrap choppers
- Tyre shredders

2.4 Jig and Fixture

Charles and Okechukwu (2015) define jigs and fixtures as "manufacturing equipment used to create interchangeable and identical components." Jigs and fixtures are specialized tool-guiding and work-holding devices used to machine and assemble large quantities of parts. Jigs and fixtures are used for a variety of reasons, including cost reduction, increased production rate, high accuracy of products with no manufacturing defects, interchangeability, easy machining of complex shaped parts, and quality reduction.

Jigs and fixtures eliminate the need for a separate set-up for each workpiece, allowing for speedier production and ensuring that each component is manufactured to exacting tolerances. Jigs vary from fixtures in that they guide the cutting tool to its exact location while simultaneously locating and supporting the workpiece. The essential features of jigs and features include:

1. Clamp position
2. Neatness of workpiece
3. Idle time reduction
4. Hardened surfaces

Jigs and fixtures are used in manufacturing to make goods that are quicker, more precise, and more dependable while also being less expensive.

2.4.1 Jig

During machining processes, a jig is a work-holding device that supports, holds, locates, and directs a workpiece. Its main purpose is to provide high levels of accuracy, interchangeability, and duplication in item manufacture, but it may also be used to adjust the placement and movement of other tools. A jig is a kind of custom-made tool used to regulate the placement and motion of another instrument, according to H Radhwan (2019). They realized that in product production, the main goal of a jig is to assure reproducibility, precision, and interchangeability. The most common jigs are drilling and boring jigs, as seen in Figure 2.6 Common Jigs.

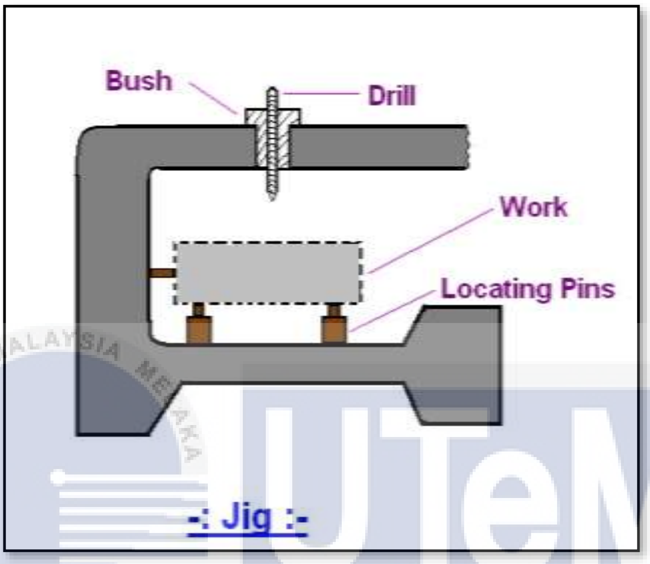


Figure 2.6 Common jig

2.4.2 Fixture

A Fixtures are sturdy and durable mechanical devices that enable for high-speed, high-precision machining with consistent quality, interchangeability, and reduced lead times. Fixtures do not position, guide, or locate the cutting tool as a work holding mechanism; this is achieved by making appropriate adjustments on the machine. The “main purpose of a fixture,” according to Charles and Okechukwu (2015), is to “locate and, in certain instances, retain a work-piece throughout either a machining operation or some other industrial processes.” Fixtures are different in that they are all built to suit a given form or section, according to him. Figure 2.7 displays a typical fixture.

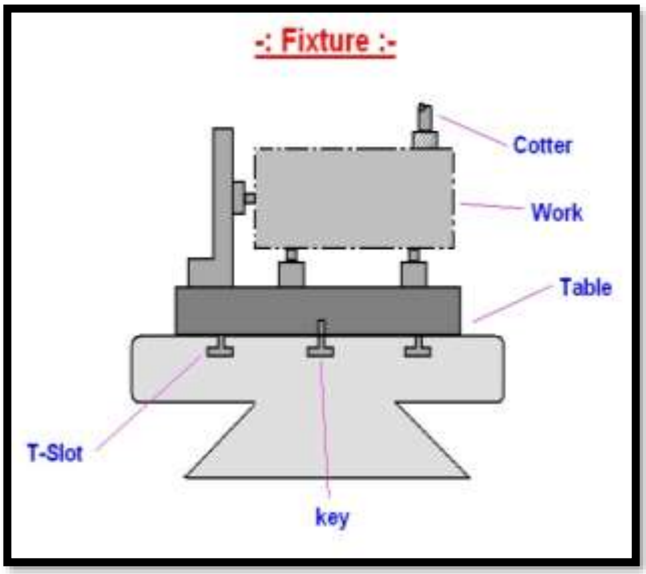


Figure 2.7 Typical Fixture

While fixtures are always identifiable by the machine tool to which they are attached, they have a broader use than jigs and are designed for operations where the cutting tools, such as drilling or boring tools, cannot be easily manipulated. Welding fixtures, tapping fixtures, milling fixtures, bore-ring and drilling fixtures, milling fixtures, turning fixtures, and so on are examples of different types of fixtures.

2.5 Previous Study Aluminum Alloy in FSW

Weldability, machinability, low strength, good corrosion resistance, strong formability, and low weight are only a few of the benefits afforded by aluminium alloys. The chemical composition of aluminium alloy 6061 was used: 97.57 percent aluminium, 0.525 percent silicon, 0.339 percent iron, 1.062 percent magnesium, 0.120 percent copper, and 0.080 percent manganese (Dawood et al., 2015). The lap junction between A6061-T6 aluminium alloy and ultra-low carbon steel has been successfully developed by FSW (Helal et al., 2019). FSW investigated the joint tensile strength, toughness, and fracture behaviour of two distinct pin profiles of AA6061-T6 to AA 2014-T6 at varied spindle speeds and feed rates (Raturi et al., 2019). In dry and submerged circumstances, friction stir welding of AA6061-T6 and AISI-304 (thin sheet) at different values of and PD was accomplished (Mahto et al., 2019). The influence of cooling medium water on the mechanical characteristics of AA6061 joints generated by the FSW method has been investigated via experimental experiments (Fathi et al., 2019).

On the aluminium alloy 6061, the influence of the water cooling medium on the microstructure and mechanical characteristics of Underwater Friction Stir Spot Welding (UFSSW) and Friction Stir Spot Welding (FSSW) was investigated (Shekhawat et al., 2020). Previous investigations looked into the effect of welding speed during FSW on the following reactivity of an AA6061-T6 aluminium alloy (Malopheyev et al., 2016). FSW aluminium alloy 6061-T6 joints were examined for microstructure, microhardness, tensile strength, impact characteristics, and fatigue crack growth behaviour (Zhang et al., 2020). Friction-welded joints of 6061-T6 aluminium alloy were used to assess microstructure, residual stress, microhardness, and fatigue performance (Abdulstaar et al., 2017). Previous research has shown that the aluminium alloy 6061 may be used in the Friction Stir Welding technique.

2.5.1 Aluminium Alloy 6061 Series

Aluminum alloys are contemporary structural materials utilized in many engineering components due to their low density and excellent mechanical properties (I. Zagórski and T. Warda, 2018). Transportation sectors have been driven to lower the weight of their goods due to environmental concerns and tight greenhouse gas emission limits. Replacement of typical stainless steel raw materials with lightweight materials such as aluminum and magnesium alloys or composites has become a popular and effective technique to meeting weight requirements. The high strength-to-weight ratio, strong corrosion resistance, and comparatively inexpensive prices compared to the compound have all been employed widely for automotive and aviation constructions in the lightweight materials family.

Panel components, which account for a substantial amount of the body structure bulk, have been the subject of much study for automotive applications. The usage of high-strength aluminum alloys in the past helped to reduce the poor ductility at room temperature. Rapid advancements in forming technology have lately resulted in the production of sophisticated, high-speed aluminum panel components, which have substantially broadened their uses. The white body structures of several premium automobiles, such as Jaguar, Land Rover, and Audi, are built of aluminum alloys (N. R. Harrison et al, 2014). Even though this alloy is the strongest, the manufacturer has developed a vehicle that crashes such that the crumpled region absorbs the impact and protects the passengers. When an accident occurs, the material should absorb the force of immersion rather than the car's rigid construction.

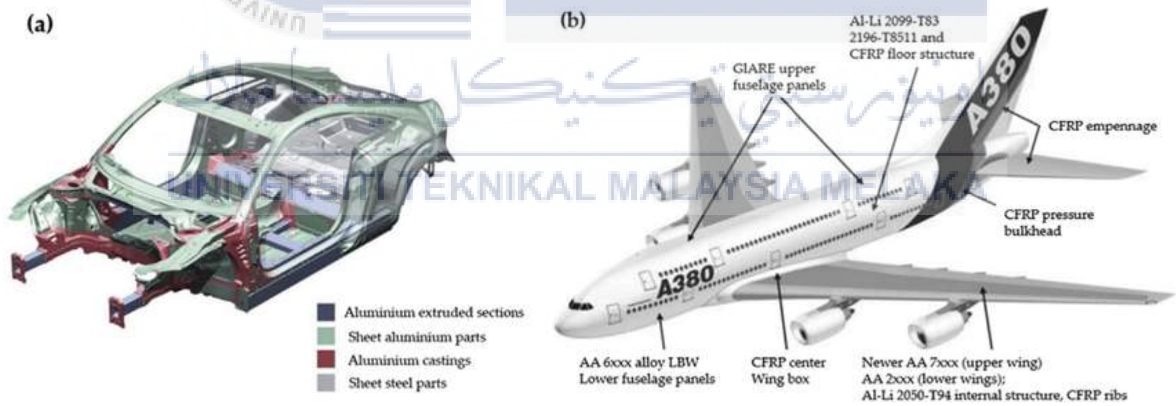


Figure 2.8 Aluminum alloy panel structures used in automobiles and aircraft: (a) Audi TT coupe and (b) Airbus 380

Aluminum alloy AA6061 was created, which has a high weight-to-strength ratio and excellent corrosion resistance. Because of its widespread use in the industrial industry, researchers have conducted much study on it. Liu et al. investigated the tensile strength of AA6061 that had been friction stir welded and discovered that the welding speed enhanced the tensile strength. The mechanical characteristics of two linked AA6061 plates by friction stir tool are determined by the welding speed, according to Li et al.

Table 2.1 Chemical composition of aluminium alloy AA6061 series

Al	Mn	Si	Fe	Zn	Ti	Cr	Mg	Cu
Bal	0.03	0.61	0.20	0.02	0.01	0.13	0.81	0.29

Table 2.2 Main chemical compositions of some aluminium alloys (wt%). (Kailun Zheng et

Material	Chemical compositions							
	Mn	Si	Fe	Zn	Ti	Cr	Mg	Cu
AA5754	0.24	0.03	0.26	<0.01	<0.01	<0.01	3.0	0.02
AA2024	0.50	0.41	0.40	0.20	0.12	0.07	1.5	4.5
AA6082	0.68	1.05	0.26	0.02	0.01	0.01	0.80	0.04
AA7075	0.04	0.07	0.22	5.40	0.02	0.19	2.20	1.40

2.6 Surface Roughness

Friction stir welding (FSW) surface topography has a significant impact on joint performance. According to Rajesh Kumar Bhushan (2020), Surface roughness and topography are essential factors in determining component surface quality and performance (such as wear resistance, fatigue characteristics, and stress corrosion resistance). The greater the surface roughness, the greater the stress concentration, resulting in fatigue damage and a loss in part fatigue strength. Supplementarily, in the much previous study, (Deepak Sharma, 2020) stated that ss the surface roughness and weld distortion of the linked sheets rise, so does the weld strength.

Continuously, (Sano et al., 2012) in their research acknowledged that, the fatigue strength of unwelded specimens (base material; BM) was 110 MPa at 107 cycles, and LPwC increased the strength by 60 MPa despite an increase in surface roughness due to the laser pulses being irradiated directly to the naked surface of the specimens.

Figure 2.9 Surface Topography of UFSW

2.7 Welding Morphology

According to (S.T.Selvani,2021) due to their high strength-to-weight ratio, good formability, and considerable machinability, aluminium alloys are considered weightless components in industrial applications such as structural, architectural, and aviation assembly. While weight reduction has a little influence on manufacturing costs, it has a significant impact on the life cycle cost of aluminium alloys. Generally, due to changes in the phase composition and microstructure during the welding process, aluminium is more active and susceptible to pitting type corrosion and stress corrosion cracking.

In previous study done by (Ragu, Balasubramanian, Malarvizhi and Rao, 2015) the chemical composition of the filler metal and the process heat input have a significant effect on the microstructure of fusion welded connections. In general, more heat input results in a slower cooling rate, resulting in coarse grains in the welded metal. Reduced heat input, on the other hand, results in a rapid cooling rate, which results in a fine microstructure. While a lower heat input may result in finer grains than a larger heat input, the intrinsic character of the process also contributes significantly to the refinement of the weld metal microstructure.

