WELDING INITIATION AT THE ENTRY STAGE OF BOBBIN FRICTION STIR WELDING (BFSW)

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Manufacturing Process) (Hons.)

by

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I hereby, declared this report entitled “Welding Initiation Strategy at The Entry Stage of Bobbin Friction Stir Welding (BFSW)” is the result of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Manufacturing Process) (Hons). The member of the supervisory committee are as follow:

(Dr. Mohamad Kamil Bin Sued)
ABSTRAK

Kimpalan bobbin geseran dan pusingan ialah proses kimpalan yang digunakan putaran alat silang melalui plat kimpalan untuk membentuk menyertai antara dua plat. Tujuan kajian ini dijalankan adalah untuk mengetahui strategi permulaan kimpalan pada peringkat kemasukan Bobbin geseran Kacau Welding (BFSW). eksperimen dijalankan dengan menggunakan mesin CNC Milling. Set parameter yang digunakan adalah jenis kemasukan, pendekatan strategi, kelajuan putaran dan kelajuan perjalanan dengan menggunakan Al-aloi siri 5XXX dengan dimensi 140mm x 140mm x 6mm menggunakan alat bobbin tetap. kajian yang dijalankan sejak pembentukan weld baik dipengaruhi oleh permulaan kimpal yang baik. Kecacatan seperti pelemparan material, pembentukan flash, tidak sah dan terowong di peringkat kemasukan boleh dikurangkan dengan mencadangkan kaedah penyertaan. Dalam kajian ini, dua jenis kemasukan telah digunakan; kemasukan tepi dan lubang berpandu kemasukan didekati. Nilai maksimum yang diberikan oleh kaedah kemasukan tepi adalah 12,794 mm² kawasan ubah bentuk dengan 0,074% daripada bahan sia-sia dan digunakan 27 672,75 J tenaga untuk melengkapkan satu kitaran proses kimpalan. Suhu maksimum dicapai ialah 387 ° C. Analisis Fourier digunakan untuk menganalisis sambutan frekuensi mesin yang digunakan dan menganalisis pembentukan kualiti kimpalan yang baik dan buruk. Untuk masuk kelebihan, baik kualiti kimpalan yang telah kerap dihasilkan. Hasil minimum yang diambil dari kekerasan dan tegangan ujian adalah 28.24 HV dan 33,2292 MPa. Untuk lubang berpandu, nilai maksimum kawasan ubah bentuk adalah 43,160 mm² dengan 0,499% daripada bahan terbuang dan jumlah maksimum penggunaan tenaga untuk melengkapkan kitaran kimpalan telah 57 960 J. Suhu maksimum dicapai ialah 438 ° C dan menghasilkan kualiti kimpalan buruk kerap dalam analisis Fourier. Nilai minimum dicapai dalam ujian kekerasan dan ujian tegangan adalah 26.5 HV dan 12,5625 MPa. Pada akhir kajian ini, kaedah terbaik kemasukan alat yang telah dicadangkan untuk mendapat kualiti yang lebih baik kimpalan.
ABSTRACT

Bobbin Friction Stir Welding is a welding process that uses rotational tool cross through the welding plate to form joining between two plates. The purpose of this research conducted was to find out the welding initiation strategy at the entry stages of Bobbin Friction Stir Welding (BFSW). The experiment conducted using CNC Milling machine. The parameter set used were type of entry, strategy approaches, rotational speed and travel speed by using Al-Alloy 5xxx series with dimension 140mm x 140mm x 6mm using fixed bobbin tool. The study conducted since good weld formation influenced by good weld initiation. Defects such as material ejection, flash formation, void and tunnel at the entry stages can be reduced by suggesting the entry method. In this study, two types of entry were used; edge entry and guided holes entry approached. The maximum value given by edge entry method was 12.794 mm$^2$ of area deformation with 0.074% of material wasted and used 27 672.75 J of energy to complete one cycle of welding process. The maximum temperature reached was 387°C. Fast Fourier Transform was used to analyse the frequency response of the machine used and analyse the formation of good and bad weld quality. For edge entry, the good weld quality were frequently produced. The minimum result obtained from hardness and tensile test were 28.24 HV and 33.2292 MPa. For guided holes, the maximum value of area deformation was 43.160 mm$^2$ with 0.499% of material wasted and the maximum amount of energy consumption to complete a welding cycle was 57 960 J. The maximum temperature reached was 438°C and produced bad weld quality frequently in Fast Fourier Transform analysis. The minimum value reached in hardness test and tensile test were 26.5 HV and 12.5625 MPa. At the end of the study, the best tool entry method was suggested in order to obtained better weld quality.
DEDICATION

TO MY BELOVED PARENTS & FAMILY,
Mahrob Bin Sarno and Rafiah Binti Suradi
Mohamad Amal, Muhamad Mursid and Muhammad Naim Iman
For their continuous supports and prays through the journey of my life

TO RESPECTED SUPERVISOR
Dr. Mohammad Kamil Bin Sued
For his advices and motivation
ACKNOWLEDGEMENT

In the name of ALLAH, the most gracious, the most merciful, with the highest praise to Allah that I manage to complete this final year project successfully without difficulty.

