COMPARISON OF COOLING APPROACH ON FSW WELD JOINT TOWARDS MECHANICAL PROPERTIES

Submitted in accordance with the requirement of Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons.)

By

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DECLARATION

I, hereby declared that this report entitled 'Comparison of Cooling Approach on FSW Weld Joint Towards Mechanical Properties' is the results of my own research except as cited in reference.

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APPROVAL

The report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.). The members of the supervisory committee are as follow:

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(DR. MOHD KAMIL BIN SUED)

ABSTRAK

Secara amnya, Friction Stir Welding (FSW) adalah proses penyatuan keadaan pepejal yang biasanya menggunakan haba geseran yang dihasilkan oleh alat berputar untuk bergabung dengan bahan. Peranti yang tidak habis digunakan, probe berprofil, dan bahu berputar dan terjun ke antara muka antara dua benda kerja. Ia kemudian bergerak di sepanjang paksi sendi, membiarkan bahan menjadi panas dan melembutkan. Bahu juga mengandungi bahan plastik ini (apabila dua bahagian menghasilkan panas dan mula mencair di kawasan kontras), yang dicampur secara mekanikal untuk membentuk kimpalan fasa padat. Selain memilih Bobbin Friction Stir Welding (BFSW) sebagai pengelasan berkualiti tinggi, ada keperluan untuk mengelakkan pergerakan haba yang berlebihan ke zon kimpalan dan aliran haba keadaan tetap ke alat Aluminium Alloy. Oleh itu, penyelidikan kritikal memerlukan mencari pelinciran penyejuk yang paling sesuai dengan kaedah penyejukan yang sesuai. Baru-baru ini, skopnya telah meningkat. Sebaliknya, penyelidikan yang signifikan telah diperluas dalam mencari kadar penyejukan yang betul sambil menggunakan kaedah penyejukan yang tepat untuk memperbaiki produk yang dikimpal. Selain itu, Ultimate Tensile Strength (UTS), Hardness Testing dilakukan untuk memperkukuhkan penyelidikan kami untuk mencari penyelesaian yang paling berkesan dan mampan.

ABSTRACT

Generally, Friction Stir Welding (FSW) is a solid-state joining process that commonly uses the frictional heat produced by a rotating tool to join materials. The non-consumable device, profiled probe, and shoulder rotate and plunge into the interface between two workpieces. It then moves along the joint axis, allowing the material to heat and soften. The shoulder also contains this plasticized material (when two parts create heat and start to melt at the contrast area), which that mechanically mixed to form a solid phase weld. Besides choosing Bobbin Friction Stir Welding (BFSW) as the high-quality welding, there's a need to avoid the movement of excessive heat to the welding zone and a steady-state heat flow to the Aluminium Alloy tool. So, critical research requires to find the most suitable refrigerant lubrication at the appropriate cooling method. More recently, the scope has increased. On the other hand, significant research has extended in finding a proper cooling rate while using the right cooling method to improve the welded products. Besides, Ultimate Tensile Strength (UTS), Hardness Testing are conducted to strengthen our research to find the most effective and sustainable solution.

DEDICATION

My beloved father, Jegatheesan Muthu

My appreciated mother, Thanalakshmi Tamby

My adored sisters, Sharmilla, Sharmaneish and Sharumati

For giving me moral support, money, cooperation, encouragement and also understandings

Thank You So Much & Love You All Forever

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In God's blessing, with the highest praise I can dedicate to Him, I can manage to complete this final year project successfully without any difficulties.

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Finally, I would like to give a special thanks to my university mates who were helping hands in completing this report. They gave me so many motivations and cooperation mentally while completing my final piece. Special thanks to my beloved sister, Sharmilla, who gave so many critical ideas and suggestions to improve my project studies. Thanks to all these people and for this friendship.

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FSW	-	Friction Stir Welding
BFSW	-	Bobbin Friction Stir Welding
UTS	-	Ultimate Tensile Strength
CFSW	-	Conventional Friction Stir Welding
RSM	-	Response Surface Methodology
CNC	-	Computer Numerical Control
IEA	-	International Energy Agency
THI	-	The Fastening Institute
AS	-	Advancing Side
RS	-	Retracting Side
RSW	-	Resistance Spot Welding
AHSS	-	Advanced High Strength Steel
MQL	-	Minimum Quantity Lubricant
HV	-	Vickers' Hardness

LIST OF SYMBOLS

°C	-	Degree Celsius
%	-	Percent
μm	-	Micro metre
mℓ	-	Millilitre
mm	-	Millimetre
cm	-	Centimetre
rpm	-	Rotation per minute
Mpa	-	Mega pascal
Sec	-	Second
h	-	Hour

CHAPTER 1
INTRODUCTION

In this chapter, the project study is explained regarding problem statement, objectives, and scope to achieve. The study of this research is typically brief in this chapter to understand more about the importance of this research project.