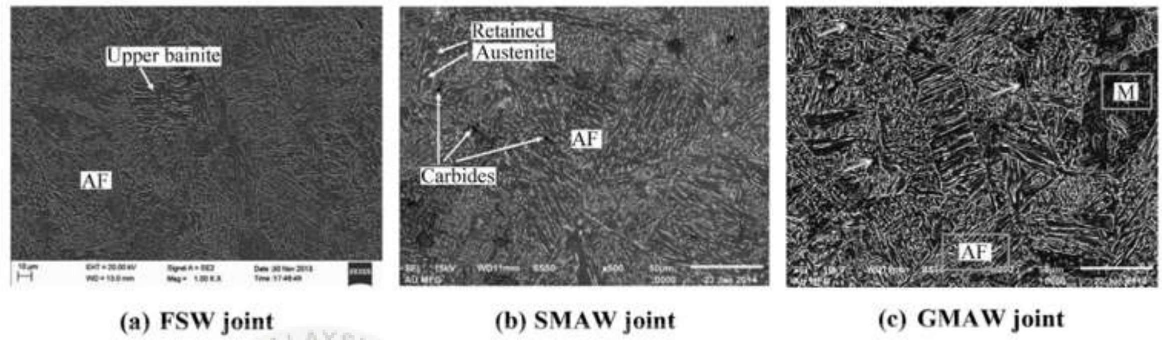


Figure 2.10 SEm Micrographs of weld metal region

In figure 2.10 show as the FSW method delivers a lower heat input (1.05 kJ/mm) to the weld area than the SMAW and GMAW procedures, which provide 1.493 kJ/mm and 1.530 kJ/mm, respectively. While the rapid cooling rate (i.e., decreased heat input) and mechanical action for refining the microstructure process are connected, it is feasible to create higher bainite with a trace of acicular ferrite. This might be one of the causes for the presence of higher bainite grains in the stir zone in the FSW joint.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter delves into the correlation of microstructure - surface roughness effect on Friction Stir Welding lap joint using AA6061 Aluminum Alloy during dry and underwater friction stir welding (UFSW). Based on past research, the students or instructors investigated, tested, and demonstrated the influence of aluminum Alloy AA6061. This material will provide a better idea of how this work will be done, as well as the studies and processes that will be used to determine the best field and area for this project. This chapter shows how to meet the specified goals in Chapter 1 from the tool bit preparation to the final test.

3.2 Research Design

This research presents an integrated analytical technique for determining the effect of surface roughness and microstructure grain on aluminum alloy plate while friction stir welding in dry and underwater conditions with various tool pin types.

3.3 Proposed Methology

A flowchart is a graphical representation of a problem-solving process that shows each stage in the process. When it's important to illustrate connectivity between key components that don't include little bits, a process flow chart is employed in production engineering. This flowchart depicts the general flow of the project, as well as the procedures and equipment required to complete it.

A Conventional Lathe Machine and CNC Milling Machine is utilized in this project to build the tool FSW, which is made of AISI D2 Steel round bar material and is responsible for forming the tool's tip into an accurate and precise size and diameter. The tool is manufactured of AISI D2 steel, which provides excellent harness and is hence ideal for this purpose. After the tool has been manufactured, the Friction Stir Welding operation will be performed using a Conventional Milling Machine in condition dry and underwater testing. This procedure is carried out utilizing many types of tool pins with varying parameters, including the spindle, and welding speed rate, for the experiment settings.

Following that, the workpieces will be tested for surface roughness using a Mitutoyo Surface Roughness tester. After that, this workpiece has been cut into specimen using an EDM wire cut machine. Next, before being tested in the Scanning Electron Microscopy (SEM), this workpiece has been polished first using Metallographic Polishing Machine. Finally, the FSW sample will be used to determine the microstrucuture using Scanning Electron Microscopy (SEM). Following that, the specimen will be analyzed to see how the surface roughness of the two overlapping aluminum alloy sheets affected the microscopic structure during friction stir welding in both dry and underwater settings. The data acquired via this observation and analysis will be analyzed and compared to arrive at the optimal result for the various kinds of tool pins used.

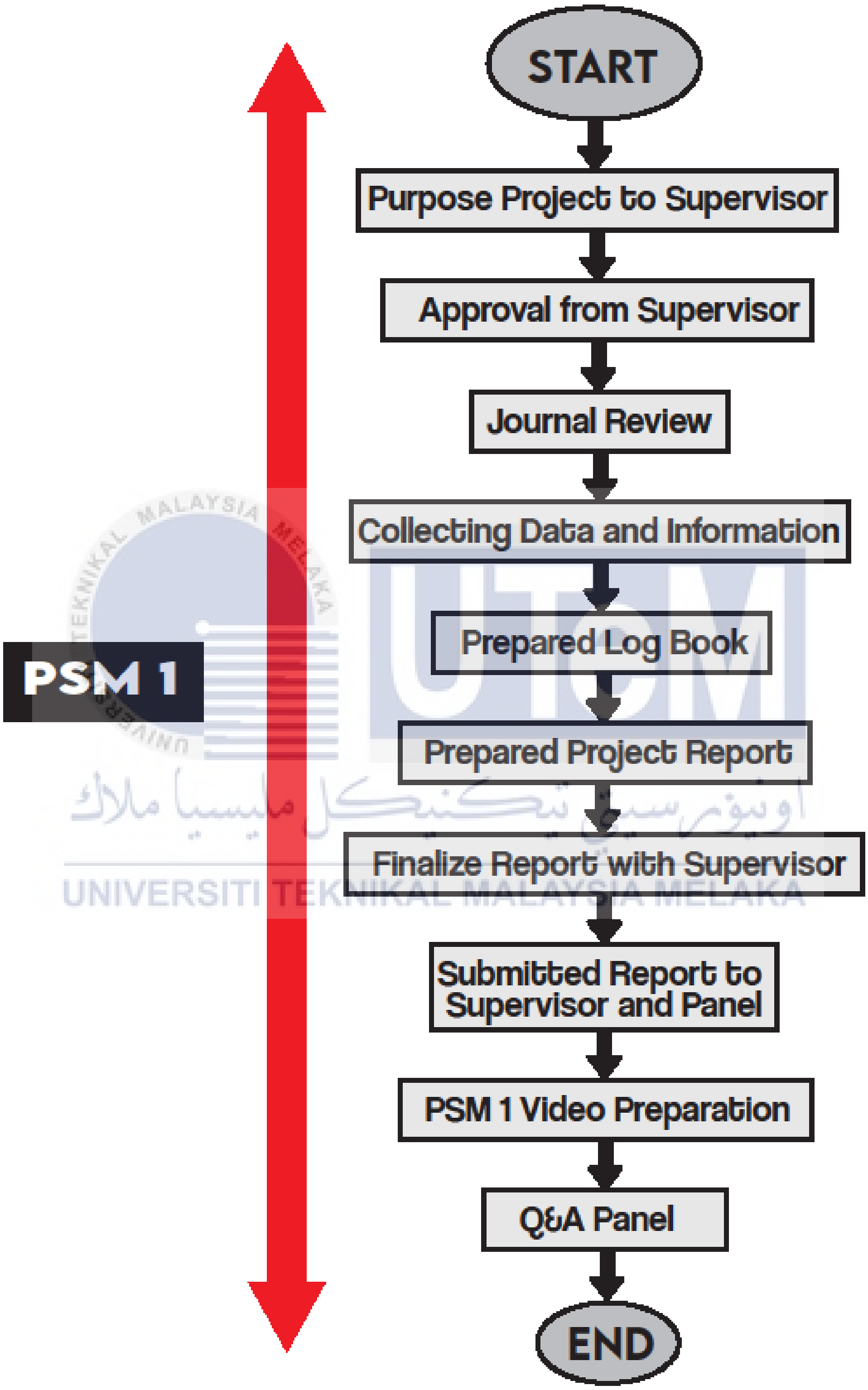


Figure 3.1 Project 1 Flow Chart

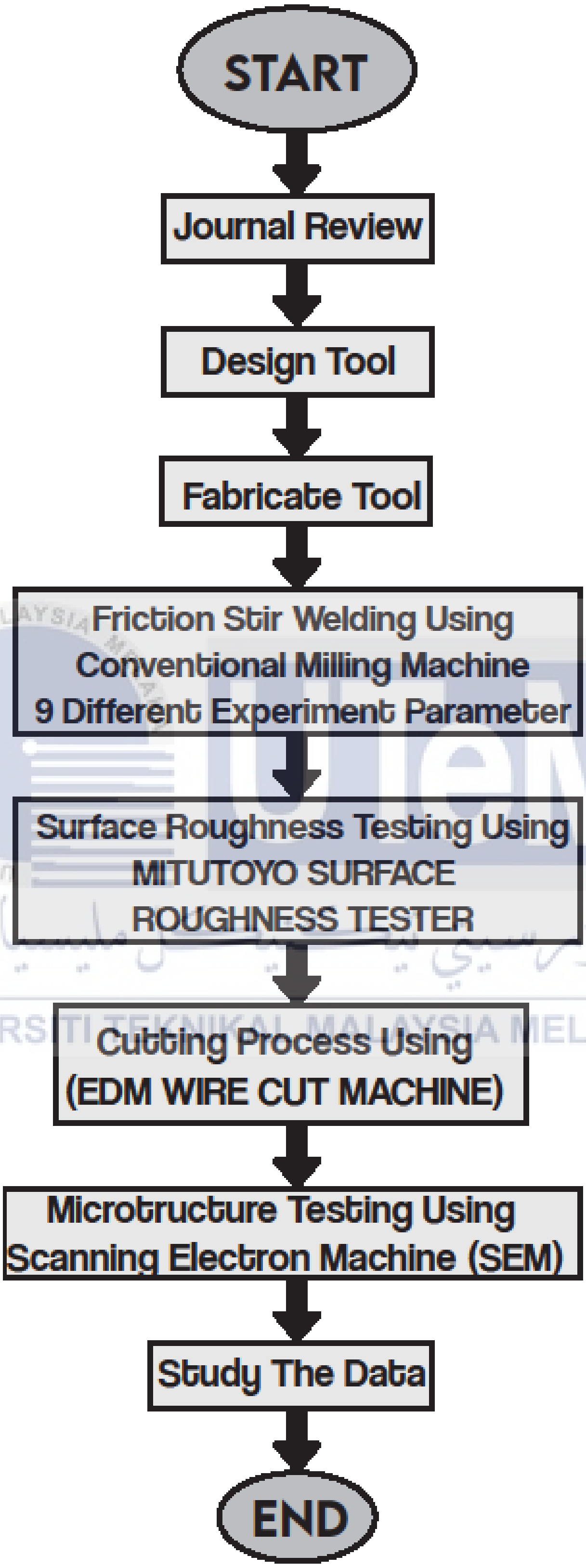


Figure 3.2 Project 2 Flow Chart

3.3.1 Experiment Setup

The experiment will be set up to begin the project in this topic. To begin, the design and material chosen for the tool bit. Second, the tool is made from AISI D2 Steel. Next, aluminum alloy 6601 was chosen as the workpiece's material. In completing the project, run the FSW, prepared for surface roughness testing and microstructure testing as well.

3.3.1.1 Friction Stir Welding Tool Fabrication

Tool is very important to complete this project. Diameter of the tool material of the round bar is 50 mm whereby the mechanical properties is AISI D2 Steel.

a) Tool Design

The tool will be designed using the SOLIDWORKS software. The tool was designed with a 25 mm holder that is compatible with collet chuck tool holders. Apart from that, the tool's total length is 50.9 mm. The design and operation of the Friction Stir Welding Tool are illustrated in Figures 3.3 to 3.8.

