# THE EFFECT OF BOBBIN FRICTION STIR WELDING REPETITION PROCESS ON THE MICROSTRUCTURE OF THE ALUMINIUM ALLOY 1100

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

by

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# DECLARATION

I hereby, declared this report entitled “The Effect of Bobbin Friction Stir Welding Repetition Process on the Microstructure of the Aluminium Alloy 1100” is the result of my own research except as cited in references.

Signature : ……

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Date : 27/12/2019

# 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 (Hons). The member of the supervisory committee are as follow:

…….....

**(DR. MOHAMMAD KAMIL BIN SUED)**

# ABSTRAK

Bahan yang digunakan sebagai bahan kerja untuk disertai dalam kajian ini adalah aloi aluminium 1100. Alloy aluminium 1XXX adalah bentuk aluminium yang murni kerana ia mengandungi minimum 99.00% aluminium. Kimpalan pengadukan Bobbin (BSFW) serasi untuk kimpalan AA 1100 kerana ia merupakan proses mesra alam yang mengurangkan pengeluaran haba dan pencemaran. Masalah bagi kajian ini adalah untuk memahami pengubahsuaian ciri-ciri bahan apabila kaedah multipass digunakan. Selain itu, cabaran lain adalah untuk menentukan kemampuan multipass untuk membaiki sendi dengan menggabungkan semula. Di samping itu, sambungan antara harta mekanikal sifat bahan dan logam perlu dipastikan untuk menganalisis keupayaan multipass untuk menghasilkan sambungan kimpalan yang baik. Kaedah untuk menyelesaikan masalah adalah dengan menjalankan percubaan untuk mengenal pasti peningkatan ciri-ciri bahan oleh multipass dan menemui di mana jumlah pas akan menghasilkan bersama dengan kualiti yang tinggi. Kaedah yang sama akan berguna untuk menentukan sama ada multipass boleh membantu menyambung semula kimpalan untuk dihasilkan bersama. Tambahan lagi, kaedah metalurgi dilakukan untuk mengkaji sifat sampel logam. Kaedah metallurgical yang digunakan untuk kajian ini adalah mikroskop optik (OM) dan mikroskop elektron pengimbasan (SEM) untuk memerhatikan evolusi struktur mikro dan juga perisian yang dikenali sebagai ImageJ digunakan untuk menentukan saiz butiran. Mesin mikrohardness digunakan untuk menganalisis kekerasan sampel dan ujian kekuatan tegangan muktamad juga dijalankan. Setelah melakukan kajian, hasil yang dijangkakan adalah penentuan bilangan pas yang dapat meningkatkan sifat material dan juga untuk memperbaiki sendi. Kemudian, korelasi antara harta mekanik dan harta logam boleh dibuat berdasarkan kajian yang dijalankan. Oleh itu, dengan menggunakan proses (BSFW) yang memperkenalkan haba yang rendah akan menjadikannya sebagai proses kimpalan keadaan pepejal yang sesuai untuk AA 1100.

# ABSTRACT

The material used as a work piece to be joined in this study is Aluminium alloy 1100. Aluminium alloy 1XXX is a pure form of aluminium as it contains minimum 99.00 % of aluminium. Bobbin friction stir welding (BSFW) is compatible for welding AA 1100 as it is an environmental friendly process that reduce the production of heat and pollution. The problem for this study is to understand the modification in characteristic of material when multipass method utilized. Moreover, another challenge is for determining the capability of multipass for repairing joint by rejoin. In addition, connection between mechanical property of a material and metallurgical properties need to be determined for analyzing the ability of multipass for producing good weld joint. Methods for solving the problem is by conducting the experiment to identify improvement of in characteristic of material by multipass and discover at which number of passes will produce joint with high quality. The same method will be useful for determining whether multipass can help for rejoining of weld for the joint produced. Furthermore, metallurgical method done for examining metallurgical property of sample. Metallurgical method used for the study is optical microscope (OM) and scanning electron microscope (SEM) for observing the microstructure evolution and also software known as ImageJ used for determining the grain size. Microhardness machine utilized for analyzing the hardness of sample and ultimate tensile strength test also carried out. After performing the study, expected outcome is determination of which number of passes can improve material characteristic and also for repairing the joint. Then, correlation between mechanical property and metallurgical property can be made based on the study carried out. Thus, by using (BSFW) process that introduce low heat will make it as a suitable solid-state welding process for AA 1100.