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<td>AA</td>
<td>Aluminium alloy</td>
</tr>
<tr>
<td>Al</td>
<td>Aluminium</td>
</tr>
<tr>
<td>AS</td>
<td>Advancing side</td>
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<tr>
<td>ASTM</td>
<td>American society for testing and materials</td>
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<tr>
<td>BFSW</td>
<td>Bobbin Friction stir welding</td>
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<td>CFSW</td>
<td>Conventional friction stir welding</td>
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<td>CNC</td>
<td>Computer numerical control</td>
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<td>HAZ</td>
<td>Heat affected zone</td>
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<td>RS</td>
<td>Retreating side</td>
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<td>SEM</td>
<td>Scanning electron microscope</td>
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<td>SOP</td>
<td>Standard operation procedure</td>
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<td>SZ</td>
<td>Stirring zone</td>
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<td>TMAZ</td>
<td>Thermo-mechanically affected zone</td>
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<td>UTM</td>
<td>Universal testing machine</td>
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<td>WNZ</td>
<td>Weld nugget zone</td>
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<td>--------</td>
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</tr>
<tr>
<td>%</td>
<td>Percent</td>
</tr>
<tr>
<td>wt. %</td>
<td>Weight percent</td>
</tr>
<tr>
<td>mm</td>
<td>Millimetre</td>
</tr>
<tr>
<td>MPa</td>
<td>Mega Pascal</td>
</tr>
<tr>
<td>GPa</td>
<td>Giga Pascal</td>
</tr>
<tr>
<td>°C</td>
<td>Degree Celsius</td>
</tr>
<tr>
<td>W/mK</td>
<td>Watt per metre per Kelvin</td>
</tr>
<tr>
<td>K</td>
<td>Kelvin</td>
</tr>
<tr>
<td>nm</td>
<td>Nanometre</td>
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<tr>
<td>kg</td>
<td>Kilograms</td>
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<tr>
<td>mm/min.</td>
<td>Millimetre per minute</td>
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<tr>
<td>rpm</td>
<td>Revolution per minute</td>
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<tr>
<td>kN</td>
<td>Kilo newton</td>
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CHAPTER 1
INTRODUCTION

Friction Stir Welding is used to join two materials together using the solid state approach. Welding initiation is important to guarantee the success of the welding process to achieve good weld quality. However, there are less researches and study that were conducted before for the welding initiation for Bobbin Friction Stir Welding. This study is done to investigate the best tool entry position for Bobbin Friction Stir Welding.

1.1 Background Study

It is crucial for every welder to determine the best tool position and starting point of welding process before the welding is performed. The position of tool is one of several issues that need to be further investigated in welding process (Sahu, Pal, Pal, and Jain, 2016). Many researches and study were done before to improve the quality of weld with zero defects problems. This scenario happens due to the enlargement of critical industry such as automotive and aerospace. Since these industry used welding as the joining technique, it become inhibitor to the researches to find out more in details about welding process (Dawood, Mohammed, Rahmat, & Uday, 2015).

In 1991, Friction Stir Welding (FSW) was invented by The Welding Institute (TWI) in the United Kingdom. FSW is a welding process that combining two parent plate together by using rotational tool which is mechanically transverse through the plates. FSW is categorized as solid state joining technique since there is no melting material is involved to performed the welding (Sued, Pons, Lavroff, & Wong, 2014). FSW is much better compared to the traditional joining process such as riveting and adhesive bonding in designing of light structures product with lower manufacturing cost (Cavaliere, Nobile, Panella, & Squillace,
2006). This kind of joining capable to remove defects; distortion and low residual stress compared to the other joining process (Bussu & Irving, 2003).

There are types of FSW; conventional friction stir welding (CFSW) and bobbin friction stir welding (BFSW). The major differences for the both types of the FSW is the design and features of the tool used in the welding process. CFSW tools come with design of single shoulder with pin while BFSW comes with double shoulder and a pin. BFSW gives advantages compared to the CFSW. BFSW comes with a pair of shoulder; top and bottom that provides several differences while using it. These two shoulder provide better heat generation while the welding process is done that give improvement on the material flow. The material flow will affecting the grain size and the quality of weld produced. Secondly, using the BFSW will remove the using of backing plate called anvil that is use in CFSW. The use of anvil give make the welders to consume more time due to preparation of welding especially when vertical welding position take places. The position of the anvil must be adjusted when the thickness of the parent plate use is changes.