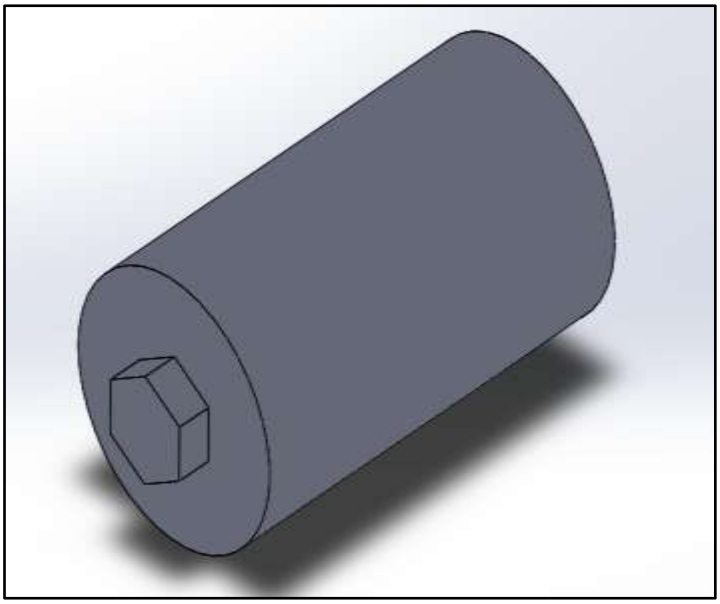


Figure 3.3 Hexagon Toolbit as Tool 1

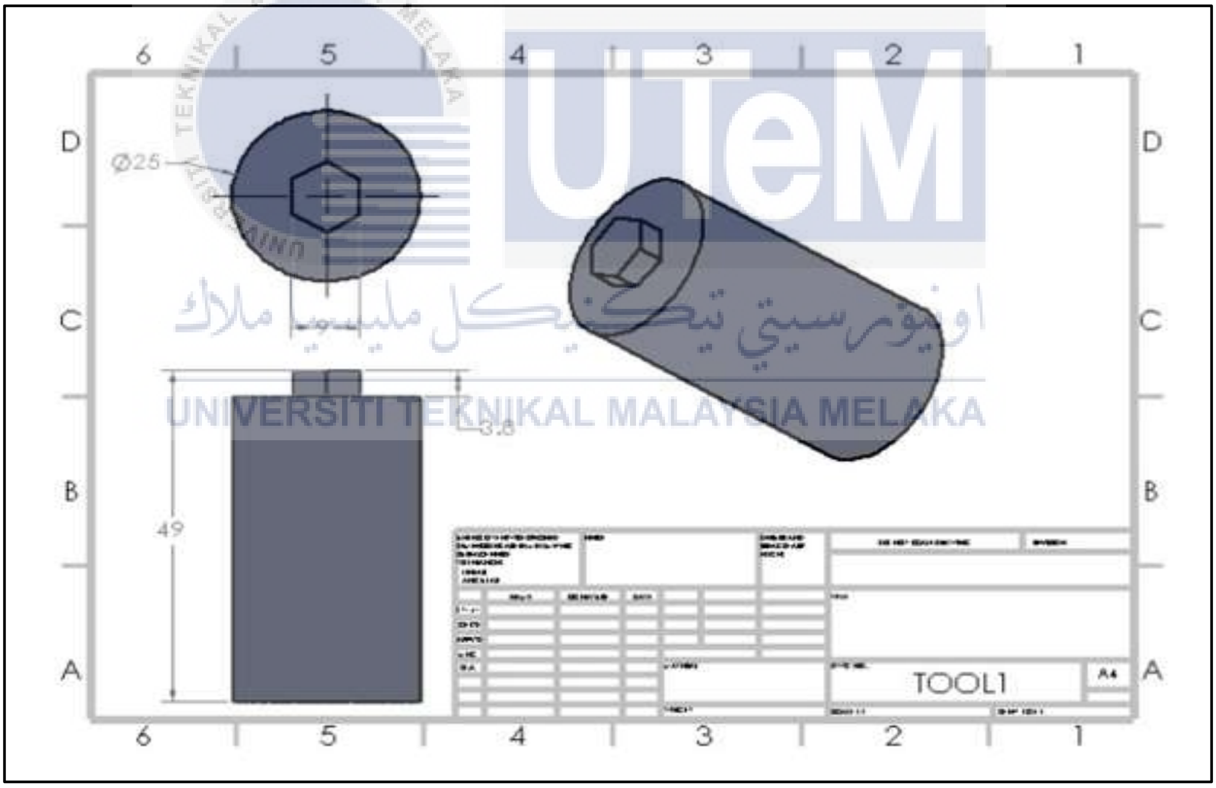


Figure 3.4 Tool 1 Drawing

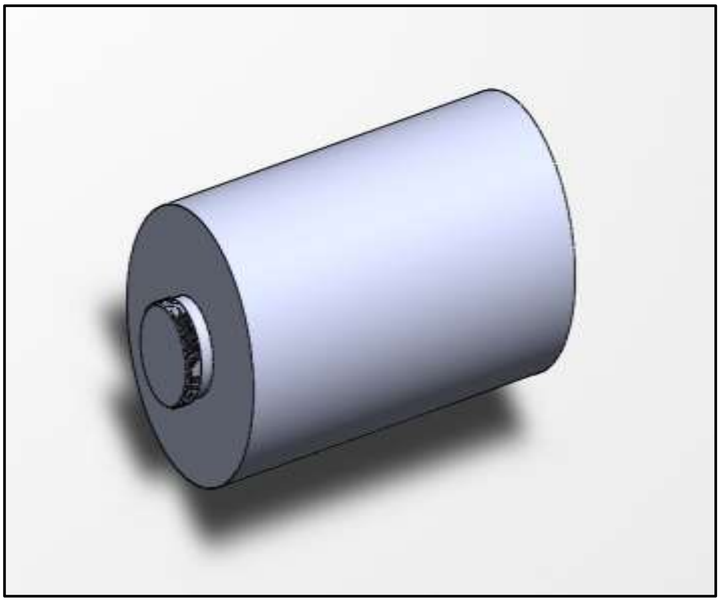


Figure 3.5 Thread toolbit as Tool 2

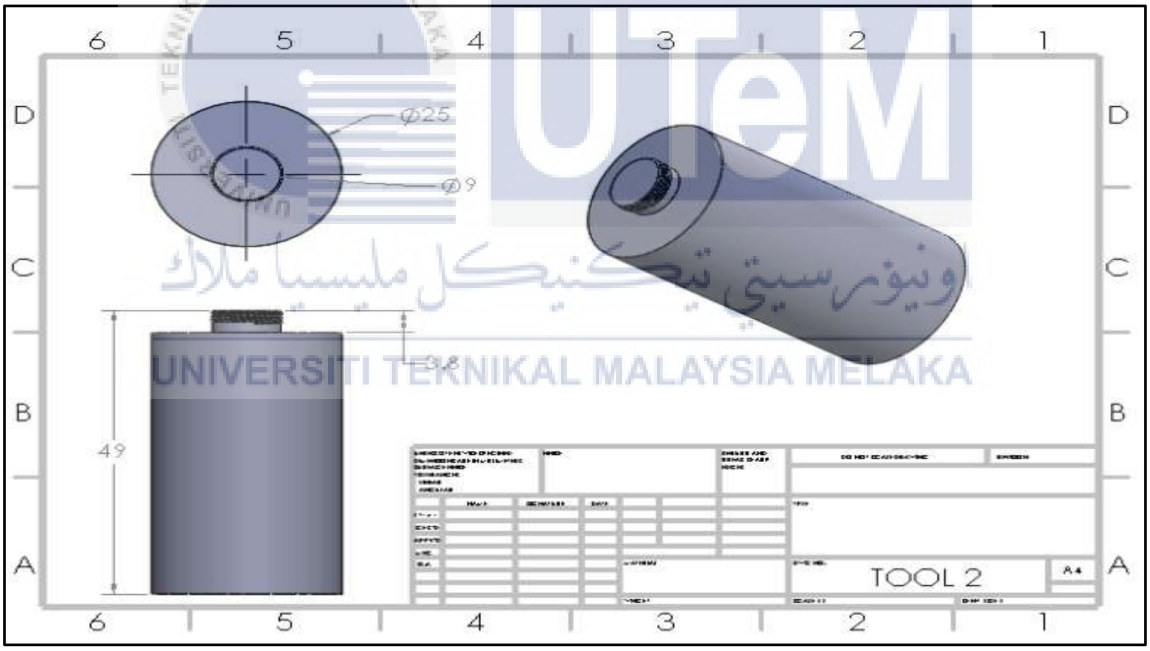


Figure 3.6 Tool 2 Drawing

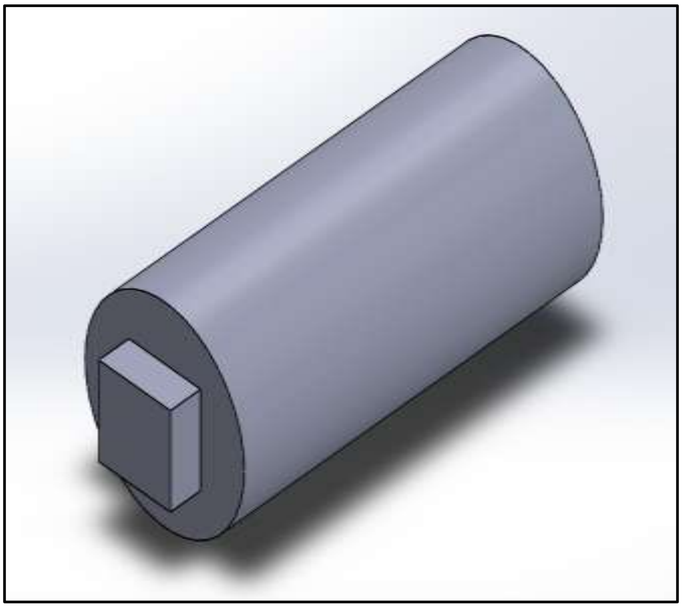


Figure 3.7 Square Toolbit as Tool 3

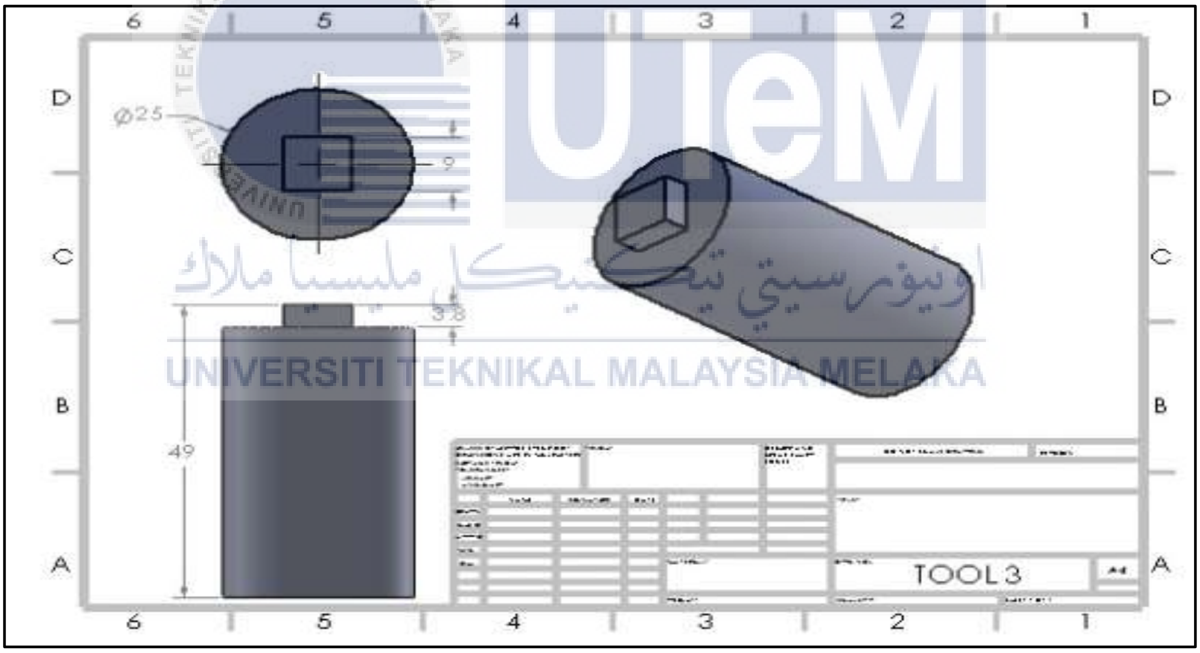


Figure 3.8 Tool 3 Drawing

b) Fabrication of Tool using Conventional Lathe Machine

Conventional Turning Machine OPTi turn D 420 x 1000 has been used followed with AISI D2 Steel as tool material. This process is to remove initial shoulder diameter from 30mm to 25mm as per CAD Design.

Figure 3.9 Process to Remove Initial Diameter using Conventional Turning Machine

Figure 3.10 shows Conventional Turning Machine OPTi turn D 420 x 1000 and Table 3.1 show the specification of Conventional Turning Machine OPTi turn D 420 x 1000.

Figure 3.10 Conventional Turning Machine

Table 3.1 Conventional Turning Machine Specification

DESIGNATION	UNIT	VALUE
Machine data		
Electrical connection	V	400
Total connector value	kW	4.5
Working area		
Center height	Mm	210
Center widht	Mm	1000
Bed width	Mm	250
Speed		
Spindle speed	mm-1	45-1800
Number of step		16
Dimension		
Length	Mm	2025
Width x Height	Mm	915 x 1375
Net weight	Kg	1550
Slide		
Travel top slide	Mm	140
Travel cross slide	Mm	230

c) Fabrication of Tool using CNC Lathe Machine

After determining the dimensions of the tool's shoulder and holder, the material will be CNC Lathed to ensure the proper dimension and form of the tool's tip. The machine that will be utilized is a CTX 310 Ecoline CNC Lathe. In compared to a typical lathe, a CNC lathe was precise and could be set up automatically. The CNC milling machine was not used to make the tool tip since the CNC lathe is more convenient due to the cylindrical form of the tool.

Figure 3.11 Process to make the tool tip

Figure 3.12 Thread type tools

The CTX 310 Ecoline CNC Lathe's specifications and figure are shown in the table 3.2 and figure 3.13 below.

Figure 3.13 CNC Milling Machine

Table 3.2 Specification of CNC Milling Machine

DESIGNATION	VALUE	UNIT
Chuck		
Chuck Diamter	210	mm
Max Chuck Diameter	200	mm
Working Area		
Max. X Travels	600	mm
Max. Z Stravels	500	mm
Workpiece Dimension		
Max. Workpiece Diamter	200	mm
Spindle		
Standard Speed	5000	rpm
Spindle Bore	68.5	mm
Tool Magazine		
Number Of Tool On Turret	12	
Number Of Rotating Tools	6	
Travel Path		
Max. X Axis	160	mm
Max. Z Axis	450	mm

3.3.1.2 Friction Stir Welding process

FSW is a linked thermomechanical process in which heat, and mass transfer alter weld characteristics and microstructure. Base material is heated by the frictional heat generated by the shoulder and agitated by the spinning pin as it passes along the weld line.

a) Raw Material

After went thru the research, aluminum alloy 6601 plate will be used as main component of workpiece which mean will have two plates of AA6061 will be joined. Characteristic of the workpiece as shown as figure 3.14 where the dimension is 120 mm x 50mm x 2mm. According to melting temperature of AA6061, it should be able to be joined using Friction Stir Welding even though thickness of the workpiece only 2mm.

Furthermore, the mentioned size also is to fit onto the jig that will be used during Friction Stir Welding process.

