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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

THE IMPACT OF BOBBIN FRICTION STIR WELDING FIXTURE ON THE WELD DEVELOPMENT

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Master of Manufacturing Engineering (Manufacturing System Engineering)

2019

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**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

2019

UTeM

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BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA

TAJUK: **THE IMPACT OF BOBBIN FRICTION STIR WELDING FIXTURE ON THE WELD DEVELOPMENT**

SESI PENGAJIAN: **2018/2019**

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I declare that this thesis entitled "The Impact Of Bobbin Friction Stir Welding Fixture On The Weld Development" 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 candidature of any other degree.

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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 as a partial fulfillment of Master of Manufacturing Engineering (Manufacturing System Engineering).

Signature : ....

Supervisor Name : Dr. Mohammad Kamil Bin Sued

Date : ....10. 4. 2019..........

DEDICATION

To my beloved mother, father, husband, son and daughters. Thanks for the valueable time that you all had been sacrified for me.

ABSTRACT

Welding process is in high demand, which required a competitive technology to be adopted. This is important for sustaining the needs of the joining industries whithout ignoring the impact of the process enviroment. The quality of Bobbin Friction Stir Welding (BFSW) is depending on the material stirring by the tool and fixture. Bobbin Friction stir welding (BFSW) is a relatively new solid-state joining process. This joining technique is energy efficient, environment friendly, and versatile. In particular, it can be used to join high-strength aluminum alloys and other metallic alloys that are hard to weld by conventional friction stir welding (CFSW). BFSW is considered to be the most significant development in metal joining in a decade. In this review article, the current state of understanding and development of the BFSW are addressed. Particular emphasis has been given to: (a) to quantify vibration generated from different fixture design of BFSW, (b) To investigate the impact of vibration on weld formation and weld strength through mechanical test and (c) To suggest the suitable fixture design of BFSW using design of experiment approach .Using Taguchi with factorial model in order to identify the correlations between response parameters and the total of 9 experiments were conducted. The problem was vibration was a major problem during the production process and greatly affects the quality of the product strength. The result collected was optimized using Taguchi and p-value and R-square were calculated using analysis of variance (ANOVA). According to the result Design C is the best design fixture that indicate 25 mm of shoulder gab with 17.5978 mm/s of vibration velocity, 32.0167 HRH of hardness value and 77.1898 Mpa of tensile strength value.

ABSTRAK

Proses kimpalan adalah proses yang mendapat permintaan yang tinggi, yang memerlukan teknologi kompetitif untuk diterima pakai. Ini penting untuk mengekalkan keperluan industri yang bergabung tanpa mengabaikan impak dari lingkungan proses. Kualiti kimpalan melalui geseran bergantung pada bahan yang digunakan.Kimpalan ini adalah proses baru. Teknik ini merupakan teknik yang cekap, mesra alam, dan serba boleh. Khususnya, ia boleh digunakan untuk menggabungkan aloi aluminium berkekuatan tinggi dan aloi logam lain yang sukar dikimpal oleh kimpalan lain . Penekanan khusus telah diberikan kepada: (a) untuk mengukur getaran yang dijana daripada reka bentuk lekapan BFSW yang berbeza, (b) Untuk menyiasat kesan getaran pada pembentukan kimpalan dan kekuatan kimpalan melalui ujian mekanikal dan (c) Untuk mencadangkan reka bentuk yang sesuai BFSW menggunakan reka bentuk pendekatan percubaan. Menggunakan Taguchi dengan model faktorial untuk mengenal pasti korelasi antara parameter tindak balas dan jumlah 9 eksperimen yang dijalankan. Oleh itu getaran merupakan masalah utama semasa proses pengeluaran dan sangat mempengaruhi kualiti kekuatan produk. Hasil yang dikumpul dioptimumkan menggunakan Taguchi dan p-nilai dan R-square dikira dengan menggunakan analisis varians (ANOVA). Menurut hasil dapatan reka bentuk C adalah reka bentuk terbaik melalui jarak rekabentuk jig iaitu sebanyak 25 mm dengan 17.5978 mm / s halaju getaran, 32.0167 HRH nilai kekerasan dan 77.1898 Mpa nilai kekuatan tegangan.