1.1 Introduction

Generally, Friction Stir Welding (FSW) is a solid-state joining process that commonly uses the frictional heat produced by a rotating tool to connect materials. The non-consumable device, profiled probe, and shoulder rotate and plunge into the interface between two workpieces. It then moves along the joint axis, allowing the material to heat and soften.

1.2 Background Study

Welding techniques are a common technique used in many product developments nowadays, and it shows that these techniques are able to weld various metals, including the AA1100 alloys. (According to M K Sued et al. 2017), Friction Stir Welding (FSW) is an excellent technique that does not harm the environment due to low energy consumption, which cannot be achieved by traditional arc welding. In FSW, proper selection of filler metal used, the weld pool shield gas control, and the immediate action of removing the oxide surface right after welding at the joint edge preparation will be done. Furthermore, the long and continuous performance of FSW techniques resulting in distortion of the metal. Friction stir welding (FSW) is well known for joining processes and specialized in aluminum alloy and other soft structured alloys. FSW can perform a long and continuous weld, resulting in high-quality welds at the same time able to produce a minimum amount of distortion of metal. There are two types of friction stir welding: conventional friction stir welding (CFSW) and bobbin friction stir welding (BFSW). In this research, the BFSW method chose to do this research. The purpose of this research is the idea of applying coolant is required to investigate sudden heat reduction after weld due to high heat produced by BFSW as higher heat increases the grain microstructure. A CNC milling is used in this study, and a strategy to apply the coolant need to strategize.

1.3 Problem Statement

High-quality welding desired to have a solder joint with both good thermal and mechanical properties. Bobbin Friction Stir Welding (BFSW) is the better welding method with better quality than to Conventional Friction Stir Welding (CFSW) because BFSW can save additional energy up to 20-25% further after 50% of energy able to save between CFSW and GWAW. Unfortunately, there are few disadvantages found in this method. Firstly, BFSW produces higher heat during weld than CFSW due to a tool of BFSW consist of an extra shoulder (2 shoulders) compared to CFSW, which has one shoulder. BFSW produces more heat, and this welding method automatically produces a more apparent grain size than the Conventional FSW. When the grain size is more prominent, the weld strength of joints that welded becomes lower than CFSW (S S M Samsuri et al. 2018).

Defects in welding might happen due to weak weld joints such as crack, porosity, and fatigue. Another problem faced in previous research is that the cooling rate applied isn't optimum in refining the microstructure, leading to average mechanical properties lacking because of inefficient cooling rates and improper cooling methods. So, the idea of applying the coolant with a suitable method after welding is required with a proper strategy to generate a more refined microstructure. It is also crucial that using the coolant at the appropriate rate is necessary to achieve the desired result in this research.

1.4 Objectives

The objectives of this research are:

I. Evaluating the behaviour of weld joint at different cooling medium.
II. To propose the best cooling medium for the welded joint of BFSW.

1.5 Scope

This study is carried out at CNC Laboratory at University Teknikal Malaysia Melaka to effectively access the CNC milling machine. Some investigations need to be done in this study to determine the cooling rate when handling BFSW. The type of bobbin tool is the fixed one that consists of two shoulders. The workpiece will be specified in the dimension of (140mm x 140mm x 6mm) and the material for the workpiece is AA1100. Besides, ECOLUBRIC E200 is chosen as a lubricant, and the spraying (mist) method for cooling is selected for this study. The researcher will analyze the volume of coolant used for the cooling rate while BFSW is carried out. The best volume of coolant that makes the grain size smaller after welding will be finalized to strengthen the weld strength. On the other hand, few testings were carried out to determine the mechanical properties of the AA1100. Ultimate Tensile Strength (UTS) and Hardness Test will apply to get finer microstructure and observe the right method that needs to carry out to achieve the research objective.

1.6 Significance of Studies

These studies' importance is to improve the weld joint strength through the cooling effect, which involves the coolant, cooling method, and the volume of coolant used. These factors are essential to produce a stronger weld joint while conducting BFSW.