Figure 3.14 Workpice Aluminium Plate

b) Jig and Fixture

A jig is a tool that holds and locates a workpiece while also guiding and controlling one or more cutting tools. The work is held in true positions relative to the tool, and the tool is guided in real positions related to the work. A jig in construction is made up of a plate, a structure, and a box made of metal or non-metal with provisions for holding the components in identical positions one after the other, and then guiding the tool in the correct position on the work in accordance with the drawing, specification, or blueprint.

Figure 3.15 Templete Jig

c) Welding Process

Conventional Milling Machine is the main machine to run the FSW process. This function is to collect data with different parameters to run FSW on plate AA6061 using Conventional Milling Machine Full Mark FVH-260S.

Figure 3.16 Welding process for Dry Friction Stir Welding

Figure 3.17 Welding process for Underwater Friction Stir Welding

Table 3.3 and Figure 3.18 show the specification and detail of the Conventional Milling Machine.

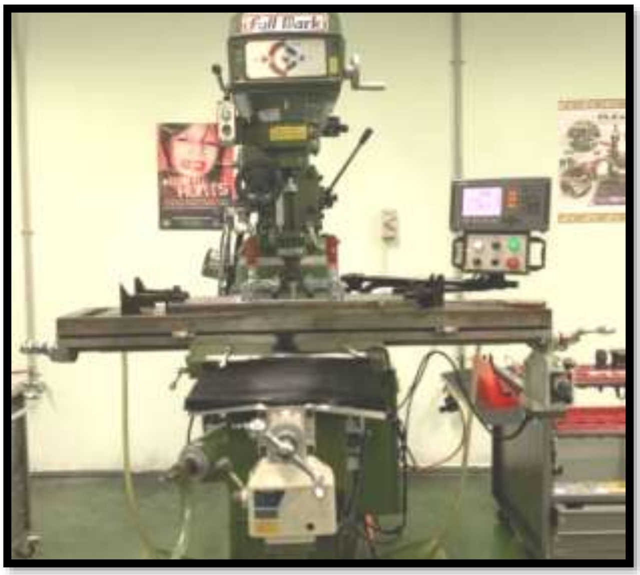


Figure 3.18 Conventional Milling Machine

Table 3.3 Specfication of Conventional Milling Machine

DESIGNATION	UNIT	VALUE
	Table dimension	
Max. Table load	Kg	300
Working surface	Mm	300 x 1370
	Spindle speed	
Vertical spindle speed (50hz)	Rpm	73, 163, 193, 201, 428, 471, 527, 1046,1288
Head tilting	Degree	45 right/left
	Feed rate	
Gear Feed X,Y axis	Mm/min	0-1300 (rapid feed)
	Motor	
Vertical & horizontal spindle (5HP)	kW	3.7
Coolant Pump	HP	1/8

d) Welding Parameter

The parameter is essential for the successful completion of each experiment. This project's experimental parameters are spindle speed, welding speed, and tool pin form. The first option is the tool pin profile, which may be hexagonal, threaded, or square in form. Following that, the spindle speed parameter is set to 1400rpm, 1575rpm, or 1750rpm for dry and underwater condition. Finally, the welding speed is adjusted to 20mm/min, 25mm/min and 30mm/min. The table below summarizes the project's many experimental parameters.

Table 3.4 Welding parameters for dry and underwater friction stir welding

EXPERIMENT NO	TOOL PIN PROFILE	SPINDLE SPEED (RPM)	FEED RATE (mm/min)
1	Hexagon	1400	20
2	Hexagon	1575	25
3	Hexagon	1750	30
4	Thread	1400	20
5	Thread	1575	25
6	Thread	1750	30
7	Square	1400	20
8	Square	1575	25
9	Square	1750	30

3.3.1.3 Surface Roughness Testing

After the FSW procedure has done, the first testing has been carried out which is the surface roughness testing. In this testing, Mitutoyo Surface Roughness Tester has been used.

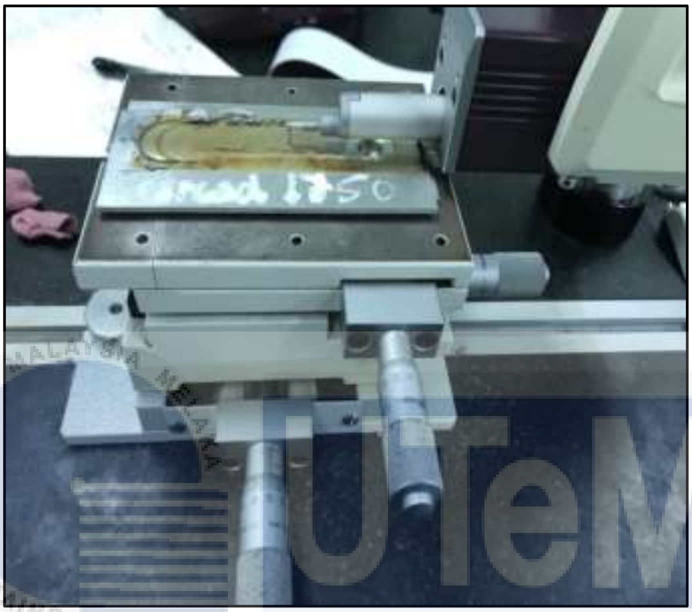


Figure 3.19 Surface Roughness test

The specification of the machine is as on the figure 3.20 and table 3.5 below.

Figure 3.20 Mitutoyo Surface Roughness Machine

Table 3.5 Mitutoyo Surface Roughness Tester Specification

TECHNICAL SPECIFICATIONS	
Table Dimensions	130 x 220 mm
Maximum load	15 kg
Inclination adjustment angle	±15°
Swiveling angle	±3°
X/Y-axis travel range	±12.5mm
Machine dimensions (W x D x H)	262 × 233 × 83mm

3.3.1.4 Specimen Preparation for Testing Scanning Electron Microscopy (SEM)

Metallography is the technique of uncovering microstructural information on a specimen's metal surface. There are four primary steps in metallographic techniques:

a) Cutting.
b) Polishing and Etching.
c) Microstructure Examination.

a) Cutting

After the FSW process completed, the workpieces must be cut into the specimen test. The cutting operation will be carried out using an EDM Wire Cut Sodick VZ300L Machine.

Figure 3.21 Process of cutting the specimen

The specifications and details of the EDM Wire Cut Machine are shown in Table 3.6 and Figure 3.22.

Figure 3.22 EDM Wire Cut Machine

Table 3.6 Specification of EDM Wire Cut Machine

TECHNICAL SPECIFICATION	
X/Y/Z Axis Travel	350 X 250 X 220 mm
U/V Axis Travel	80 X 80 mm
WORK Tank Dimension (W x D x H)	810 x 650 mm
Max. Workpiece Weight	500 kg
Distance from floor to tabletop	900 mm
Macine Dimension (W x D x H)	1895 x 2180 x 1960 mm
Machine Installion dimension	2600 x 2950 mm
Machine Weight	2400 kg
Taper Angle	±15°
Wire Diameter	D 0.15 mm ~ D 0.3 mm
Wire Tension	3-23 N
Max. Wire Speed	420 mm/sec
Max. Workpiece dimensions (W x D x H)	780 x 570 x 215 mm
Controlled axis	5

b) Polish and Etching

Grinding is used to reduce the thickness of the damaged layer caused by the sectioning process. Figure 3.23 depicts the grinder machine used in this procedure. It's usually done using revolving discs coated with SiC sheets and lubricated with coolant. As illustrated in Table 3, several available grades of 400, 600, 800, and 1200 grit (grains per square inch) were employed. Light pressure was given to the sample's centre during the grinding operation. The flatness of the sample surface must be maintained throughout the grinding operation.

Figure 3.23 Process of polishing specimen

The following are the specifications for the metallographic polishing machine:

Figure 3.24 Metallographic Polishing Machine

Table 3.7 Metallographic Polishing Machine Specifications

TECHNICAL SPECIFICATION	
Rotation Speed	20-70 RPM
Power Supply	230 V
Pressure	Individual
Motor Power	750 W

Figure 3.25 Finishing mechanism after polishing

Polishing is done until mirror-like surface is achieved. Steps involved in polishing are described as follow:

a) Keller's reagent is mixed.

b) Reagent is applied on the sample surface by using cotton swab or by immersing about 5 seconds. Etching is done in stages to avoid over etching.

c) Sample is washed with running distilled water and followed with alcohol. iv. The sample is checked with optical microscope. If microstructure still can’t be seen, etching process need to be repeated.

The goal of etching is to expose the metal's microstructure by targeted chemical assault. It's also significant for exposing grain size, rolling direction, and welding zone, among other things. Figure 20 shows the etching apparatus in action. The sample is etched by swabbing it with a cotton tip soaked in etchant or immersing it in it. Beginning with light assault, a microscope analysis, and only additional etching, if necessary, the procedure should always be done in phases. The polishing technique must be repeated on an over-etched sample. Keller's reagent is used as an etchant for aluminum. Keller's reagent is made up of the following ingredients:

i. Impurity of aluminum plates

ii. Incorrect method uses during grinding and polishing

c) Microstucture Examination

Zeiss EVO SEM Machine is used for Scanning Electron Microscopy (SEM). Microscopic examination is utilized to determine the microstructure grain of the workpiece's welded zone.

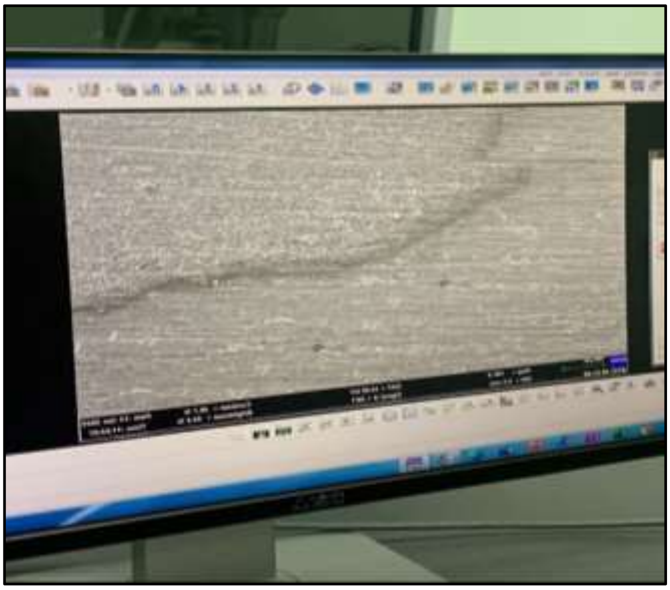


Figure 3.26 Prosess of scan microstructure

The specfication of the machine are as follows:

Figure 3.27 Zeiss EVO SEM Machine

Table 3.8 Zeiss EVO SEM Machine Application

TECHNICAL SPECIFICATIONS	
Max. Specimen heights	100 mm
Max. Speciment Diamater	230 mm
Max. Speciment 1 testing	8x
Motorized Stage Travel XYZ	80 x 100 x 35 mm

3.4 Limitation of Proposed Methology

i. Planning to conduct the welding process using Advanced Welding Machine, because of the machine unable to run the spindle above 900rpm, decided changed the planned to Conventional Milling Machine to run the machine with studied parameters.

ii. Another issue is thread of the tool tip, which changed from a shape tip tool to a round tool after the first run on the machine. This happens because the tool can't handle the friction throughout the procedure. As a result, only one sample of the Thread tool bit form may be made. The result isn't very conclusive since only 6 samples can be made from three tools.

3.5 Summary

As a summary, all equipment, and facilities at Faculty of Mechanical and Manufacturing Engineering Technology Laboratories in UTeM are verry helpful and functional in completing the studies.

Development all the preparations which is processes must be carried out properly as per flow chart into getting desire result to ensure that achieve the objectives. A part of that, communication with supervisor is play important roles to specify the error occur.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Intorduction

The findings of the experimental tests will be methodically evaluated and contrasted using graphs and tables in this chapter, which will be followed by research based on types of samples of Aluminum Alloy 6061 with Friction Stir Welding in dry and underwater conditions. Surface Roughness Testing and Scanning Electron Microscopy were used to examine the responsive samples (SEM). The Surface Roughness Tester from Mitutoyo will be used, and the Zeiss EVO SEM Machine will be used for Scanning Electron Microscopy (SEM).

4.2 Result and Analysis

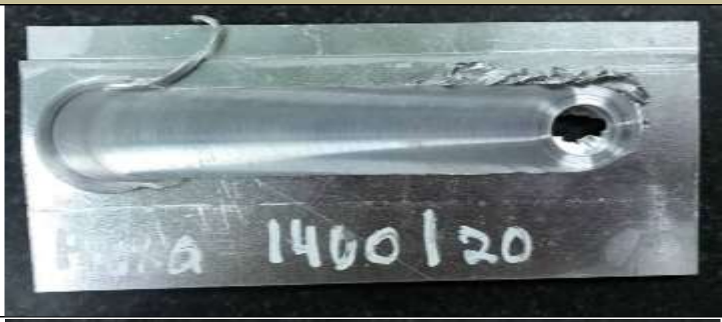
Research was done by evaluated the specimen three times for each tool bits but different parameters. As shown in table 3.4, the evaluation also was done based on different parameter in welding the material.

