BOBBIN FRICTION STIR WELDING OF AA1100

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

by

MUHAMMAD IZZUDDIN BIN SHAMSHARHADI
B051510023

940912-04-5261

FACULTY OF MANUFACTURING ENGINEERING
2018

© Universiti Teknikal Malaysia Melaka

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: BOBBIN FRICTION STIR WELDING OF AA1100

SesiPengajian: **2017/2018 Semester 2**

Saya **MUHAMMAD IZZUDDIN BIN SHAMSHARHADI (940912-04-5261)**

Mengaku membenarkan Laporan Projek Sarjana Muda (PSM) ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. *Silatandakan (√)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktubdalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/ badan di mana penyelidikan dijalankan)

☐ TIDAK TERHAD

Disahkan oleh:

______________________ ______________________

AlamatTetap:
ST 37 KM34 AIR HITAM
DARAT
78300 MASJID TANAH
MELAKA
Tarikh: 06JULAI 2018

Cop Rasmi:

Tarikh: ______________________

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

© Universiti Teknikal Malaysia Melaka

DECLARATION

I hereby, declared this report entitled "BOBBIN FRICTION STIR WELDING OF AA1100" is the results of my own research except as cited in reference.

Signature :…………………………………………

Author's name : **MUHAMMAD IZZUDDIN BIN SHAMSHARHADI**

Date : **6TH JULY 2018**

© Universiti Teknikal Malaysia Melaka

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfilment of the requirement for the degree of Bachelor of Manufacturing Engineering (Hons.). The member of the supervisor is as follow:

……………………………………………………..

(Dr. Mohammad Kamil Bin Sued)

© Universiti Teknikal Malaysia Melaka

ABSTRAK

Kimpalan pengadukan Bobbin‘*Bobbin Friction Stir Welding’* (BFSW) adalah teknik kimpalan dengan menggunakan alat tahan haus yang akan berputar di antara kedua-dua bahagian itu perlu dikimpal untuk menghasilkan cantuman kekal. Tujuan kajian ini adalah untuk mengkaji parameter kimpalan optimum pada aloi AA1100. Dalam kajian ini, parameter telah ditetapkan kepada kelajuan putaran spindle dan kelajuan kimpalan. Eksperimen ini akan dijalankan menggunakan mesin larik konvensional yang akan bertindak sebagai mekanisme pemuutara mata alat untuk mengimpal bahan tersebut. Bahan yang dikimpal adalah dalam ketebalan 6mm dengan panjang 140mm dan lebar 140mm. Parameter yang dipilih ialah kelajuan spindle (800, 900 dan 1000 rpm) dan kelajuan kimpalan (80, 115, dan 155 mm / min) adalah berdasarkan keupayaan mesin dan kajian yang terdahulu. Semasa proses kimpalan, tindak balas daripada getaran, arus dan suhu juga telah direkodkan untuk menyiasat tindak balas tersebut semasa proses kimpalan. Selepas proses kimpalan, sampel kimpal kemudian menjalani ujian mekanikal menggunakan peranti dan kaedah yang sesuai. Kaedah Permukaan Respon‘*Response Surface Methodology’* (RSM) dengan jenis data sejarah‘*Historical Data’* digunakan sebagai reka bentuk exkperimen dan menggunakan Kekuatan Tegangan Tepat‘*Ultimate Tensile Strength’* (UTS) sebagai tindak balas output untuk mencari parameter optimum untuk proses kimpalan. Di akhir kajian telah menyatakan bahawa parameter optimum dicapai apabila kelajuan spindle pada 1000 rpm dengan kelajuan kimpalan 155 mm / min . Keputusantelah diluluskan dengan ralat peratusan minimum 8.43%

© Universiti Teknikal Malaysia Melaka

ABSTRACT

Bobbin friction stir welding (BFSW) is a welding technique by using a non-consumable tool that will rotate between the two part need to be weld to produce joining. The purpose of this research is to study the optimum weld parameter on an AA1100 alloy. In this research, the parameter has been set to the spindle and welding speed. The experiment will be conducted using a conventional milling machine that will act as the rotational device for the tool to weld the material. The material to be weld is in 6mm thickness with length of 140mm and width 140mm. The parameters selected which are spindle speed (800, 900 and 1000 rpm) and welding speed (80,115, and 155 mm/min) are based on the machine capability and previous recorded study. During the welding process, the weld response which are vibration, current and temperature also had been recorded to investigate the behavior of the weld response during the welding process. After the welding process, the weld sample then undergoes mechanical test using the appropriate devices and methods. Response Surface Methodology (RSM) with historical data type is used as the design of experiment and using Ultimate Tensile Strength (UTS) as the output response to find the optimum parameter for the welding process. The finding has stated that the optimum parameter was achieved when the spindle speed is at 1000 rpm with welding speed of 155 mm/min the results was approved with a minimum percentage error of 8.43%.