1.7 Organizations of Projects

This report has organized in order into three chapters. Firstly, Chapter 1 is discussing the introduction studies for this research. Chapter 1 includes the background, problem statement, objective of the study's research, and scope. Then, Chapter 2 explains all about the literature review that related and detailed references for this research. The cooling rate parameter, studies about BFSW, and tests to determine the mechanical properties are the examples that will be discussed in this chapter. On the other hand, Chapter 3 describes the methodology of the experiment design of the thesis. The BFSW cooling rate methods will discuss the required processes and techniques for this research further in the form of a flow chart and experimental procedures and, not to forget, testing procedures.

CHAPTER 2
LITERATURE REVIEW

In the previous chapter, the project information is described generally. Thus, this chapter will explain the project in further detail based on the study case later researcher and engineers. The Conventional Friction Stir Welding, also known as (CFSW) and Bobbin Friction Stir Welding (BFSW), will be explained later in this chapter.

2.1 Friction Stir Welding

Friction Stir Welding, known as (FSW), is a solid-state fastening method that makes joint the behind tool to move forward. Based on the International Energy Agencies (IEA), compared to the year 2012, the emission of dioxide has increased to 2% in 2013. Friction Stir Welding (FSW) technology was introduced by The Fastening Institute (THI), UK, in 1991. The standard alloy used to manufacture the chemical container, the container for the food industry, cookware, reflector for lamps, cable sheathing, and architecture flashing. There are typically a few harmful effects on porosity, cracking formation, blowhole, and shrinkage. (M K Sued et al. 2018).

After that, other processes are also required to reshape it to its original shape to enhance the welding's negative impacts. Perfect welding can be done by taking into consideration on few matters. For instance, control of weld pool shield gas, the immediate action of removing the oxide surface at joint edge preparation right after welding the joint edge preparation, and selective of the filler metal used. Besides, taking a long time and performing continuous welding performance using welding methods resulting in metal distortion. This due to the metal that has been exposed to a high temperature for a long time.

Other processes are also required to reshape it to its original shape to enhance the welding's negative impacts (Lafayette, 2017). The FSW method is known for its bending technique and specialized in aluminium alloys and other structured alloys. On the other hand, FSW also is capable of conducting long and continuous welding, resulting in high-quality welding at the same time capable of creating a minimal amount of metal distortion.

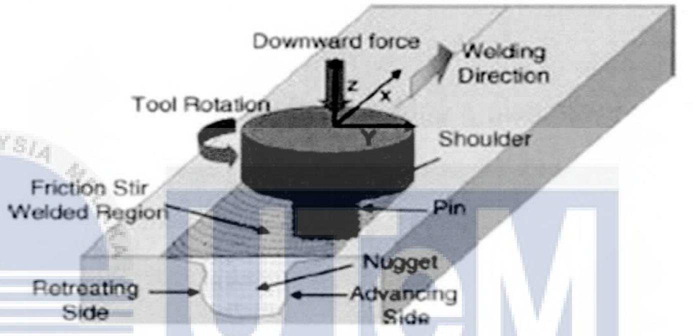

Figure 2.1: Schematic diagram of friction stir welding (Sued, 2015).

2.2 Conventional Friction Stir Welding (CFSW)

Based on figure 2.1, the process started by having the rotating tool sink the workpieces where the edges fitted at the joins. Then, the pin is immersed in the material, as shown in figure 2.1. While navigating through the material, tool heat and stir material from the Advancing Side (AS) to the Retreating Side (RS) by making a joint line at the tool's back. The issue arising from the process needed the plates a clamping of vertical and horizontal ways to avoid being separated from the high force exerted by the CFSW tool.

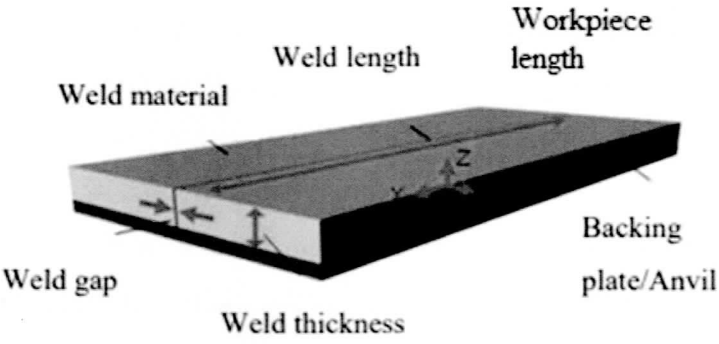

Figure 2.2: Schematic diagram of the material setup (Sued, 2015).