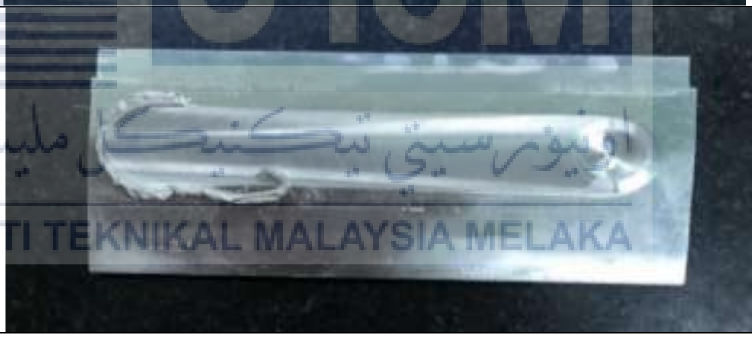
4.2.1 Sample Friction Stir Welding (FSW)

Outcome of the Friction Stir Welding (FSW) are divided into eighteen sample depend on the conditions either Dry Friction Stir Welding or Underwater Friction Stir Welding as shown in Table 4.1 and Table 4.2.

4.2.1.1 Dry Friction Stir Welding Sample

Table 4.1 Sample of Dry Friction Welding

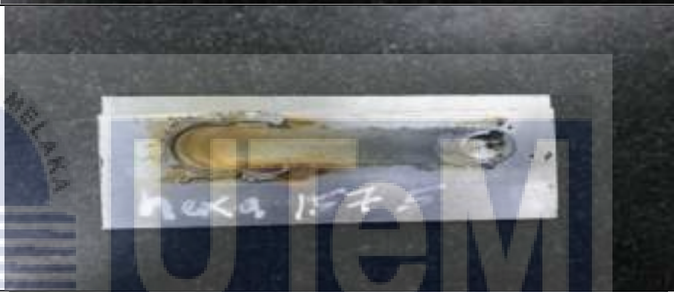
EXPERIMENTAL NO	SAMPLE
1	
2	
3	
4	
5	

6	
7	
8	
9	

4.2.1.2 Underwater Friction Stir Welding Sample

Table 4.2 Sample of Underwater Friction Welding

EXPERIMENTAL NO	SAMPLE
1	
2	
3	
4	
5	

6	
7	
8	
9	

4.2.2 Surface Roughness test

Surface roughness testing is the testing that has been done on overlapping joint of the welded zone. The average of the surface roughness values of each welded plate was calculated by taking two readings on the surface of each welded plate. In the table 4.3, 4.4 and figure 4.1, 4.2 below, stated that the results of the tests for both dry and underwater friction stir welding.

4.2.2.1 Surface Roughness Test Result of Dry Friction Stir Welding

Table 4.3 The Data Result of the Surface Roughness Test to the Sample Dry Friction Stir Welding

Experimental No	Sample	Tool Pin Profile	Spindle Speed (rpm)	Feed Rate (mm/min)	Surface Roughness (µm)	Average value of Surface Roughness (µm)
1	1	Hexagon	1400	20	0.872	0.852
	2				0.833	
2	1	Hexagon	1575	25	1.200	1.249
	2				1.297	
3	1	Hexagon	1750	30	1.372	1.462
	2				1.551	
4	1	Thread	1400	20	0.913	0.931
	2				0.949	
5	1	Thread	1575	25	1.739	1.636
	2				1.532	
6	1	Thread	1750	30	2.591	2.690
	2				2.788	
7	1	Square	1400	20	2.711	2.846
	2				2.980	
8	1	Square	1575	25	2.253	2.142
	2				2.031	
9	1	Square	1750	30	1.478	1.470
	2				1.461	

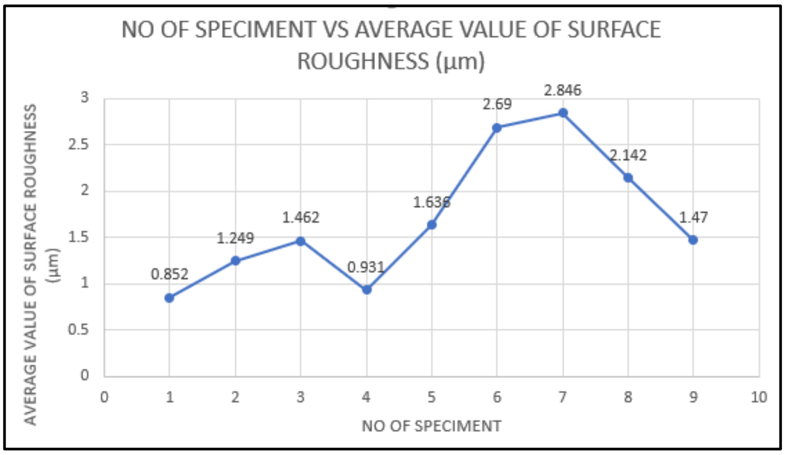


Figure 4.1 No of Speciment vs Average of Surface Roughness (µm) of Dry Friciton Welding

4.2.2.2 Surface Roughness Test Result of Underwater Friction Stir Welding (UFSW)

Table 4.4 The Data Result of the Surface Roughness Test to the Sample Underwater Friction Stir Welding

Experimental No	Sample	Tool Pin Profile	Spindle Speed (rpm)	Feed Rate (mm/min)	Surface Roughness (µm)	Average value of Surface Roughness (µm)
1	1	Hexagon	1400	20	2.407	2.468
	2				2.529	
2	1	Hexagon	1575	25	2.684	2.604
	2				2.524	
3	1	Hexagon	1750	30	7.841	7.628
	2				7.415	
4	1	Thread	1400	20	6.529	6.375
	2				6.221	
5	1	Thread	1575	25	2.782	2.530
	2				2.277	
6	1	Thread	1750	30	1.741	1.604
	2				1.467	
7	1	Square	1400	20	7.030	7.220
	2				7.410	
8	1	Square	1575	25	8.374	8.293
	2				8.212	
9	1	Square	1750	30	4.832	4.781
	2				4.729	

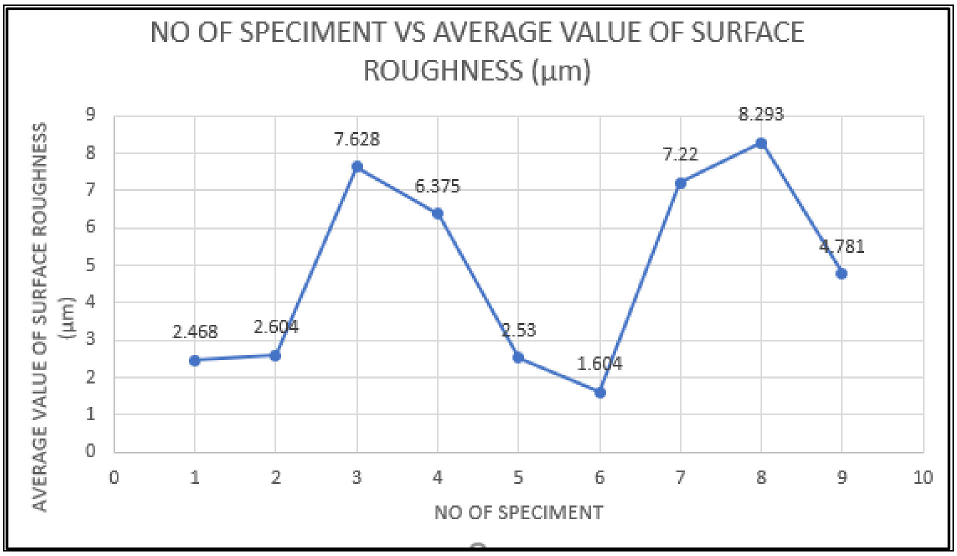


Figure 4.2 No of Speciment vs Average of Surface Roughness (µm) of Underwater Friciton Welding

4.2.3 Scanning Electron Microscopy (SEM) Test

The quality of the FSW zones in all the joints studied in this research was determined using Scanning Electron Microscopy (SEM) by utilizing a Zeiss EVO SEM Machine. According to the outcome, thread tool is the best tool bit in resulting the best microstructure for Dry Friction Stir Welding and hexagon tool is the best tool bit in getting good microstructure for Underwater Friction Stir Welding.

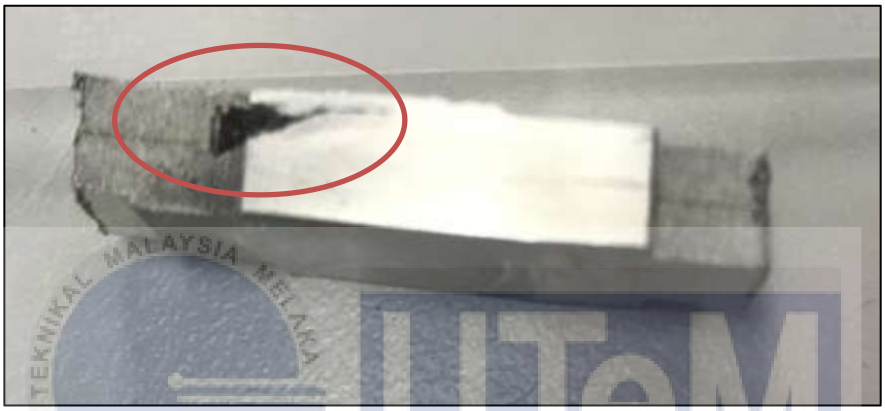


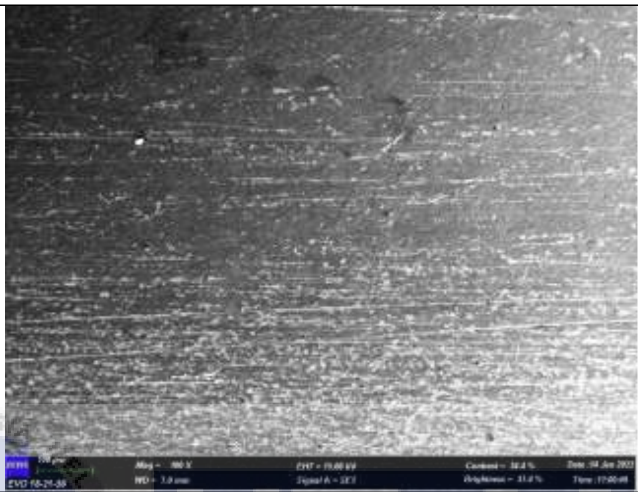
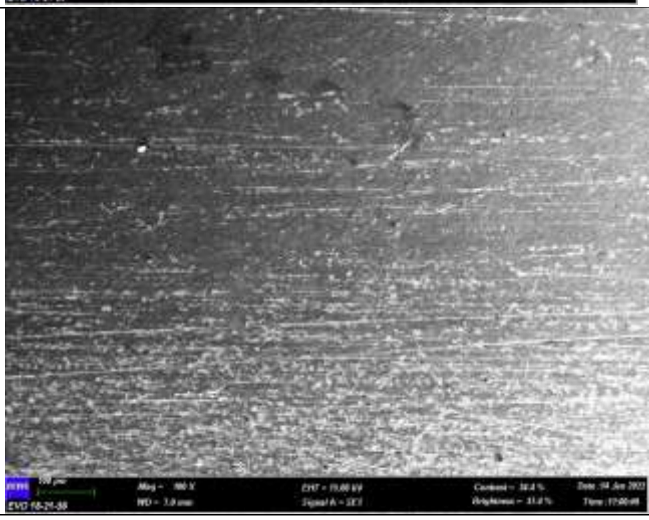
Figure 4.3 Region on samples where microstructure image capture using Scanning Electron Microscopy (SEM)

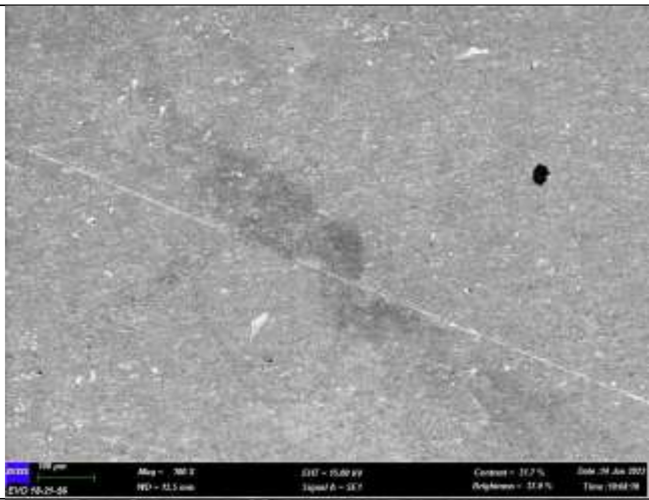
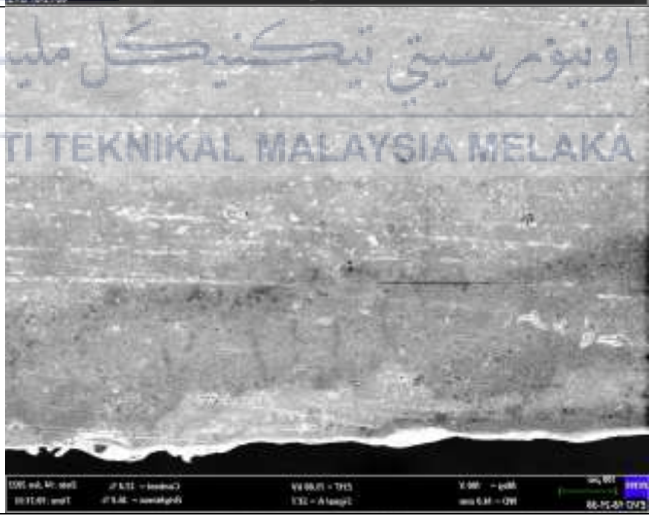
From Scanning Electron Microscopy (SEM), comparison of the result is done based on different tool bit shape with different parameters.