ACKNOWLEDGEMENTS

"Bismillahirrahmanirrahim"
"In the name of Allah, The Most Beneficent, The Most Merciful"

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my supervisor Dr. Mohammad Kamil Bin Sued from the Faculty of Manufacturing Engineering Universiti Teknikal Malaysia Melaka (UTeM) for his essential supervision, support and encouragement towards the completion of this thesis.

Particularly, I would also like to express my deepest gratitude to the En. Mohd Hanafiah Bin Mohd Isa as Assistant Engineer at CNC laboratory from Faculty of Manufacturing Engineering, also to Dr Mohammad Kamil fulltime student Master and PHD, Najihah and Azmi for their assistance and efforts in all the lab and analysis works.

Special thanks to all my peers, my beloved mother, late father, husband, children and siblings for their moral support in completing this Master. Lastly, thank you to everyone who had been to the crucial parts of realization of this project.

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CHAPTER 1

INTRODUCTION

Welding is a fabrication or sculptural that join material. Traditional welding such as metal inert gas (MIG) and tungsten inert gas (TIG) is widely used in the industry. However, to weld difficult material such as aluminium alloy and magnesium alloy, these technology is quite challenging. Defects such as blow hole, incomplete weld and cracks are commonly present. The main reason is because of melting metal. To solve these issues, solid state welding is introduced. This is the focus of this thesis, whereby investigation about Bobbin Stir Friction Welding (BFSW) is conducted. The aim is to quantify the impact of rigidity on the fixture towards weld quality formation.

1.1 Background of Study

Bobbin Stir Friction Welding (BFSW) is one of the welding that are new and been develops in the manufacturing industries. Previously, the welding is been made using conventional welding machine, as there a new material that had been introduce in manufacturing product there a limitation to joining the part of difficult materials. So the present of Bobbin Stir Welding (BFSW) is one of the improvement to solve the problem. In this thesis the main aims is to investigate the rigidity of the fixture during the welding process. In this process a rotating welding tool is traversed along the joint path between the work pieces to be joined. The rotation of the tool generates frictional heat, which softens the joining materials around the weld line. The combined transverse and rotation motions of the tool mix the softened material in the joining area and a high-quality welded joint is obtained.

1.2 Problem Statement

In Friction Stir Welding many of the research focus on heat generation and material flow to form a good weld. Where the condition is suitable when material is fed inside stirring zone. Consequently, it is believed that if tool meets the work piece, it will run into material stiffness and the process tolerance because of the adjustment to the mechanical compliance. It is believed that the tool especially the pin is under stress that force it in the reflex angle position. This situation alters heat generation and material flow. The condition is more crucial when the clamping fixture or support produce additional movement. This cause difficulty for process optimization that contribute to unreliable process prediction. This mechanical compliance is known as rigidity. So to encounter the problem, in this research we have overcome with these objective below.

1.3 Research Objectives

The objectives of the research are:

i. To quantify vibration generated from different fixture gap diameter of BFSW

ii. To investigate the impact of vibration on weld formation and weld strength through mechanical test.

iii. To suggest the suitable fixture gap of BFSW using design of experiment approach.

1.4 Scope of Study

This study will involve Aluminium 1100 series 6mm as the welded material. The type of Bobbin tool used is a fixed type that comes along with cylinder pin with a flat shoulder to perform this welding operation. Three different fixture slot design are used to generate different strength on weld support. This welding operation is done by using CNC machine. Spindle speed and travel speed (process parameter) are varied. A combination of fixtures and process parameters are feed into the design of experiment matrix. All of the welded plate are subjected to the mechanical and metallurgical test. Mechanical testing consist of tensile test using Universal Testing Machine (UTM) and micro hardness. ASTM-E8 standard and Vickers hardness of 20g are applied.