# DEDICATION

**TO MY DEAREST PARENTS,**

Mr Vellasamy Subbiah and Mrs. Komalavalli Ramasamy

**TO MY BELOVED SISTER,**

Sobitha Vellasamy

**TO MY HONOURED SUPERVISOR**

Dr. Mohammad Kamil Bin Sued

*For his advices, support, motivation and guidance during accomplishment of this project*

**TO ALL STAFF & TECHNICIANS**

*For their direction and advices during completion of this project*

**TO MY MOTIVATOR**
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*For your love, motivation and support*

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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| CFSW | - | Conventional Friction Stir Welding |
| FSW | - | Friction Stir Welding |
| FSP | - | Friction Stir Processing |
| TIG | - | Tungsten Inert Gas Welding |
| MIG | - | Metal Inert Gas Welding |
| BFSW | - | Bobbin Friction Stir Welding |
| AA 1100 | - | Aluminium Alloy 1100 |
| GMAU | - | Gas Metal Arc Welding |
| RSM | - | Respond Surface Method |
| TWI | - | The Welding Institute |
| BM | - | Base Metal |
| SEM | - | Scanning Electron Microscope |
| OM | - | Optical Microscope |
| TEM | - | Tunneling Electron Microscope |
| XRD | - | X-ray Diffraction |
| AS | - | Advancing Side |
| RS | - | Retreating Side |
| TMAZ | - | Thermal Mechanical Affected Zone |
| SZ | - | Stir Zone |
| NZ | - | Nugget Zone |
| RPM | - | Revolution per minute |
| ASTM | - | American Standard Testing of Material |
| UTM | - | Ultimate Tensile Machine |
| ANOVA | - | Analysis of Variance |
| SMAW | - | Shielded Metal Inert Gas Welding |

| | | |
|---|---|---|
| HAZ | - | Heat affected zone |
| DCZ | - | Dynamic recrystallization zone |
| GBCD | - | Grain boundary character distribution |
| SRX | - | Static recrystallization |
| EBSD | - | Electron backscatter diffraction |
| BSE | - | Back-scattered electron mode |
| IPF | - | Inverse pole figure |
| OIM | - | Orientation Imaging Microscopy |
| GOS | - | Grain Orientation Spread |
| UTS | - | Ultimate tensile strength |
| MAD | - | Misorientation angle distribution |
| DRV | - | Dynamic Recovery |
| CDRX | - | Continuous Dynamic Recrystallization |
| FE-SEM | - | Field emission scanning electron microscope |
| FAZ | - | Filling Affected Zone |
| IMCs | - | Intermetallic |
| BUE | - | Built-up edge |
| WZ | - | Weld zone |

# LIST OF SYMBOLS

| | | |
|---|---|---|
| ℃ | - | Degree Celsius |
| MPa | - | Mega Pascal |
| mm/min | - | Millimeter per minute |
| µm | - | Micrometer |
| kN | - | Kilo Newton |
| kgf | - | Kilogram force |
| N | - | Newton |

# CHAPTER 1
# INTRODUCTION

## 1.1 BACKGROUND STUDY

In this current modernization era, manufacturing industries need to enhance the manufacturing process used in order to produce a product that have high strength and less in defects. One of the crucial part in manufacturing process is joining process. Most common joining process involves welding process. Welding process is widely used for many applications such as for manufacturing of marine transports, automotive and aerospace. Welding process offers permanent joint with a high strength.

Friction stir welding (FSW) is one of most significant joining process. It is known as a solid state joining process. It was founded by The Welding Institute (TWI), which located at United Kingdom in 1991 (Fuse & Badheka, 2019). The working principle of Friction stir welding (FSW) technology is by utilizing a non-consumable tool that rotates mechanically. The tool will travel through the area of workpiece that intended to be joined. As the tool rotates at high speed, it produces heat from friction that will make the material softer and closes the weld (Mohammad K. Sued & Pons, 2016). Hypothetically, the grains of material will be transferred and reorganized between two parts of material that intended to be weld without causing it to melt. The advantage of this welding method is producing joint with high mechanical properties, has high efficiency of energy and it can be used to weld many types of aluminium allow as it is a solid state joining process. Other types of welding technique such as Metal Inert Gas (MIG), Gas Metal Arc Welding (GMAU) and Tungsten Inert Gas (TIG) can be categorized under category known as fusion welding. This category is really contrasting in terms of its working principle as in fusion welding will be performed by melting the base metal by supplying heat to

it. Moreover, a filler material is included to the base metal when it undergoes melting process. By doing so, it will will increase the strength to the joint that intended to be weld. According to (Shanavas & Raja Dhas, 2017) for (FSW) process, it does not involve the usage of fusion material. Thus, this process avoids the occurrence if defects at welded areas caused by reaction of metallurgical and deforms in fusion welding process.