4.2.3.1 Scanning Electron Microscopy (SEM) in Condition Dry Friction Stir Welding

The results are compared using Scanning Electron Microscopy (SEM) using several tool bits with varying settings and translational speeds. Translational speed varies somewhat. When comparing the sizes of tool bits (Sample 1: Hexagon, Sample 4: Thread, and Sample 7: Square), sample 4 seems to be the smallest. The smallest grain size is preferred because it creates more grain boundaries, which reinforce the material. Aluminum's strength is increased by grain boundaries, which prevent dislocations from moving around in the microstructure. As a result, when a material has a high number of grain boundaries, more force is needed to bend it.

Table 4.5 Scanning result of 100x magnifications for Dry Friction Stir Welding

Magnification	100 x
Sample 1 (Hexagon tool/ spidle Speed 1400rpm / Feed rate 20mm/min)	
Sample 2 (Hexagon tool/ spidle Speed 1575rpm / Feed rate 25mm/min)	
Sample 3 (Hexagon tool/ spidle Speed 1750rpm / Feed rate 30mm/min)	

Sample 4 (Thread tool/ spidle Speed 1400rpm / Feed rate 20mm/min)	
Sample 5 (Thread tool/ spidle Speed 1575rpm / Feed rate 25mm/min)	
Sample 6 (Thread tool/ spidle Speed 1750rpm / Feed rate 30mm/min)	

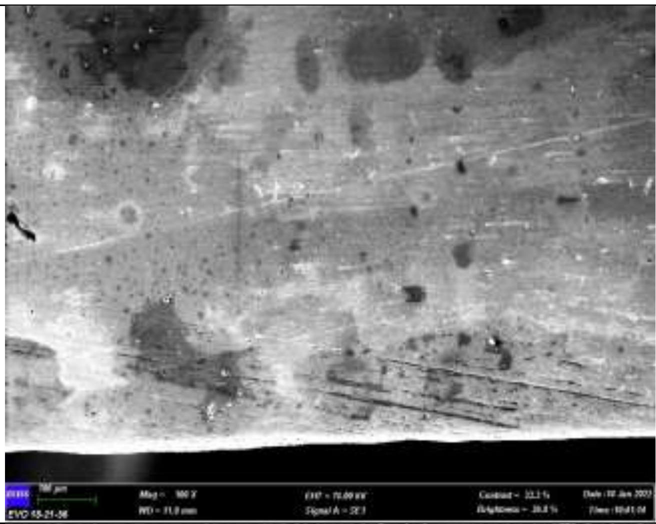
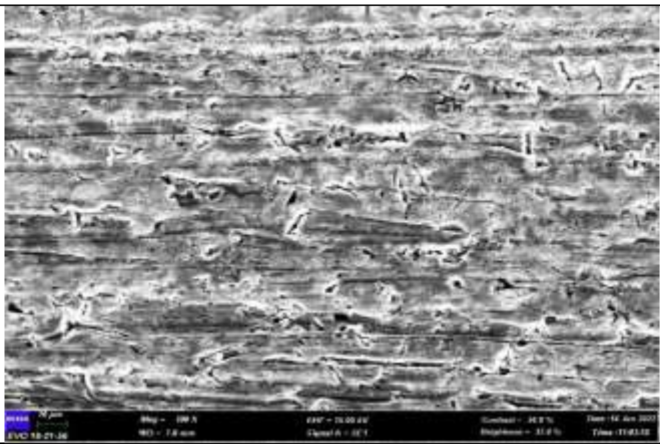
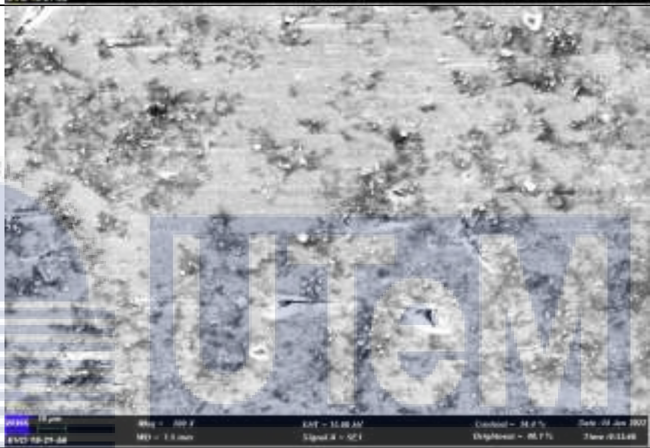
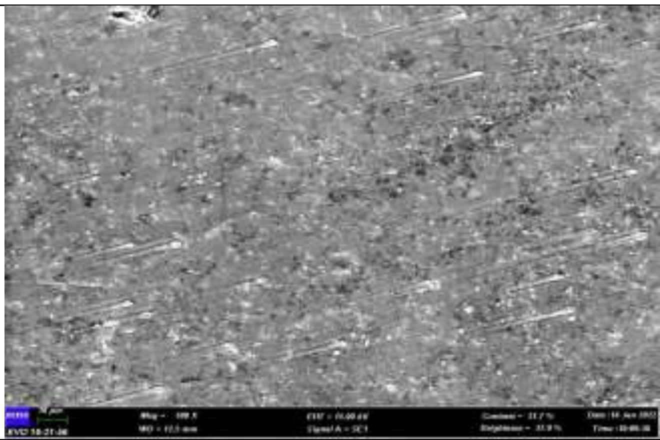
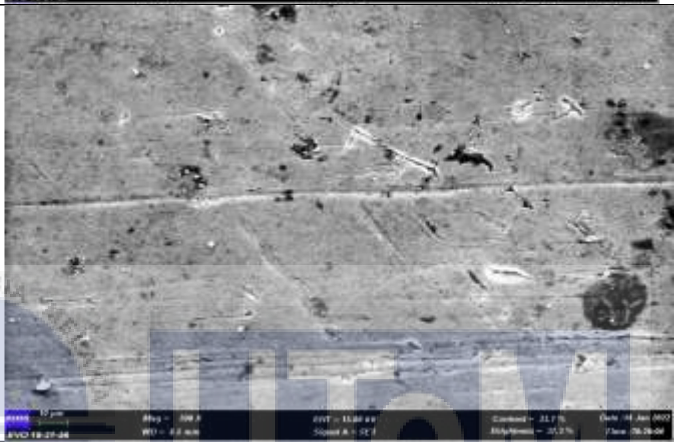
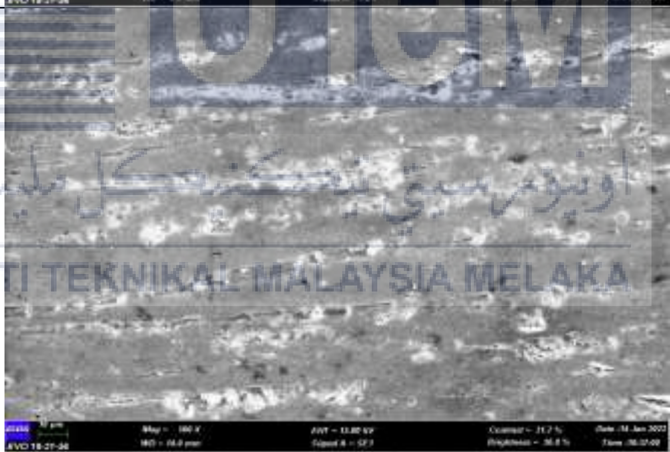
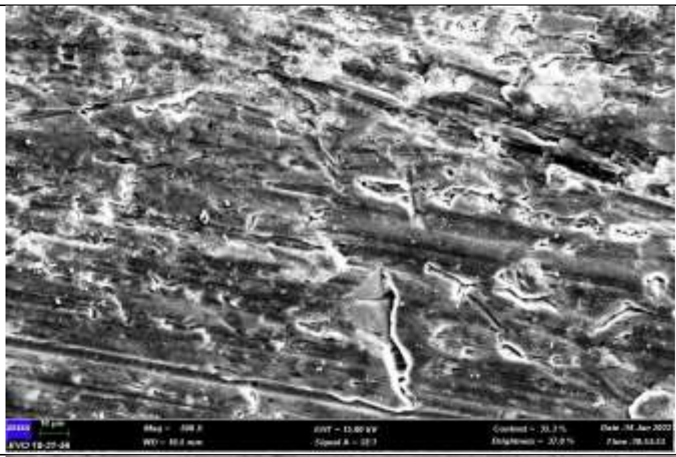
Sample 7 (Square tool/ spidle Speed 1400rpm / Feed rate 20mm/min)	
Sample 8 (Square tool/ spidle Speed 1575rpm / Feed rate 25mm/min)	
Sample 9 (Square tool/ spidle Speed 1750rpm / Feed rate 30mm/min)	

Table 4.6 Scanning result of 500x magnifications for Dry Friction Stir Welding

Magnification	**500 x**
Sample 1 (Hexagon tool/ spidle Speed 1400rpm / Feed rate 20mm/min)	
Sample 2 (Hexagon tool/ spidle Speed 1575rpm / Feed rate 25mm/min)	
Sample 3 (Hexagon tool/ spidle Speed 1750rpm / Feed rate 30mm/min)	

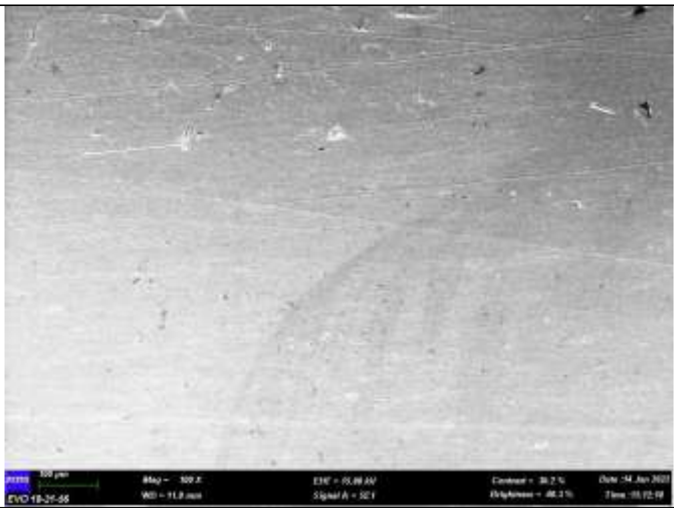
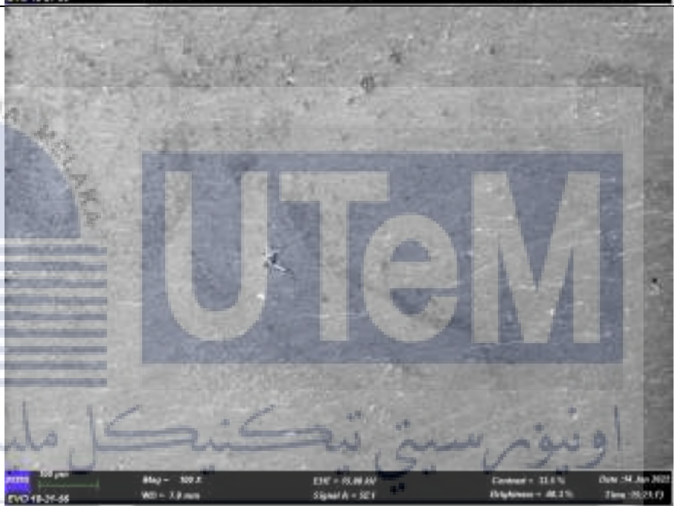
Sample 4 (Thread tool/ spidle Speed 1400rpm / Feed rate 20mm/min)	
Sample 5 (Thread tool/ spidle Speed 1575rpm / Feed rate 25mm/min)	
Sample 6 (Thread tool/ spidle Speed 1750rpm / Feed rate 30mm/min)	
Sample 7 (Square tool/ spidle Speed 1400rpm / Feed rate 20mm/min)	

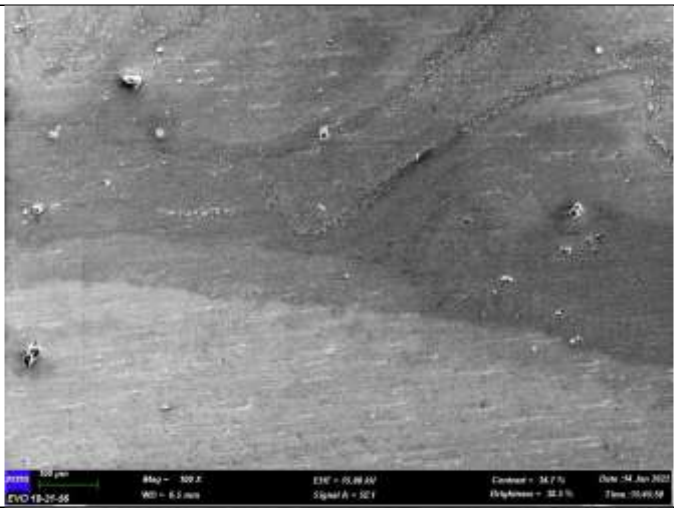
Sample 8 (Square tool/ spidle Speed 1575rpm / Feed rate 25mm/min)	
Sample 9 (Square tool/ spidle Speed 1750rpm / Feed rate 30mm/min)	

4.2.3.2 Scanning Electron Microscopy (SEM) in Condition Underwater Friction Stir Welding

The results are compared using Scanning Electron Microscopy (SEM) using several tool bits with varying settings and translational speeds. Translational speed varies somewhat. When comparing the types of tool bits (Sample 1: Hexagon, Sample 4: Thread, and Sample 7: Square), sample 1 seems to be the smallest. The smallest grain size is preferred because it creates more grain boundaries, which reinforce the material. Aluminum's strength is increased by grain boundaries, which prevent dislocations from moving around in the microstructure. As a result, when a material has a high number of grain boundaries, more force is needed to bend it.