According to the Guillo and Dubourg (2016), they stated that the parameters of the FSW set gives a big effect on producing the weld quality. The parameters such as the speed of tool weld rotates and the position of pin during the welding conducted must be perfectly studied to achieve the best weld quality. However, the best tool position at the entry stages for BFSW are still in the researches. As the tool pin position in the FSW is significantly crucial, BFSW bobbin tool position also must be determined to get the best weld quality. As the conclusion, in this project, BFSW will be the main highlighted since there is lack of information about tool entry position for BFSW that need to be investigated in further details.

1.2 Problem Statement

As mentioned before, BFSW seem to have large potential to growth larger in the critical industries. However, the studies on the BFSW is fewer compared to the CFSW. For BFSW, there are so many aspects need to be investigated and studies further to improve the welding performance and weld quality. For this project, it will focused on the welding initiation at the entry stages of the BFSW.
The best tool position important to be determined to reduce any related problems that are usually produced by any types of welding processes. One of the major problem occurs at the entry stages of BFSW is the amount of the material waste produced. The material waste leads to the increasing of the cost consumption and so that the best method for the entry position need to be determined to lower the percentages of the material waste produced.

The best tool position seem to be capable to reduce the defect formation in the entry stages of the welding process. The major defects produced in the initial of welding processes are material ejection formation, void, flash and tunnel defects. These problems seem to be related on the material readiness to be welded at the entry stages of the BFSW.

The signal output responses of BFSW must be observed to see the behaviour of the responses produced from the different parameters set in every experiment conducted. Based on the problem arises, the investigation on the tool entry method need to be carried out in order to solve the problems stated before.

1.3 Objectives

The objectives of the researches are:
1. To suggest the suitable tool entry method for good weld formation of BFSW process.
2. To analyse the behaviour of temperature, current and force signal at the entry of the welding process.
3. To evaluate the weld initiation formation of different entry approaches of BFSW using mechanical test, visual inspection and metallurgical work.
1.4 Scope Of Project

This project will be focused on two different tool entry approaches. The first method is the entry from the edge of the materials and second is using guided hole. This experiment will be conducted using Aluminium 3xxx series. The dimension of the material to be welded is 140 mm (length) x 140 mm (width) x 6 mm (thickness).

The type of bobbin tool used is a fixed type with the 5.8mm distance between the two shoulders. The tool consists of two features; shoulder and pin. The tool will be designed by using the Solidwork 2013. The tool will be fabricated by using Conventional Lathe Machine. The fixtures is also to be designed and fabricated using material of mild steel. After the material preparation and tool preparation are completed, the experimental work will be proceeded for the next stages of the experiment. The BFSW will be performed by using Computer Numerical Control (CNC) Milling.

Three signal measurement will be conducted and analyse which are current behaviour, force signal and the temperature of the welding plate at the entry stage of the welding process. A dynamometer; a tool that will calculate the amount of force received will be attached to the welding plate during the welding process is conducted. Thermocouple type-K, a device uses to measure the temperature while the clamp current metre is used to measure the current signal of the experiment.

After the experiment is done, the visual inspection will be done conducted to check the present of the defect on the workpieces. The visual inspection is to be conducted to see and observe the defect formation on the welding plate and the length of defect occurs will be measure using the vernier callipers. Metallurgical work also will be conducted to inspect the microstructure of the specimen. The polishing and grinding must be perform before the microstructure of the specimen is observed carefully. Scanning Electron Microscope (SEM) will be used to see the microstructure of the work pieces.

Besides, the mechanical test also will be taking place after the experimental work is done. The mechanical test that will involve in this experiment are tension test and hardness test. The tension test will be conducted using Ultimate Testing Machine (UTM) while the hardness test to be performed is Vickers Hardness test. By the end of the experiment, the
most suitable tool entry approach must be suggested by evaluating the result of the visual inspection testing, metallurgical works and mechanical testing done.

1.5 Significant Of Study

The important of the study on the welding initiation at the entry stage of BFSW is to observe the defect formation on the weld bead based on the visual inspection. The defect produced are tunnel formation, the flash formation and rooster head produced by material ejected. Other than that, material waste can be reduced by determined the best tool positioning of bobbin tool. Material waste cannot be eliminated at the entry stage of BFSW but the amount of the material waste can be reduce by identifying the best tool position of BFSW. These kind of problems occurs would give low weld quality produce in terms of physical and mechanical properties of the product produced. It can be seen by the reduction of tensile strength in tensile testing.