Friction stir welding (FSW) process can be grouped into two types, which is conventional Friction Stir Welding (CFSW) and bobbin Friction Stir Welding (BFSW). The categorization is done by referring on the design of tool used. Even though, the process for both types of tool is identical but the method of the joint formed is affected by contrasting approach. This is because, the presence of additional shoulder in (BFSW) that eliminate force of plunge and tilting angle. Figure below shows the difference between two types of tool categorization.

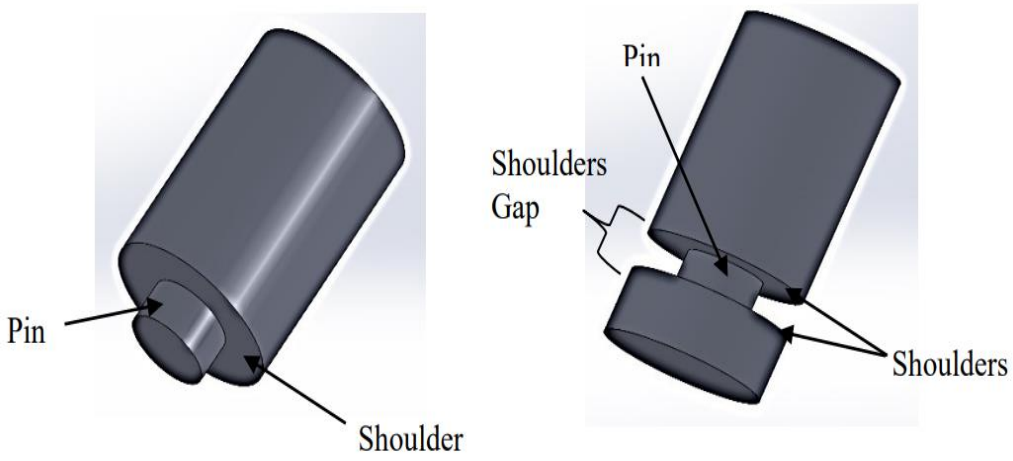


Figure 1.1: Types of FSW. (a) CFSW (b) BFSW (M K Sued, Samsuri, Kassim, & Nasir, 2018)

Friction stir welding is use commonly as solid state joining process to weld aluminum alloy. Aluminum alloy 1100 is widely used in manufacturing of metal sheets as it is light in weight and able to withstand corrosion. Material that has been welded by FSW process will encounter plastic deformation at high temperature that will cause the development of fine and equiaxed recrystallized grains. The presence of fine microstructure by friction stir welding will generate a joint with high strength (Kulkarni, Pankade, Andhale, & Gogte, 2018).

There are defect in welding such as kissing bond, cavity and groove during friction stir welding (FSW). Mostly, this defect is caused by inappropriate of parameter setting or conditional of technological. The presence of defects will affect the mechanical properties of the joints. Thus, repairing welding process of joint is required but there is deficiency in associated studies. Moreover, groove defect is one of the major defects that occurs because of rupture pin tool. The defect will cause degeneration of the weld joint and to the mechanical properties as it has larger size.

Friction stir welding (FSW) is used as repair welding process. To obtain an ideal repair process of welding, the main focus is set on microstructural characteristic and mechanical properties of the joint that undergoes repairing process (H. Liu & Zhang, 2009). (FSW) process used a method for repairing joint for different type of metals such as copper, titanium and aluminum. In addition, the process used to alter the microstructure for material with worn out or corroded surface. Repair welding technique is crucial in manufacturing of products. Structures that undergoes repair process have high fracture toughness, ductility and good strength (Salami, Khandani, Asadi, & Besharati Givi, 2014). For this study, AA 1100 will be weld by using bobbin friction stir welding (BFSW) process in multi-pass way and observation is fully focused on the microstructure evolution.

## 1.2 PROBLEM STATEMENT

Welding process of aluminium alloy are crucial in manufacturing industry for a wide variety of fields such as automotive, aircraft, marine and for architecture purposes. Aluminium alloy possess vital properties such high machinability, light in weight, high ductility, good weldability and recyclability. Furthermore, it has high resistance towards corrosion. In this research, the material used is an Aluminium alloy 1100 (AA 1100) and is known as wrought alloy whereas its composition is about 99.00% made up of aluminium. It is also known as non-heat treated alloy and its strength is fabricated by alloying the aluminium with other elements. AA 1100 will undergo strain hardening or cold working to acquire its strength.