Table 4.7 Scanning result of 100x magnifications for Underwater Friction Stir Welding

Magnification	**100 X**
Sample 1 (Hexagon tool/ spidle Speed 1400rpm / Feed rate 20mm/min)	
Sample 2 (Hexagon tool/ spidle Speed 1575rpm / Feed rate 25mm/min)	
Sample 3 (Hexagon tool/ spidle Speed 1750rpm / Feed rate 30mm/min)	

Sample 4 (Thread tool/ spidle Speed 1400rpm / Feed rate 20mm/min)	
Sample 5 (Thread tool/ spidle Speed 1575rpm / Feed rate 25mm/min)	
Sample 6 (Thread tool/ spidle Speed 1750rpm / Feed rate 30mm/min)	

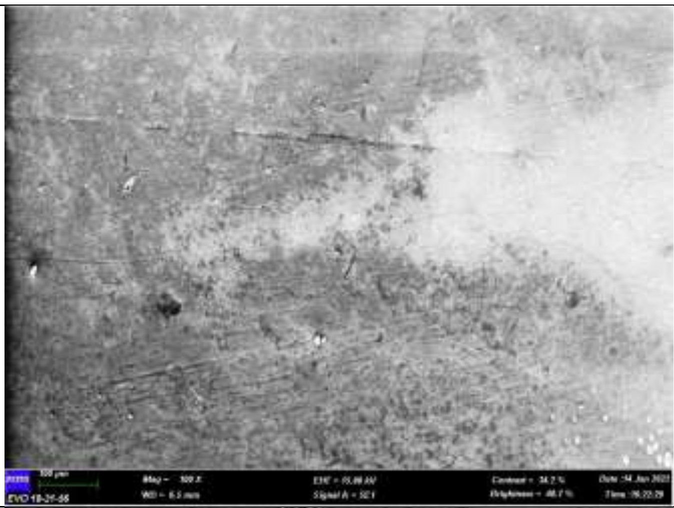
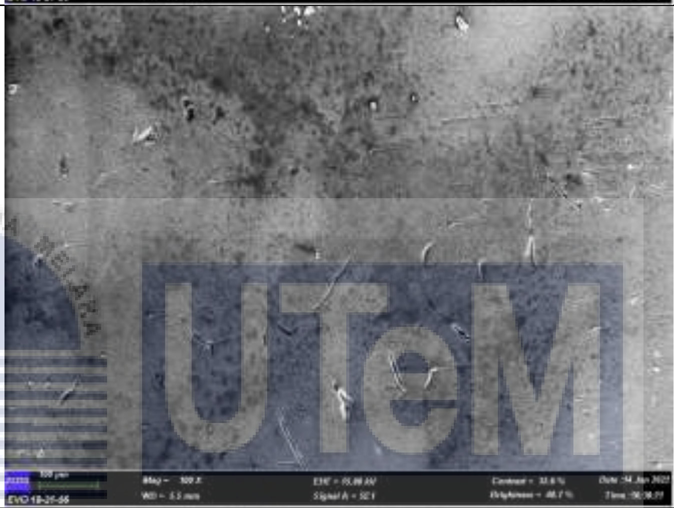
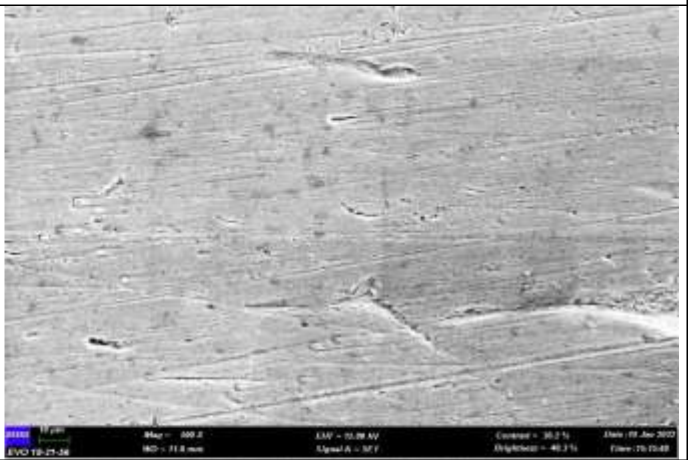
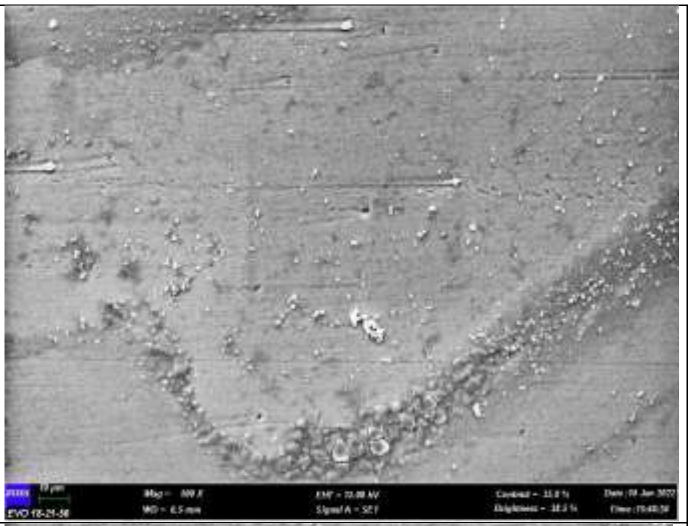
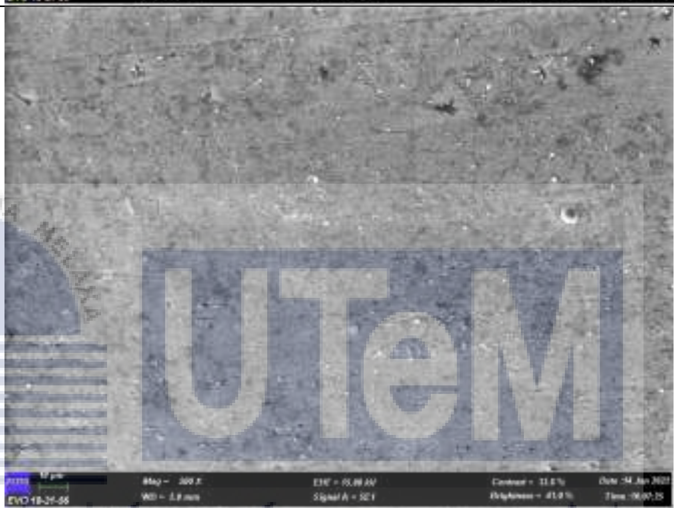
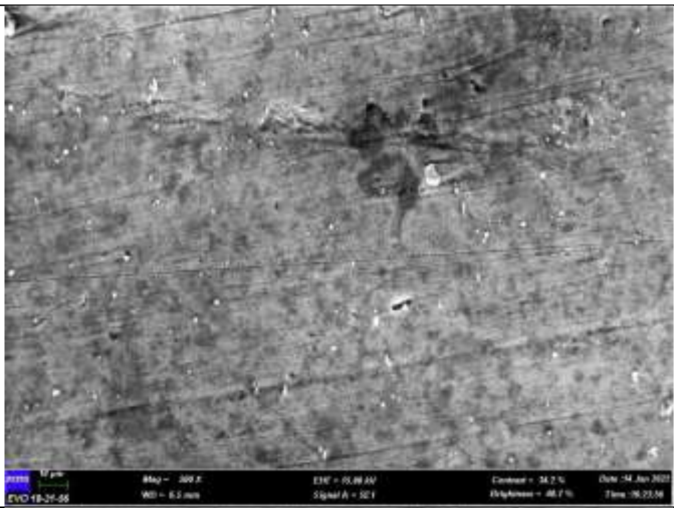
Sample 7 (Square tool/ spidle Speed 1400rpm / Feed rate 20mm/min)	
Sample 8 (Square tool/ spidle Speed 1575rpm / Feed rate 25mm/min)	
Sample 9 (Square tool/ spidle Speed 1750rpm / Feed rate 30mm/min)	

Table 4.8 Scanning result of 500x magnifications for Underwater Friction Stir

Magnification	500 X
Sample 1 (Hexagon tool/ spidle Speed 1400rpm / Feed rate 20mm/min)	
Sample 2 (Hexagon tool/ spidle Speed 1575rpm / Feed rate 25mm/min)	
Sample 3 (Hexagon tool/ spidle Speed 1750rpm / Feed rate 30mm/min)	

Sample 4 (Thread tool/ spidle Speed 1400rpm / Feed rate 20mm/min)	
Sample 5 (Thread tool/ spidle Speed 1575rpm / Feed rate 25mm/min)	
Sample 6 (Thread tool/ spidle Speed 1750rpm / Feed rate 30mm/min)	

Sample 7 (Square tool/ spidle Speed 1400rpm / Feed rate 20mm/min)	
Sample 8 (Square tool/ spidle Speed 1575rpm / Feed rate 25mm/min)	
Sample 9 (Square tool/ spidle Speed 1750rpm / Feed rate 30mm/min)	

4.3 Summary

Result of the scanning might have slightly error because of the polishing process. The final surface from polishing process was done by eye-ball view whereby there is no standardized to determine how smooth the surface of the sample.

Machine condition also play important role to get the best result whereby the machine must always in cold temperature. Exposed to room temperature or no air condition will cause high temperature to the machine that resulting error in outcome.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

As conclusion, there are several processes has been done in completing this Final Year Project. There are started with designing the tool bit types, decided to choose type of welding joint for Aluminum Alloy 6601 and scanning method to study the microstructure on welded specimen.

The first objective for this project, is to design and fabricate the tool bits for Friction Stir Welding was achieved as shown in chapter 3 because Conventional Lathe Machine and CNC Milling Machine able to fabricate the required tool bit types as per CAD Drawing. Both machines also able to shape AISI D2 material event though this is tough material whereby commonly used for tool bit.

Aluminum Alloy 6061 also successful welded using Friction Stir Welding either dry condition or underwater condition whereby meet the second objective of this project. By using Conventional Milling Machine and overlapping joint method event though with different parameter and tool bits also able to weld the material successfully.

Last but not list, the studies also successful to determine surface roughness for each tool bits as well the microstructure which is meet the objective of this project. There are different numbers in the surface roughness result and microstructure display because smallest grain size is preferred into it creates more grain boundaries, which prevent dislocations from moving around in the microstructure.

5.2 Recommendation

Friction Stir Welding rarely used in industry whereby because of this is a new technology and many people done have a good knowledge in this technology. Enhancement can be done to gain new knowledge in this technology with further study. There are several recommendations that might be considered for further studies which is:

i. Using different method of welding joint with desire parameters.

ii. Using Taguchi technique to optimize the data of the studies.

iii. Using different material such as plastic with different color to study the flow pattern of mix material.

5.3 Project Potential

The Friction's Potential Stir welding and its derivatives are employed in a variety of industries, including shipbuilding and offshore drilling. For the first time, FSW was utilized to weld hollow aluminum panels for fishing boats. This welding technology is now widely employed in the welding of aluminum freezer panels used in the bodies and hulls of ships. Aluminum panels can keep their form even with lengthy welds because to FSW's reduced distortion. Aside from that, FSW manufactures aluminum fuel tanks for spacecraft. The domes are welded to the cylindrical construction that makes up these gasoline tanks using this joining procedure. FSW is also utilized for the aircraft's fuselage's joint lightweight aluminum frames. This is since the procedure is substantially lighter than bolting or riveting.

Friction stir welding is also used to manufacture high-speed trains on hollow profiles and T-stiffener extrusions. As a result, it is one of the most active users of FSW technology.

High-tolerance components, such as those made by FSW, are impossible to replicate using traditional welding procedures. FSW is also more attractive than any other kind of aluminum welding because of its quick welding times.