1.5 Significant and Important of Study

The BFSW is the one potential welding process with can be deformed joining the lower melting heat material such as aluminium. But in BFSW there are situation where the fixture will produce vibration when the solid to solid material component meet. It is believe that the fixture plays very important role in BFSW as it maintains the position of the welding work piece from going apart in plunging phase and in operation. In fixture gaping for BFSW the considering factors are high temperature reaching during welding operation and in extreme condition. A fixture should be very stiff in order to transmit the vibration without adding extra noise. The welded work piece are likely to remain stuck to the fixture compromising both the fixture integrity and soundness of the joint. Fixture should be designed and fabricated so that it should bear the forces and rising temperature during welding process without distortion.

1.6 Research Planning

Research planning of this research is outline in Gantt chart as in Appendix 1

CHAPTER 2

LITERATURE REVIEW

The focus of this study is to investigate the impact of Bobbin Friction Stir Welding fixture on the weld development and microstructures characteristic. This chapter reviews and explain about the past studies that have been done previously. The literature review is a proof of research or study in related field, which is describe to justify the statement and examines respectively to the source.

2.1 Friction Stir Welding

This Friction Stir Welding (FSW) process is relatively new solid state joining process and it is focused in attention in joining of low and high temperature of material (Lakshminarayanan, Balasubramanian et al. 2010). In FSW process there are two components need to be considered. The components are the material to be welded and the other one is rotated tool, which is to rub the material under the axial load. This method can provide the joining of both similar materials and dissimilar materials (Sassani and Neelam et al. 1998) .When a pair of the work piece is urged together through this process, this causing a frictional heat and consequently a column of material softens underneath of the tool form a plastic deformation (Karami, Jafarian et al. 2016). The tool is non-consumable and usually the material use to build the tool is stronger than the work-piece materials (Mishra and Sidhar 2016).

According to Mishra and Ma (2005), to produce a good quality of weld in FSW there are three factors that need to be consider to control the material flow pattern and temperature distribution which this will affect the microstructure of the material. Those factors include tool geometry, welding parameters and joint design. FSW is known as a green process appeared as an easy, ecological and promising welding method that is to reducing the material waste, radiation and harmful gas emission that usually linking with the fusion welding processes (Lakshminarayanan, Balasubramanian et al. 2010).

2.2 CFSW versus BFSW

Friction stir welding (FSW) can also know as conventional friction stir welding (CFSW). According to Koning (2002), FSW adopt a technique whereby a mandrel is moved over the boundary surface of an elements that travelling through it path. As stated earlier in the Introduction chapter this welding process did not involve any melting phase and can be conducted on either similar or dissimilar metal joining. In CFSW, the tool consist a rotating shoulder on top of a work-piece and a rotating pin that thrust out from the shoulder into the depth of work piece. The main axial force that imposes by the tool on the work piece is reacted through a ridged backing anvil under the work piece as shown in Figure 2.1.

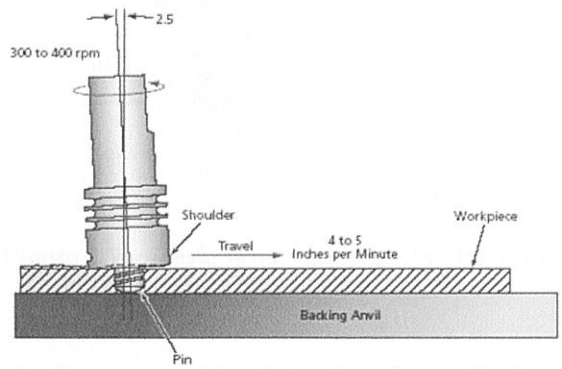

Figure 2.1: In CFSW, the force exerted by the tool on the work piece is reacted by the backing anvil.