© Universiti Teknikal Malaysia Melaka

DEDICATION

TO MY BELOVED PARENT,

Shamsharhadi Bin MohdSarif with Norazian Binti Mohd Salleh

For their supports in my whole life

TO MY HONOURED SUPERVISOR,

Dr. Mohammad Kamil Bin Sued

For his advices, support, motivation and patience during completion of this project

TO ALL STAFF & TECHNICIANS,

For their cooperation and advices during completion of this project

AND TO ALL MY COLLEAGUE,

For their encouragement, cooperation and effort in this study

Only Allah S.W.T can repay your kindness and hopes Allah S.W.T bless your lives.

© Universiti Teknikal Malaysia Melaka

ACKNOWLEDGEMENT

In the name of Allah, the most gracious and merciful I would like to express my gratefulness as I managed to complete my undergraduate project for Bachelor Degree of Manufacturing Engineering within the time given. All thanks to Allah as only He can give the permission for me to complete this project.

My deep hearted appreciation goes to my supervisor Dr. Mohammad Kamil Bin Sued for all his guidance, ideas, thoughts and encouragements throughout the completion of the project. Thousands of thanks also I would like give to all UTeM staffs especially in Faculty of Manufacturing Engineering for their cooperation with me from starting of this project until the end.

And finally, my deepest hearted appreciation goes to my family, especially my parents, Shamsharhadi Bin Mohd Sarif and Norazian Binti Mohd Salleh for their endless prayer and loving support in my whole life. Without them, I may not manage to finish this project within the given period of time. Thanks also to all of my colleagues that have been directly or indirectly give a contribution along in completion of this project.

© Universiti Teknikal Malaysia Melaka

TABLES OF CONTENTS

© Universiti Teknikal Malaysia Melaka

© Universiti Teknikal Malaysia Melaka

© Universiti Teknikal Malaysia Melaka

LIST OF TABLES

© Universiti Teknikal Malaysia Melaka

LIST OF FIGURES

© Universiti Teknikal Malaysia Melaka

© Universiti Teknikal Malaysia Melaka

LIST OF ABBREVIATION

AA	-	Aluminium Alloy
AS	-	Advancing Side
ASTM	-	American Standard of Testing Material
BFSW	-	Bobbin Friction Stir Welding
CFSW	-	Conventional Friction Stir Welding
GMAW	-	Gas Metal Arc Welding
GTAW	-	Gas Tungsten Arc Welding
HAZ	-	Heat Affected Zone
MIG	-	Metal Inert Gas
Rpm	-	Revolution per minute
RSM	-	Response Surface Methodology
RS	-	Retreating Side
SZ	-	Stir Zone
TIG	-	Tungsten Inert Gas
TWI	-	The Welding Institute
TMAZ	-	Thermo-Mechanically Affected Zone
WNZ	-	Weld Nugget Zone

© Universiti Teknikal Malaysia Melaka

CHAPTER 1

INTRODUCTION

1.0 Background Study

Friction stir Welding (FSW) was invented at The Welding Institute (TWI), United Kingdom in 1991**.** It is an alternative method of joining technology process**.** FSW is categorized as a solid state joining whereby the coalescence between two parts of the material need to be joined occurred at the temperature just below the melting point of the material being joined. Kumbhar et al., (2008) claimed that the joining process occurred when frictional heat produced by the FSW tool when in contact with the area need to be weld combining with the surrounding temperature causing the stirred material to be softened and mixed. Theoretically, the grains of the material at the welded area were transferred and re-arranged between the two parts and at the same time the material were not being melted. The benefits of this welding technique include minimum observing during process, low in energy consumption, potentially good weld strength and also minimum requirement for secondary process or finishing process needed. Other welding techniques such as Gas Metal Arc Welding (GMAU), Tungsten Inert Gas (TIG) and Metal Inert Gas (MIG) are placed under the fusion welding category which differs in terms of working principal where in fusion welding the base metal is being melted by applying heat to it. Usually a filler metal is added during the melting process of the base metal in order to strengthen the welded joint.