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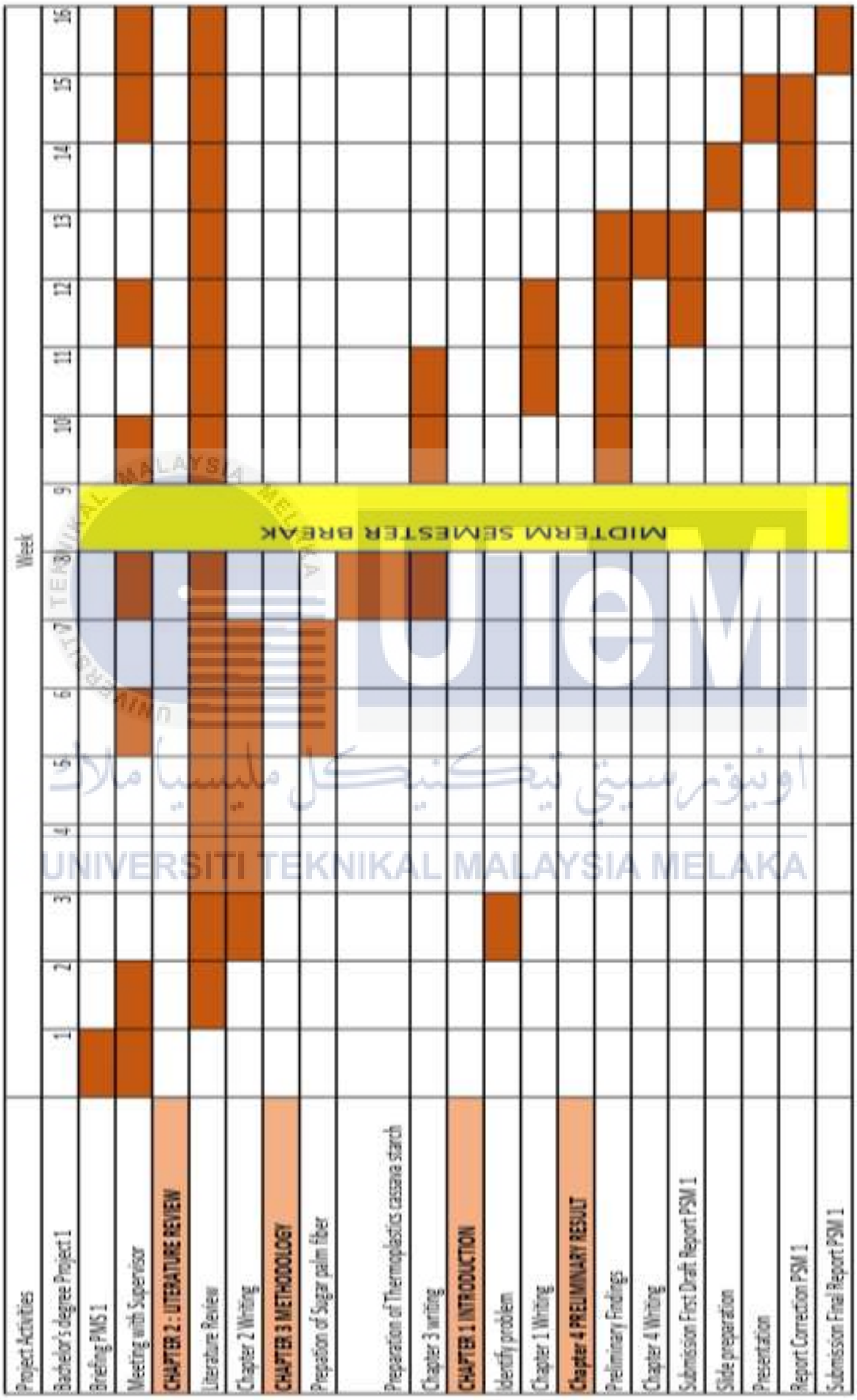
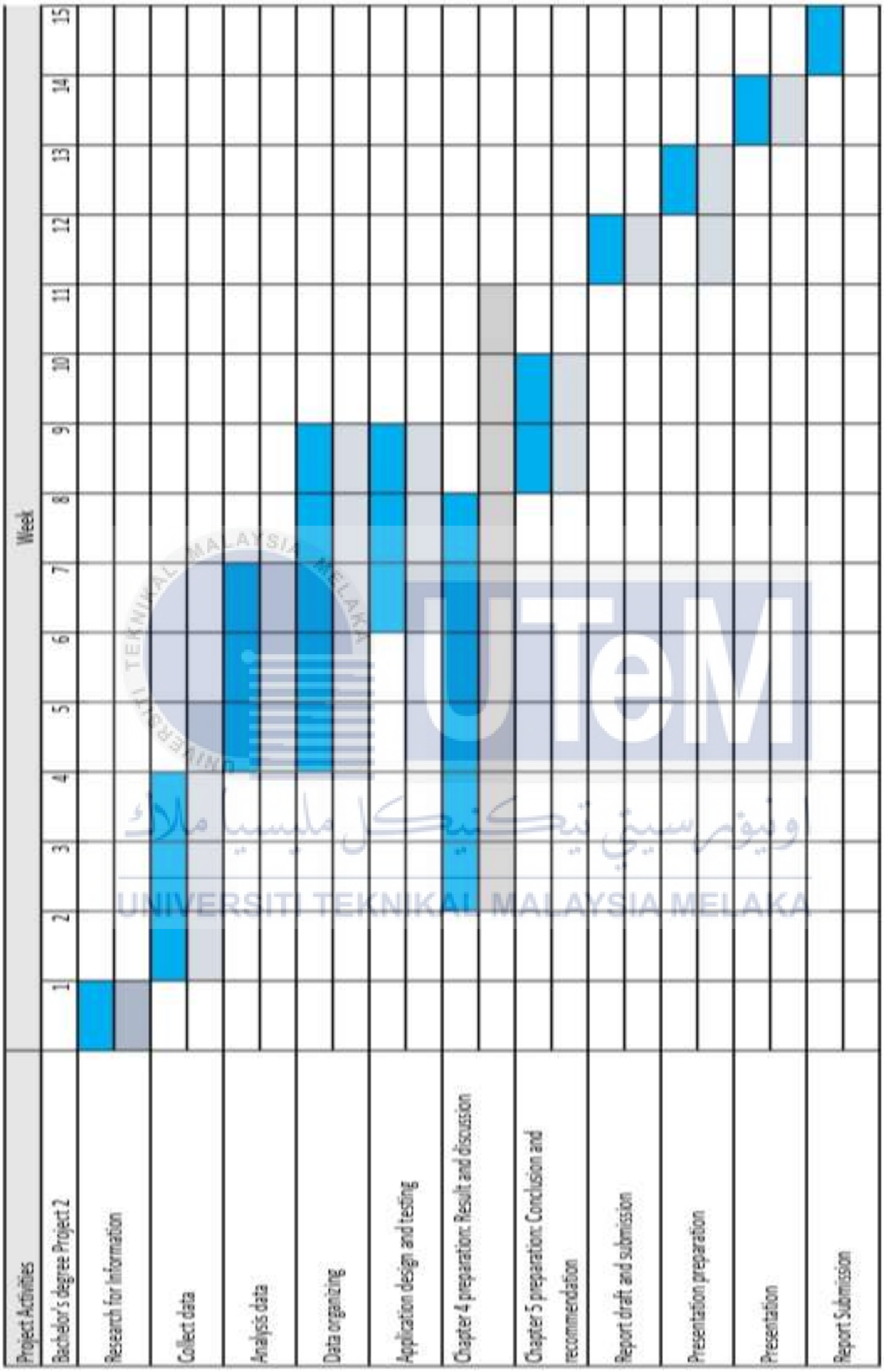
APPENDICES

APPENDIX A Gantt Chart PSM 1



APPENDIX B Gantt Chart PSM 2



APPENDIX C   AISI D2 PARAMETER CHARACTERISTICS

▼ Characteristics

CODE:

JIS	AISI	WNr	DIN
SKD11	D2	1.2379	1.2379

CHEMICAL COMPOSITION (Typical analysis %)

C	Si	Mn	Cr	Mo	V
1.15	0.25	0.30	11.50	0.70	1.00

STEEL PROPERTIES

Ledeburitic Cr-steel for cold work. High wear resistance. Very good toughness, compression strength and dimensional stability. Nitriding capability.

Yield Strength (Mpa)	Tensile Strength (Mpa)	Elongation (%)	Compressive Strength
-	-	-	2140 Mpa @ 60 HRC

PHYSICAL PROPERTIES

Thermal conductivity W/(m.K) [illegible]   Density g/cm³ [illegible]

Coefficient of linear thermal expansion

10^{-6}	20-100	20-200	20-300	20-400	20-500	20-600	20-700	20-800
	9.8	11.7	12.1	12.8	12.9	13.0	13.2	13.5

APPLICATIONS

High performance cutting tools, stamping-, woodworking-, moulding tools for plastics.

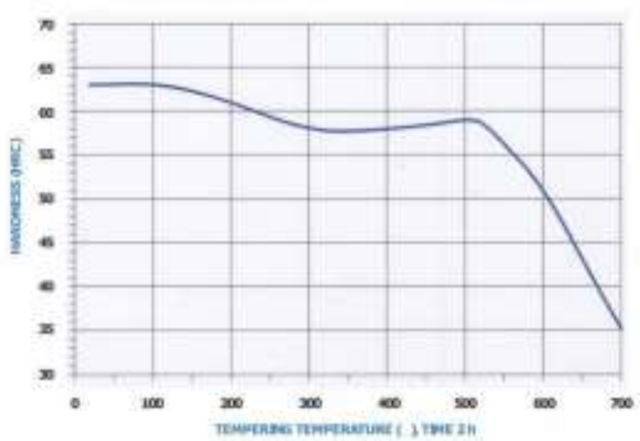
▼ Heat Treatment

SOFT ANNEALING ( )	COOLING	HARDNESS (HB)
840-880	FURNACE	MAX. 250

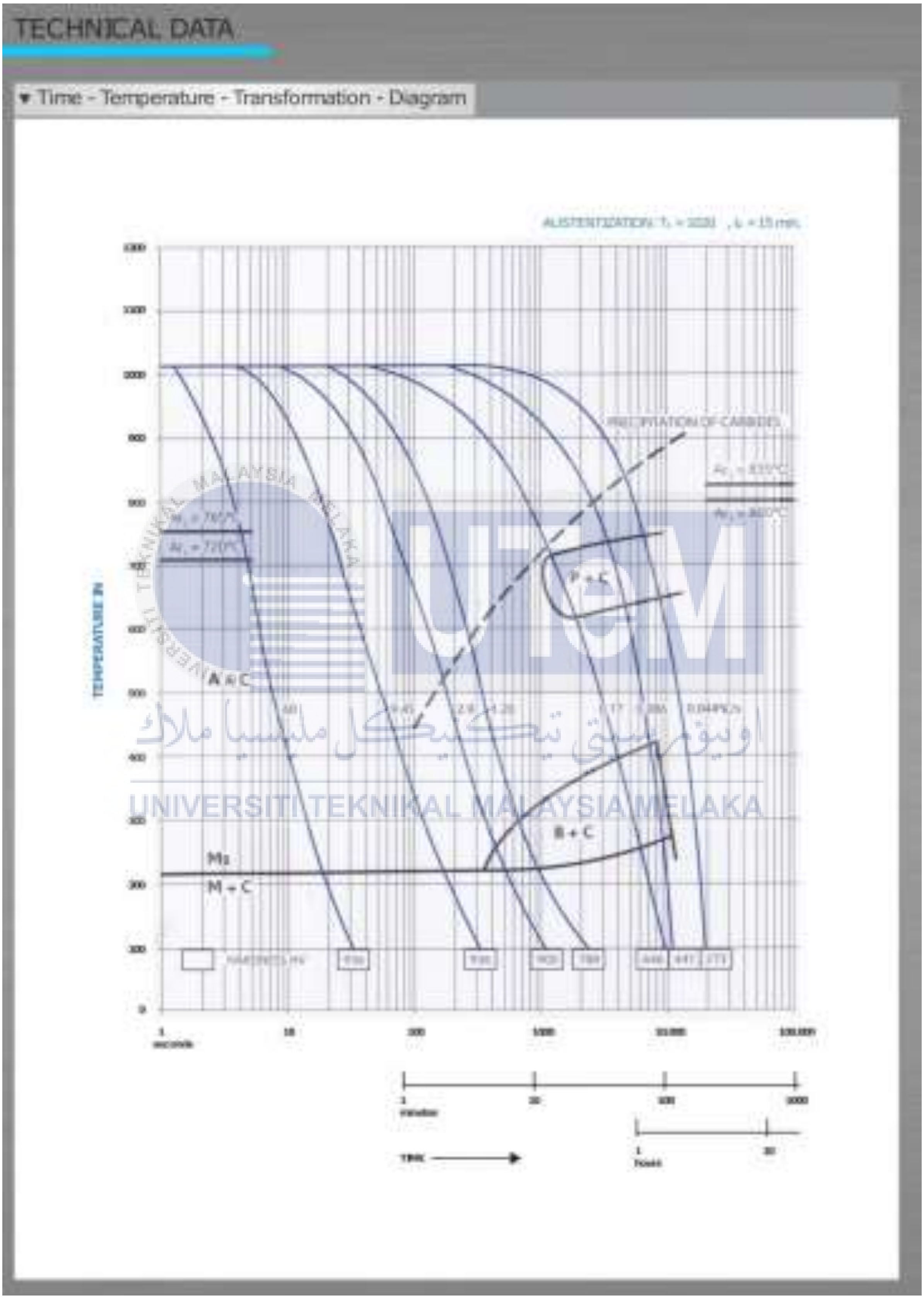
HARDENING FROM ( )	IN	HARDNESS AFTER QUENCHING (HRC)
1020-1050	OIL, AIR, THERMAL BATH 500-550	62-64

TEMPERING ( )	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HARDNESS (HRC)	61	58	58	59	58	56	51

▼ Tempering Diagram



APPENDIX D AISI D2 TIME-TEMPERATURE-TRANSFORMATION DIAGRAM



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA

TAJUK: **THE CORRELATION OF MICROSTRUCTURE – SURFACE ROUGHNESS EFFECT ON FRICTION STIR WELDING LAP JOINT USING AA6061 ALUMINIUM ALLOY**

SESI PENGAJIAN: **2021/2022 Semester 1**

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