MECHANICAL PROPERTIES OF ALUMINIUM ALLOY 1100 SERIES THICK AND THIN MATERIALS WELDED USING BOBBIN FRICTION STIR WELDING

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MASTER OF MANUFACTURING ENGINEERING
(MANUFACTURING SYSTEM ENGINEERING)

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MOHAMMAD KHAIRUL AZMI BIN MOHD KASSIM

A thesis submitted
in fulfillment of the requirements for the degree of Master of Manufacturing Engineering (Manufacturing System Engineering)

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

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DECLARATION

I declare that this thesis entitled "Mechanical Properties of Aluminium Alloy 1100 Series Thick and Thin Materials Welded Using Bobbin Friction Stir Welding" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidate of any other degree.

Signature : ……

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Date : ……

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Manufacturing Engineering (Manufacturing System Engineering).

Signature	:	…….....
Supervisor Name	:	Dr. Mohammad Kamil Bin Sued
Date	:	…….

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APPROVAL

I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality as a partial fulfillment of Master of Manufacturing Engineering (Manufacturing System Engineering).

Signature	:	……
Supervisor Name	:	Dr. Mohammad Kamil Bin Sued
Date	:	……

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DEDICATION

To my beloved family

You are my sunshine, my only sunshine

You make me happy when skies are grey

You never know, dear, how much I love you

Please don't take my sunshine away

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ABSTRACT

Friction stir welding (FSW) is one of the solid state welding coming from a combination of heat and pressure in order to obtain the joining by stated process. However, there is very lack of information regarding to the studies of Bobbin Friction Stir Welding (BFSW). Therefore, this studies are to investigate the mechanical properties of thick and thin materials welded focusing on BFSW technique. The material that used for this study was Aluminum Alloy 1100 with the thickness 3mm and 6mm. In the meantime, the design of tool might give a huge contribution to the final welded product. The parameters that has be applied for this study are the spindle speed and welding speed. All of the welding process using CNC Milling Machine. There is only 2 set of parameters that used which are 900 rpm and 310 mm/min for spindle speed and welding speed. The other parameters are 1440 rpm for spindle speed and 190 mm/min for welding speed. The final product are testing by using tensile test, micro hardness, and XRD analysis. Result of this testing shows the properties of the welded materials by applying set of parameters that have been decided. By the end of this studies, thin materials not acquire the suitable parameters since the final product still showing sign of defect such as open tunnel and entry issues. Moreover, thin material are rarely to complete the joining process since specimen tend to broke during experiment. While for thick material, the parameters can be accepted because of the tensile, hardness, and XRD analysis. Future work studies still need to be conducted in order to overcome the problem that occur on thin materials. One of the idea are by studying the influence of tool design in BFSW.

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ABSTRAK

Teknik Kimpalan Geseran (FSW) adalah salah satu kimpalan yang berlaku dalam keadaan pepejal yang terhasil dari gabungan haba dan tekanan bagi melakukan proses pencatuman. Walau bagaimanapun, maklumat mengenai Teknik Kimpalan Geseran Bobbin (BFSW) masih kurang untuk diperolehi. Oleh itu, kajian ini bertujuan bagi mengkaji sifat mekanikal bahan yang telah dikimpal sama ada tebal dan nipis dengan mengaplikasikan teknik BFSW. Bahan yang akan digunakan untuk kajian ini ialah 1100 Alloy Aluminium dengan ketebalan 3mm dan 6mm. Sementara itu, reka bentuk alat mungkin memberi pengaruh yang besar kepada hasil kimpalan. Parameter yang akan digunakan untuk kajian ini ialah kelajuan gelendong dan kelajuan kimpalan. Semua proses kimpalan akan dijalankan dengan menggunakan Mesin CNC Milling. Terdapat 2 set parameter yang akan digunakan iaitu 900 rpm dan 310 mm / min untuk kelajuan gelendong dan kelajuan kimpalan. Parameter lain ialah 1440 rpm untuk kelajuan gelendong dan 190 mm / min untuk kelajuan kimpalan. Produk akhir akan diuji dengan menggunakan ujian tegangan, kekerasan mikro, dan analisis XRD. Hasil ujian ini akan menunjukkan sifat bahan yang dikimpal dengan menggunakan set parameter yang telah diputuskan. Menjelang akhir kajian ini, bahan yang memiliki ketebalan yang nipis tidak akan memperolehi parameter yang sesuai kerana produk akhir masih menunjukkan tanda kecacatan. Walaupun begitu, untuk bahan yang tebal, parameter boleh diterima. Bagi kajian pada masa akan datang, kajian pada bahan yang lebih nipis boleh dijalankan bagi mengatasi masalah yang berlaku. Salah satu ideanya adalah dengan mengkaji pengaruh reka bentuk alat dalam BFSW.