© Universiti Teknikal Malaysia Melaka

According to (Tanwar & Kumar, 2009), As a solid state process FSW eliminates many of the defects that usually occurred in fusion welding such as shrinkage, solidification cracking and porosity. Also, the bond between the two materials occurred uniquely of the original material, giving the welded material the comparable strength, bending and fatigue properties of the parent's material. FSW is a new method that permanently joining metal in a greener way. This has been proven by Hassan et al, (2014) when an experiment was conducted between FSW and gas metal arc welding (GMAU). Both welding techniques were tested by welding pairs of 3mm thick aluminium strip. The parameter of each welding techniques was fixed and the aspects such as the welding quality, power input, macrostructure and microstructure of the welded joints were examined. Hence, the results obtained showed that the FSW was green, environment-friendly and more superior welding properties compared to the conventional GMAW.

FSW can be divided into two types. The classification is based on the tool design. Conventional Friction Stir Welding (CFSW) has one shoulder whereby Bobbin Friction Stir Welding (BFSW) has double shoulder. Figure below illustrates the differences between these two types of tool classification.

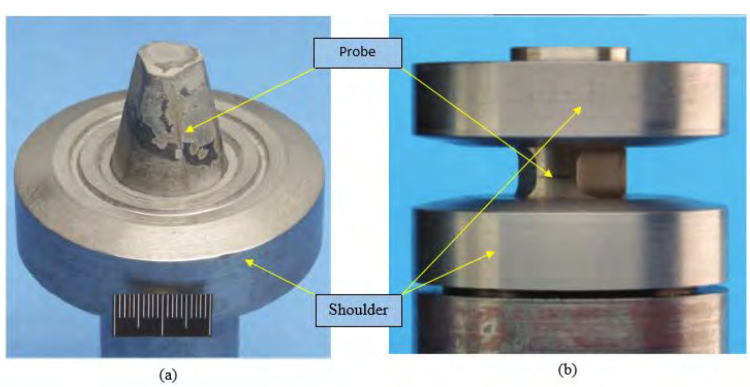

Figure 1. 1 : Differences between CFSW and BFSW (a) conventional friction stir welding, (b) bobbin friction stir welding (Thomas et al., 2009)

According to (Alloy & Sheet, 2013), aluminium alloy AA1100 (1000 series Al alloys) composition consist of almost 99% aluminium. This material can't be hardened through heat treatment and can only be hardened by cold working such as cold rolling etc. the material theoretically soften at room temperature after cold work and can archive a stable condition in a short period of time. In other words, the materials will cool down in a short time after being

© Universiti Teknikal Malaysia Melaka

worked. In welding area, this material has an excellent welding capability with all conventional methods nowadays and widely used to produce structural welds. The heat affected zones are also minimized when welding process is applied to this material. Furthermore, according to The Aluminium Association the 1000 series are classified under the non-heat-treatable alloys together with another two of its member such as 4000 series and 3000 series alloys. These alloys series also have an excellent weldability and high corrosion resistance when it comes to marine applications of the alloys. This makes the alloys generally used in the construction of buildings, pressure vessels, storages tanks etc.

This FSW technique is recommended to be applied in the industry and as for this research is to do the friction stir welding using the bobbin tool design for rolled aluminium AA1100. In addition, any common problem that usually occurred during the cooling down process at the welded joint such as cracking during solidification and porosity formation does not occur generally in FSW (Tabatabaeipour et al., 2016). This proves that FSW is way better in terms of possible number of problems that may occur can be minimized.

1.1 Problem Statement

In this research, the material used is an AA1100 aliminium alloy with thickness of 6mm. this aluminium alloy is founded to have many challenges when it comes to the joining process using conventional welding technique. This challenge includes defect formation, manual process setting and low productivity. Most of the welded parts will crack after the welding process and lack of strength when subjected to other process. In other cases, the conventional welding such as Gas Tungsten Arc Welding (GTAU), Gas Metal Arc Welding (GMAU) and Tungsten Inert Gas (TIG) are not suitable to be used for low melting point material like AA1100. Furthermore, over welding can resulted to blows at the welded area and will require a post process to fix the problem. In industry, highly skilled welders are required to produce an excellent welding process. These will force the industry to hire highly skilled welders and they also need to be paid with reasonable salary which is very high for the company to bear. Another thing that brings problem is the high heat generated from the welding process that

© Universiti Teknikal Malaysia Melaka

will affect the internal structure of the material and also the strength of it. It is believe that when BFSW is adapted as a welding technique for joining aluminium alloy, the stated problem can be eliminated. The BFSW also currently have very limited study on the selected weld response and for AA1100. In addition, the study on BFSW also not having any clear guide line regarding the process setting.