On the other hand, there is special class of FSW tools called bobbin tools (BFSW) which sometimes referred as self-reacting tools (SR-FSW). In BFSW there are two rotating shoulder that located on top and on the bottom of the work piece. The shoulders are connected by the tool pin. By having an adjustable distance between the shoulders, the tools can have a fixed gap or can allow a force controlled the welds. Only a pin have to be carried out and there is no need for a backing plate as the loads act between the two shoulders when using bobbin type tool as the main axial force impose on the work piece by the tool and front shoulder is reacted through the bottom shoulder and the treaded shaft. This results welding machines with substantially lower stiffness and yield in terms of tool design material and lifetime because it is possible to weld closed profiles (Hosseini, Basirat Tabrizi et al. 2016). Figure 2.2a and Figure 2.2b below show the basic principle of the bobbin tool.

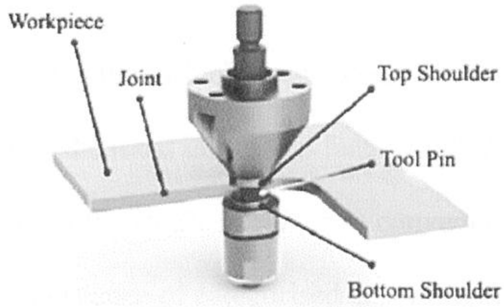

Figure 2.2a: Basic principle of the bobbin tool

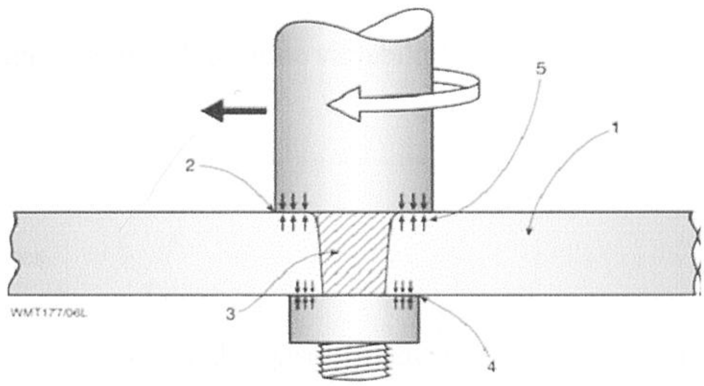

Figure 2.2b: Principle of the bobbin tool

1) Work piece
2) Upper Shoulder
3) Probe
4) Lower Shoulder
5) Force Generated

2.3 Process Variable

In a common place, BFSW involves with intricate material movement and plastic deformation. Due to the fact, welding parameters, tool geometry, and joint design impart the important of the material flow pattern and temperature distribution which at the end it will predispose the microstructural evolution of the material. The tool generates its own heat unlike fusion welding techniques which need external heat source to generate heat during process. Therefore, tool is the most influential factor in FSW and BFSW joining. There are widely researches based on the single shoulder in conventional FSW and few literature of BFSW. This lead to the existence of categorised according to pin features, shoulder feature and tool dimensions. In this topic, there are few major factors that influenced the BFSW process which need to be addressed such as tool geometry, tool types, welding parameters, welding gap compression and machine variability.

2.3.1 Pin features

At the initial stage of this process, the friction between the pin and work piece produces the heat. To increase the penetration depth of the weld or the processed zone, the tool pin is plunged into the work piece. The tool can be result in two primary function (a) heating the work piece, and (b) motion of material to produce the joint. The heating achieved by the development of plastic deformation at the welded area. By heating at the same place prompt the material to softens around the pin and the combination of the tool movement and translation encourage to movement of material from the front of the pin to the back of the and pin (V. Kočović a 2015).

A study was conducted by Sued, Pons et al. (2014) and stated that for the pin features, a vertical movement can be presented by the cylindrical threaded pin feature while on the other hand, the features which effect the horizontal movement and helps in the in blending of the weld material are flutes and flat faced. By providing a little difference, maximum of four flutes or faces is required with an additional. Moreover, by having a tapered type of pin,