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LIST OF ABBREVIATIONS

FSW	-	Friction Stir Welding
BFSW	-	Bobbin Friction Stir Welding
CFSW	-	Conventional Friction Stir Welding
AA	-	aluminium alloy
Al	-	aluminum
Cu	-	copper
HAZ	-	heat-affected zone
CNC	-	Computer Numerical Control
UTM	-	Universal Testing Machine
ASTM	-	American Standard Testing and Material
XRD	-	X-Ray Diffraction

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CHAPTER 1

INTRODUCTION

This chapter elaborates the meaning and information regarding the project where it informs on the details of the project. The idea, data and information are collected from various resources in order to understand the concept and useful information or knowledge for the project.

1.1 Background of Study

There are many previous studies on learning to improve the quality of weld product that have zero defects problem. The enlargement of industry such as automotive and aerospace has overcome all of this problem. All of these industry are using welding as their main process. Therefore, it will become inhibitor for the researchers to find out more details about the welding process (Dawodd et al., 2015).

Friction stir welding (FSW) is one of the solid state welding coming from a combination of heat and pressure in order to obtain the joining by stated process. The joining process of FSW made by the heat of friction from the mechanical rubbing between the two surfaces that's usually the rotation of one part relative to the other. The aim of this joining process is to raise the temperature at the joint interface to the hot working range while there is a pressure applied on it as well. This process operates under the solidus temperature of metal to be joined hence no melting point will takes place during the process (Sued et al., 2014). This joining process is recommended for automotive, rail, marine, and aerospace transportation industries (Godiganur and Biradar, 2014). This technique is energy efficient,

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environmentally friendly, and versatile that are parallel to our objective that is green manufacturing (Mishra and Ma, 2005). The technology of FSW is the solid state joining process that creates high-quality, high-strength joints with low distortion and is capable of fabricating either butt or lap joints. The frictional heat causes a plasticized zone to form around the tool. The rotating tool moves along the joint line and form the joint. FSW being as a solid state process eliminates many of the defects associates with fusion welding techniques such as shrinkage, solidification cracking and porosity (Bussu and Irving, 2003).

FSW is divided into two types which are conventional friction stir welding (CFSW) and as bobbin friction stir welding (BFSW). The major differences for both types of the FSW are the tool design and process variables used in the welding process. The tool that use single shoulder is known as CFSW, while the tool with double shoulders is known as bobbin BFSW as shown in Figure 1.1. For CFSW the tool has a shoulder and a pin, while for BFSW, the tool come with double shoulders that connected by a pin. It is found that, BFSW will give more advantages compared to the CFSW (Threadgill et al., 2010). The reason is because in BFSW the shoulders provide high heat generation. This improve the material flow in solid state condition. The material flow itself will affect the grain size, hence improve the weld quality (Zhang et al., 2016). In term of process variables, the additional shoulder in BFSW will remove the needs of backing plate that also known as anvil in CFSW. The absent of anvil in BFSW will reduce setup period during welding preparation.

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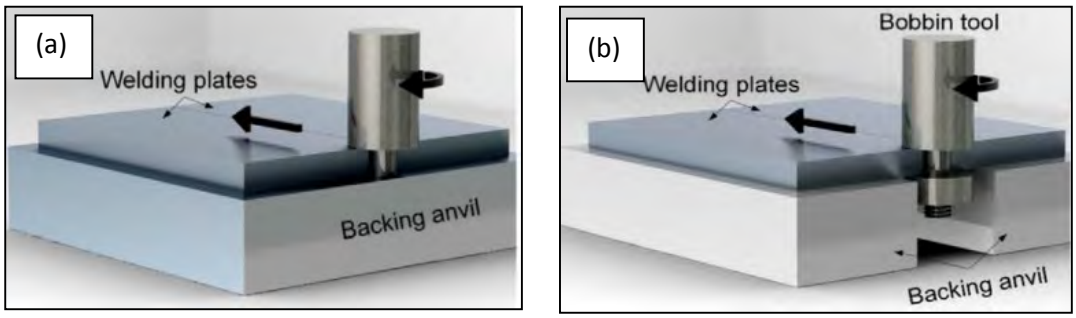

Figure 1.1: The operation of friction stir welding (Esmaily et al., 2016). (a) CFSW (b) BFSW

The application of these joining process is suitable for lightweight aerospace, automotive, and marine industries (Godiganur and Biradar, 2014). The technology of BFSW was developed to overcome some of the difficulties encountered in CFSW, such as the need of anvil and the potential root defects in the weld. This technology also eliminates root flaws, lower distortion joints produced compared with CFSW method. Guillo and Duborg (2016) have stated that the parameters of the FSW set will have a big effect on producing a good quality of weld product. Parameters such as the speed of tool weld rotates and the position of pin during the welding process must be perfectly studied to overcome the good quality of weld product. In this project, BFSW will be main highlighted point since there is lack of information about the tool entry position for BFSW that need to be investigated in a further details.