1.2 Objectives

Objective of this work are as follows:

- To measure weld response through measurement of vibration, current and temperature.
- To evaluate weld performance through mechanical test.
- To suggest optimum process parameter to weld the AA1100 using Response Surface Methodology (RSM).

1.3 Scope of Research

In the research on the Bobbin Friction Stir Welding of AA1100, there are a few constraints that have been decided. At the beginning of the research, the AA1100 need to be cut into a specific dimension (140mm X 140mm) using a shearing machine. The tool fabrication will be done by using conventional lathe machine. The material of the tool is made from H13 tool steel and will undergoing heat treatment process with 30 minutes soaking time at 1010^{o}C and will be quenched by air blast. For the welding process, only spindle speed (rpm) and welding speed (mm/min) will be manipulated throughout the whole research. In addition, the weld response of vibration, current and temperature will be monitored during the welding process to understand the relationship between each of the weld response with the welding

© Universiti Teknikal Malaysia Melaka

process itself. The weld performance will be tested its ultimate tensile strength using a tensile test machine. The sample of each weld will be cut into a dog bone shaped sample with the suitable American Standard of Testing Material(ASTM) standards before it is being tested. The results of the tensile then will be further optimized to find the optimum parameter using the Design of Experiment that has been selected.

1.4 Project Significant

a) This FSW is a new alternative way of joining techniques that can be possibly being applied to the world of manufacturing industry especially. The cost of implementing this new way of joining technique maybe a bit high for the first time but it can be more reasonable after certain period of time because it only cost the company for the maintenance of the machine only not like the current situation where the wage of the welder with high skill also need to be paid.

b) This study is important to identify the successful of BFSW welding approach to weld AA1100. The study will then be use as the foundation of technology transfer for the industry.

c) In current situation, there are very limited study in the selected field, this require more knowledge need to be explored.

© Universiti Teknikal Malaysia Melaka

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

The current welding techniques that commonly used nowadays are well established and proven to be able to weld almost every type of metals including the AA1100 alloys. Specifically in this field of study, AA1100 alloy are widely used in fabricating cookware product, chemical container, food industry containers, architectural flashing, lamp reflectors and as cable sheathing. In conjunction with that, there are several negative impacts that can occur to the external and internal properties of the welded product. Examples of the common defect are cracking formation, blow hole, porosity and shrinkage. In order to perform a perfect weld using these conventional techniques, some further attention need to be focused especially in the joint edge preparation, the need to immediately remove the oxide surface after the welding process, the proper selection on the filler metal used and the weld pool shield gas control. In addition, performing long and continuous welds using this conventional techniques can results in the distortion of the metal due to long period of the metal is being exposed to the high temperature. Hence, this problem needs another additional process in order to re-shape it to its original shape (Lafayette, 2017).

Friction stir welding (FSW) is well known to be one of the most suitable joining technique and specialized for aluminium alloy and other soft structured alloys. This FSW turns out to be far more convincing than the current traditional welding techniques as it can perform

© Universiti Teknikal Malaysia Melaka

long and continuous weld while producing minimum amount of distortion with the results of high quality weld.

2.1 BFSW Working Principle

The BFSW consist of three main stages. The first is entering of tool where the tool is being forced to enter the workpiece at the area need to be joined. Second is dwell period which occurs after the entering stage where the tool rotates in a fixed place without any traverse along the workpiece, this is due to build up enough heat to plasticize the material before the tool traverse the workpiece. Last is the welding stages where the tool started to move traverse along the workpiece to join the two parts together (Ullegaddi, Murthy, Harsha, & Manjunatha, 2017). There is an additional stage according to (G.K Padly et al, 2017) which is the retracting/cooling stage. When the tool is at almost the end of the join area, the tool then levitated horizontally from the workpiece Figure 2.0 below shows how the tool operating on the workpiece (Kumar & Kailas, 2008).