After that, a rigidly supported plate (also called backing a plate or anvil) is used by checking the vertical force. From this process, setup time decreased and limited the thickness of parts are welded. (Note that the z- axis is perpendicular to the x-axis material surface, and the y-axis is in opposite ways, as shown in figure 2.2.

2.3 Bobbin Friction Stir Welding (BFSW)

Bobbin Friction Stir Welding (BFSW) process used a non-consumable device that generates frictional heat and high bonding pressure. Generally, this welding process provides metallurgical, environmental, and energy benefits and contains three main stages as in working principles. First and foremost, the entering tool will be forced to enter the workpiece that needed to be joined. Secondly is the dwell period, where the tool rotates during a fixed place with no transverse along the workpiece after the entering stage to create up enough heat to plasticize the fabric before the tool transverse the workpiece. (Harsha et al., 2017), tool starts to move transversely along the workpiece to hold two parts together in the welding process. There's a further stage understood as the retracting/ cooling stage. The tool will be levitated horizontally from the workpiece when it is almost at the join area's top. The theory friction stir welding principle commonly occurred during a solid-state where the tool rotates the joining area into a below freezing point of the fabric (G.K Padly et al., 2017).

Moreover, the tool usually generates heat, and because the tool rotates, the blending will begin, and the metal will experience a heating process by the warmth pressure. The two sorts of friction stir welding are categorized as conventional friction stir welding (CFSW) and bobbin friction stir welding (BFSW). The difference between these two sorts of tool is supported by the amount of shoulder. Thereis only one shoulder for CFSW while two shoulders for BFSW. Based on (Mishra and Ma,2005), there are few benefits from different aspects, metallurgically, environmentally, and energy.

Figure 2.3: Benefits from different aspects, metallurgically, environmentally, and energy.

Metallurgical benefits	Environmental benefits	Energy benefits
Solid phase process	No shielding gas required	Improved materials use (e.g., joining different thickness) allows reduction in weight
Low distortion of workpiece	No surface cleaning required	Only 2.5% of the energy needed for a laser weld
Good dimensional stability and repeatability	Eliminate grinding wastes	Decrease fuel consumption in light weight aircraft, automotive and ship applications
No loss of alloying elements	Eliminate solvents required for degreasing	
Excellent metallurgical properties in the joint area	Consumable materials saving such as rugs, wire or any other gases	
Fine microstructure		
Absence of cracking		
Replace multiple parts joined by fasteners		

The friction stir welded Advanced High Strength Steel (AHSS) joints are scanty. The FSW and FSSW method usually reduce the issue related to Resistance Spot Welding known as (RSW) and allows the joining of advanced high strength steels. FSW method also can be applied for welding solid metallic material. The local operating temperature generated is from 1100°C -1200°C friction and deformation in the FSW method. Thehigh-temperature range is set to ensure the solid metallic to plasticized for stirring and welding. The high operating temperature and sufficient working forces on the FSW method's tool due to demand on the tool's material mechanical properties. (Ghosh et al. 2011).

2.4 Difference between CFSW and BFSW

There are two types of Friction Stir Welding; Conventional Friction Stir Welding (CFSW) and bobbin friction stir welding (BFSW). Figure 2.4 and figure 2.5 below show the difference between these two processes CFSW and BFSW. The way of joining has many strategies even though the method is similar and has no dive power, and inclining angle is required. Besides that, fixturing and cutting troubles in BFSW give more mechanical compliances that perhaps change the surface stream. The qualificationsare so immense hence dedicated assessments got the opportunity to be coordinated for the BFSW cycle. The findings are advantageous to evaluate the process selection and help by decreasing the atmospheric phenomena. (M K Sued et al., 2018)

Figure 2.4: Single-Sided Shoulder-CFSW (Sued, 2015).

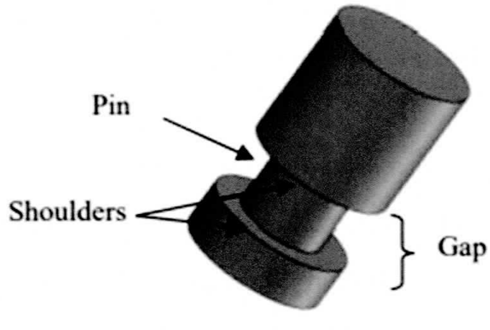

Figure 2.5: Double-sided shoulder BFSW (Sued, 2015).