According to Colligan et al. (2012) that studies about friction stir welding of thin aluminium using fixed gap bobbin tools, thin materials have been classified as a material that having below 5mm thickness. Therefore, materials that having thickness above 5mm could be classified as thick material.

1.2 Problem Statement

In BFSW, the best parameters for this process are still under research and study. Since there is still a lack of information about the parameters of BFSW, this study are conducted. The parameters that was applied during BFSW process must be determined in

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order to produce the best quality of weld product at the end of this study. The parameters of this process might help the application of BFSW in the industry. This are because, when the changeover of thickness in material, the parameters must be change as well. Therefore, by showing in this study, industry may applied the suitable parameters based on the thickness of material.

The problem are there is still a little studies about the parameters that will been used for a different thickness of the material especially thin material. However, it might be similar parameters that will be used for a thick material. Therefore, in order to proven and overcome this problem, the investigation of the different type of thickness for the friction stir welding process have been carried out.

1.3 Objectives of Study

The purpose of this study is to investigate the mechanical properties of thick and thin materials welded using bobbin tool in friction stir welding technology. The objectives for this research are:

(i) To evaluate the weld formation on welding on thick and thin materials based on different type of angle of shoulder..

(ii) To analyze the mechanical properties of welded thick and thin materials using tensile test, micro hardness, and XRD analysis.

(iii) To recommend the consideration parameters for welding thick and thin materials using bobbin tool.

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1.4 Scope of Study

Two types of material thickness used in this study are 3mm and 6mm of 1100 Aluminum Alloy. The materials are prepared to a dimension of 140mm (length) x 140mm (width) for a butt joint configuration. Fixed type of bobbin tool is used. The tool is fabricated with cylinder shoulder and pin. Proses parameters that are spindle and travel speed are varied during the experiments. To determine the weld performance, the welded plates are visually inspected for identifying the present of defect. Then, the test samples are cut following ASTM E8 for tensile test besides subjected to micro hardness measurement and XRD analysis.

1.5 Significant of Study

The important to study the difference of different thickness of material in BFSW are to observe the parameters that will be applied for each of material thickness. It might shows the influence of the thickness itself during conducting this process. Furthermore, it will observe the defect formation on the weld bead based on the visual inspection. All the defect that produced are tunnel formation, the flash formation, and rooster head that produced by material ejection. Other than that, all of the material waste can be reduced by determined the best parameters that will be applied. These kind of problem that occurs might give a low quality of weld product. It can be sure by the reduction of tensile strength in tensile testing.

Besides that, the bobbin tool that is used to give a stirring effect on the material will produce the joining process. Therefore, it is important to study related to the tool design in BFSW in order to reduce the enhancement of defect product, tool wear, and tool broken. These problem might be occur by the increasing of the amount of travel force during the welding process. The increasing of the tool forces are because of the increasing of tool speed

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travel. Since the tool moving forward at the high speed, the travel force will be increases continuously.

In order to solve all the problem stated, all of the objectives for this study must be achieved. Furthermore, this study might help the industry to growth in a positive ways especially for automotive and aircraft industries. The best parameters suggested will helps the industry to achieve a good weld quality that will capable to withstand any condition and environment with a low of manufacturing cost.

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CHAPTER 2

LITERATURE REVIEW

This chapter elaborates the meaning and information regarding the project where it informs on the details of the project. The idea, data and information are collected from various resources in order to understand the concept and useful information or knowledge for the project.

2.1 Friction Stir Welding (FSW)

Friction stir welding (FSW) is a type of welding process that used solid state joining principles (Cavaliere et al., 2006). No liquid state is formed since the welding is completed under the melting point of the material used. This happen when it apply the straight conversion from mechanical to thermal energy. Many variables will affect the degree of heat and pressure. Some factors should be considered if the objective of welding is to obtain defect free welds such as axial force, rotation speed, traverse speed, tool tilt angle and tool geometry (Sued, 2015). The temperature of the material also will be increase when the frictional heat supplied from the friction on between both of the tool and the material are enough (Dawood et al., 2015) But, the major affecting the FSW process are tool geometry, joint design, and process variables such as tool rotation and traverse speed (Mishra and Ma, 2005).

FSW itself will gives a positive impact towards the development of critical industries such as aerospace, aircraft and automotive which provides better joining performance with better weld quality to achieve the manufacturing cost reduction (Guillo and Dubourg, 2016).

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