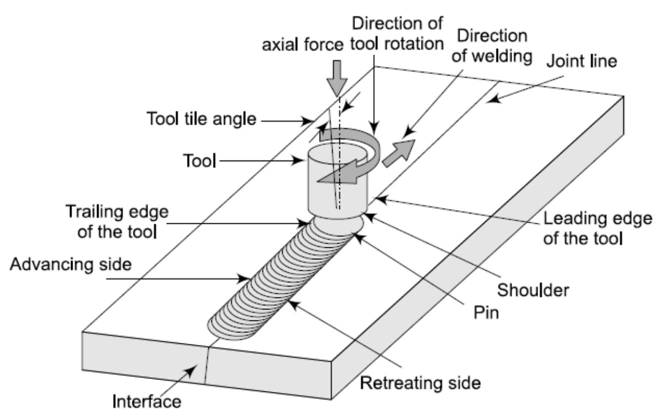

Figure 2. 1 : Schematic drawing of Friction Stir Welding
(Kumar & Kailas, 2008)

Basically, the principle of friction stir welding occurred in a solid state where the tool rotate the joining area into a below melting point of the material. The tool generates heat as the tool rotates and the mixing will began as the metal is heated by the heat pressure exerts by the

© Universiti Teknikal Malaysia Melaka

tool itself. There are two types of friction stir welding and it is categorized as conventional friction stir welding (CFSW) and bobbin friction stir welding (BFSW). The differences between these two types of tool are based on the number of shoulder it has. For CFSW only has one shoulder while BFSW has two shoulders.

2.1.1 Differences between CFSW and BFSW

According to a research carried by (W. M. Thomas et al, 2015) the use of bobbin tool type (also known as self-reacting tool) has been proven to have more advantages compared to FSW. Table 2.1 below shows several differences between FSW and BFSW that has been concluded.

Table 2. 1: Comparison between CFSW and BFSW (M K Sued, 2015, P L Threadgill et al, 2009)

Conventional Friction Stir Welding (CFSW)	**Bobbin Friction Stir Welding (BFSW)**
• Single shoulder	• Double shoulder, upper and lower
• Require backing plate to perform weld and high clamping force of the tool	• Use simple fixture to hold the weld material and less clamping force of the tool
• Equipment need to be set up correctly to avoid damage while welding	• Easy to assemble tool and require less set up time

The bobbin tool type believed to has more potential to overcome the problem faced by the conventional FSW. The presence of another additional shoulder at the lower part of the bobbin tool enhance the ability of the tool to weld the workpiece successfully. The two sets of shoulder in the bobbin tool enables the tool to balance the down force generated by each of the shoulder and at the same time will eliminate the net down force. Moreover, the bobbin tool type can perform the welding process faster and increase the efficiency of the process (Tuah et al., 2015). The need of using backing anvil like used in the FSW does not applied in the BFSW and this can make the working configuration less complex compared to FSW (Mishra

© Universiti Teknikal Malaysia Melaka

& Ma, 2005). Figure 2.2 shows the differentiation of backing anvil applied to FSW and BFSW. (Esmaily et al., 2016)

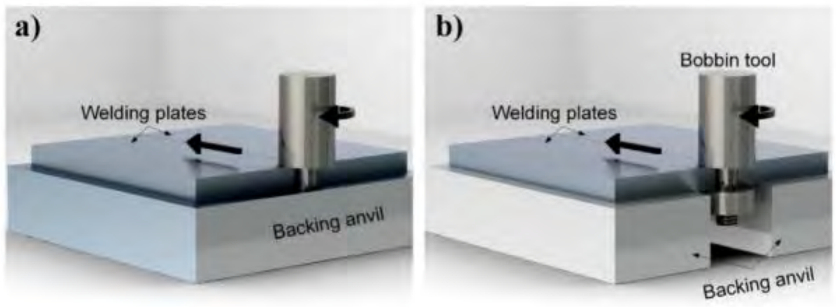

Figure 2. 2 : Backing anvil (a) backing anvil for CFSW and (b) backing anvil for BFSW (Esmaily et al., 2016)

(Esmaily et al., 2016) has concluded in their study that BFSW shows more promising result instead of FSW. They had conducted an experiment on welding thick extruded AA6005-T6 profiles. There results obtained prove that BFSW is better than FSW when the peak temperature exerts by BFSW method is high with low heat input and having higher cooling rate compared to FSW. Furthermore, the microstructure formed in the stir zone of the BFSW happens to be finer than the microstructure formed in the stir zone of the FSW. Finer microstructure of the grain produced indicates that the material have higher hardness value and ultimate strength (Esmaily et al., 2016).

2.1.2 Differences between conventional welding and BFSW

All types of conventional welding are under the fusion welding category, while BFSW is under the solid state welding. It has been observed that both of these welding categories use the different approach in order to join two or more material together. The difference is the fusion welding require the metal to reach the melting point to join the two metal together while the solid state welding achieve the same objective but by doing it under the melting point of the metal.

© Universiti Teknikal Malaysia Melaka