Besides, the bobbin tool is used to give stirring effect on the material to produce the joining. At the entry stage, the amount of the material stirred is limited. So, it is important to conduct a study on this topic to see the behaviour of stirring formation at the entry stage of the welding. Next, the most significant of the study is to reduce the enhancement of tool wear and tool broken. These problems come from by the increasing amount of the travel force during the welding process. The increasing of tool forces is due to the increasing amount of tool speed travel. As the tool moving forward with high speed, the travel force is increasing. So, it is important to see the force signal at the entry stage of the welding process.

By achieving the objectives of the study, the problems stated before can be solves. This study will also help the industry to grow larger, especially for automotive and aircraft industries. The best tool position of the bobbin tool entry will helps the industry to achieve a good weld quality that capable to withstand any condition and environment with low manufacturing cost.
1.6 Organization of Project

Chapter 1: It will provide the background of the study, problem statements, objectives, scope and the significance of the study.

Chapter 2: In this topic, it will highlight the original author’s viewpoint, provide information and generate the general ideas on the project conducted.

Chapter 3: This chapter provides detailed and precise procedural information on how the data is collected and how the data are analysed.

Chapter 4: It will provide the outcome of the experiment conducted and explain the result finding in the researches.

Chapter 5: This chapter will come out with the conclusion of the whole project and propose a recommendation for the improvement of the project.
In the previous chapter, the briefing about the project was done generally. In this chapter, the details about the project will be stated clearly by referring from the previous researches and study. The information mostly are about CFSW since there are only a few information for BFSW.

2.1 Friction Stir Welding

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. It is ways where it used straight conversion from mechanical to thermal energy. The motion between the tool and the material produced heat that makes the material undergoes plastic deformation so the joining is formed. In FSW, non-consumable is used. The tool is rotated and inserted into the joining. The material temperatures is rises when the frictional heat supplied from the friction between the tool and material is enough (Dawood et al. (2015). According to Mishra and Ma (2005), tool geometry, joint design and process variable are the key of success for FSW.

FSW gives 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). According to Bussu and Irving (2003), the usage of welding process are mostly suggested by the manufacturer to eliminate any waste from the manufacturing process. They also stated that FSW is the most suitable manufacturing process to be used to weld aluminium alloy. FSW
give high tensile strength for aluminium alloy which are widely used in vehicle and transportation industries.

The application of FSW give a lot of benefit for the manufacturer. Mishra and Ma (2005) stated that FSW gives benefit in metallurgical, environmental and energy. In metallurgical aspect, it gives low distortion in the material plate, dimensional stability, fine microstructures and the absence of crack. For environment, FSW is a green process since no shielding gas is needed. The preparation time can be reduce since no surface cleaning have to be done and the secondary process like grinding can be eliminated. In term of energy consumption, it allow the decreasing of fuel consumption by the reduction in weight for the material use.

2.2 Conventional Friction Stir Welding

As mentioned before, there are two types of FSW; conventional friction stir welding (CFSW) and bobbin friction stir welding (BFSW). CFSW is consist of a rotating tool that comes with single pin and single shoulder (figure 2.1). The joining process occurs when the heat is generated by the tools after the pin is rotated and fully penetrated into the material to produce the joining. The heating and stirring process is started from the advancing side (AS) to the retreating side (RS).

Figure 2.1: CFSW Tools
The major problems faced in CFSW is that it need more clamping forces to make sure that the parent plate is not moving horizontally or vertically during the welding process. Due to the problem faced by the welder, the parent plate is clamped on the both axis so the plate does not moving during the process due to high forces exerted by the tool to produce joining. Besides, CFSW need to have anvil; a backing plate especially when the welding process is done vertically to prevent the movement produce by vertical forces. The welding preparation done will consume a lot of time and adjustment of the anvil must be done when there is changes of parent plate thickness. Figure 2.2 shows the apparatus set up for CFSW.

![Figure 2.2: CFSW apparatus set up (Esmaily et al., 2016)](image)

2.3 Bobbin Friction Stir Welding

The word ‘bobbin’ is referring to the shape of the tool that consist of two shoulders; upper and lower (figure 2.3). The problems that happens while CFSW is used can be countered by replacing it with BFSW. Esmaily et al. (2016), stated that the present of double shoulder allowed the forces produces while the tool and the material in contact to balance and remove the net down force. BFSW eliminates the present of the backing plate or so called anvil that is used for CFSW (Hilgert, Schmidt, dos Santos, and Huber (2011). The risk of having the root flaws can be remove by using BFSW. BFSW give better efficiency in thicker section when the tool processing speed can be increases while reducing the process forces (Esmaily et al. (2016). In short, BFSW offers a lot of advantages compared to CFSW.