Purpose of this study is to perform practical study on repetitive welding by using bobbin friction stir welding (BSFW) on aluminium alloy 1100. The main concern is to identify whether multipass or repetition (BSFW) process can change material characterization for improving the weld joint produced or not. If multipass method can improve the weld joint, thus need to discover at which number of pass can improve or deteriorate the weld joint produced.

Furthermore, another aspect is for determining ability of repetition welding in term of repairing process. As the material that undergoes multipass welding technique, number of passes will influence the rejoining of weld. By performing this study, identification for occurrence of rejoint weld at which number of pass can be carried out. It was found that there is defect on welded specimen after BFSW process such as open tunnel. This caused by insufficient heat during process (M.K.A.M. Kassim, M.K. Sued & D.J. Pons 2019) and ineffective stirring between advancing side and retreating side (Tamadon, Pons, Sued, & Clucas, 2018). The problem statement is whether by performing multipass BFSW joining can reduce defects at surface joining by improving the material readiness and provide heat that will ‘soften’ the material.

By conducting this study, relationship between mechanical property of weld joint and metallurgical property for multipass will be discovered. Multipass will cause change in microstructure for the weld joint thus by correlating metallurgical technique, the relation between mechanical properties and metallurgical property can be determined. It is imperative to study the microstructural characteristic as it can indicate the variation in mechanical properties of welded joint. Thus, this study is carried out to gain more information and comprehension

regarding of repetitive welding by using (BFSW) process on Aluminium alloy 1100. It is vital for this research to be conducted as it is major impact to the propulsion of multi-pass (BSFW). Expansion of this understanding is important to advance, asses and exhibit the potential and also the advantage of utilizing bobbin friction stir welding (BSFW) and finally to obtain usefulness from the improved potential that it provides.

## 1.3 OBJECTIVE

The objectives of this study are:

1. To analyse the microstructure evolution for multipass bobbin friction stir welding by correlating with metallurgical testing method.

2. To identify the relationship between mechanical properties of material and multipass BFSW welding.

3. To recommend a solution of multipass BFSW based on metallurgical analysis.

## 1.4 SCOPE OF RESEARCH

The scope of this research is to study the the impact of multipass of bobbin friction stir welding (BFSW) process on aluminium alloy 1100. This research focus mainly on microstructural evolution at end of welding process. Bobbin friction stir welding (BFSW) used for as joining process for AA 1100. The welding process is done in multipass on the workpiece. For this welding process, parameter of the machine such welding speed (mm/min) set at 105 (mm/min) for one pass, 155 (mm/min) for two pass and 205 (mm/min) for three pass. Rotational speed of bobbin tool (rpm) is set constant at 900 rpm throughout the study for each pass. Before testing, the sample will be cut into small parts. The quality of weld will be analyzed in terms of hardness by microhardness test machine and tensile testing. The sample undergoes three processes such grinding, polishing and etching in order to obtain its detailed microstructure. Polishing is done on specimen to get a smooth surface by using abrasive silicon carbide paper with fine scale. Then, etching process is done after polishing by utilizing chemical solution, keller reagent. Both of this process is crucial to get image of a perfect microstructure for analysis purpose. As main concern is on the microstructural evolution on the surface of workpiece, it will be investigated by optical observation. Furthermore, optical microscope (OM) and scanning electron microscope (SEM) used to magnify the image of microstructure in detailed manner in order to carry out further analysis.

## 1.5 SIGNIFICANT OF STUDY

Bobbin stir friction welding (BSFW) is an effective welding method as it consumes less energy and has capability to perform welding without any fillers. Thus, it has high demand in manufacturing industry such as automotive industry. It is a suitable joining process for producing good quality of weld without defects such as porosity and it is also fully automated. As the process is fully automated, it contributes to high productivity, reduce necessity of manpower for handling purpose and decrease cost of labor. The process is considered as environmentally friendly and does not possess threat towards human's health. (BSFW) process is predominantly used for welding thin sheet of material. High quality of weld promises a strong joint that have good strength and longer durability. In conclusion, this study is crucial to be carried out for analyzing the microstructure evolution on aluminum alloy 1100 due to multipass and to discover relationship between mechanical property and metallurgical property of weld joint produced to increase the quality of weld produced by multi-pass of (BSFW) process.