PROCESS – MECHANICAL PROPERTIES EVALUATION OF FRICTION STIR WELDING LAP JOINT USING ALUMINIUM ALLOY AA6061 WORKPIECE MATERIAL

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DECLARATION

I declare that this Choose an item. entitled " Process – Mechanical Properties Evaluation on Friction Stir Welding Lap Joint using Aluminium Alloy AA6061 Workpiece Material" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 

Name : *NAJIB SHAUQI B AHMAD BUNI*

Date : 18 January 2022

APPROVAL

I hereby declare that I have checked this thesis, and, in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours.

Signature : 

Supervisor Name : *Ts. Mohd Hairizal Bin Osman*

Date : 18 January 2022

DEDICATION

Alhamdulillah, praised to Allah the Almighty for providing me with excellent health, guidance, and wisdom during this project's completion. This research is entirely devoted to my adoring parents and family for their unwavering moral, spiritual, and emotional support. Thank you to my supervisor and other relevant lecturers who have shared their expertise as well as all the assistant engineers who dealt with me patiently and offered their knowledge.

ABSTRACT

Friction Stir Welding (FSW) is an advanced solid-state joining techniques that use non-consumable tool to join two plates in a specially designed pin in underwater and dry condition. Due to the use of water in the welding process at the UFSW, the welding zone's surrounds are not harmed by high temperatures. The test analysis is to study the relationship between microstructural data and mechanical behavior of the welded joint. Spindle speed (1400, 1575, 1750 rpm) and feed rate (20, 25, 30 mm/min) with square, thread, and hexagon tool pin profiles will be the parameter used in this project. Tool material used is the AISI D2 tool steel. Cutting operation will be performed using Conventional/CNC Turning Machine and EDM Wire Cut Machine. The purpose of the test is to determine the tensile strength and porosity of the welded zone. The SHIMADZU AG-100KN PLUS Tensile Testing Machine, as well as the Zeiss AxioLab A1 Upright Light Microscope and Zeiss EVO SEM Machine, were used to conduct the test analysis. The procedure is to weld two 2mm aluminium alloy plate using overlapped joint in underwater and dry condition and look into the relationship of the welding morphology and the tensile strength. From the experiment the maximum tensile strength value for an underwater environment is 78.4927 Mpa, while the lowest tensile strength value is 50.9120 Mpa. The greatest tensile strength value for dry conditions is 83.5088 MPa, while the lowest tensile strength value is 46.1185 MPa. Overall result show that thread pin profile contributes to the lowest tensile strength value for both condition and square for the highest. The porosity visibility is on the opposite of the tensile strength value as the relationship of both of the factors is inversely proportional. The conclusion of this thesis experiment includes suggestions for future research endeavours.

ABSTRAK

Kimpalan Kacukan Geseran (FSW) adalah teknik penyatuan keadaan pepejal canggih yang menggunakan alat tidak boleh habis guna untuk menggabungkan dua plat dalam pin yang direka khas dalam keadaan kering dan bawah air. Disebabkan penggunaan air dalam proses kimpalan di UFSW, persekitaran zon kimpalan tidak terjejas oleh suhu tinggi. Analisis ujian adalah untuk mengkaji hubungan antara data mikrostruktur dan kelakuan mekanikal sambungan kimpalan. Kelajuan kincir (1400, 1575, 1750 rpm) dan kadar suapan (20, 25, 30 mm/min) dengan bentuk profil pin segi empat sama, ulir dan heksagon akan menjadi parameter yang digunakan dalam projek ini. Bahan yang digunakan sebagai alat pemutar ialah keluli AISI D2. Operasi pemotongan akan dilakukan dengan menggunakan Mesin Pusing Konvensional / CNC dan Mesin Potong Kawat EDM. Tujuan ujian adalah untuk menentukan kekuatan tegangan dan keliangan zon yang dikimpal. Mesin yang digunakan untuk pengujian adalah Mesin SHIMADZU AG-100KN PLUS Tensile Testing serta Zeiss AxioLab A1 Upright Light Microskop dan Mesin Zeiss EVO SEM. Prosedurnya adalah untuk mengimpal dua plat aloi aluminium 2mm menggunakan sambungan bertindih dalam keadaan bawah air dan kering dan melihat hubungan morfologi kimpalan dan kekuatan tegangan. Daripada eksperimen nilai kekuatan tegangan maksimum untuk kimpalan bawah air ialah 78.4927 Mpa, manakala nilai kekuatan tegangan terendah ialah 50.9120 Mpa. Nilai kekuatan tegangan terbesar untuk kimpalan kering ialah 83.5088 MPa, manakala nilai kekuatan tegangan terendah ialah 46.1185 MPa.

Keputusan keseluruhan menunjukkan bahawa profil pin ulir menyumbang kepada nilai kekuatan tegangan terendah untuk kedua-dua keadaan dan segi empat sama untuk yang tertinggi. Keterlihatan liang adalah bertentangan dengan nilai kekuatan tegangan kerana hubungan kedua-dua faktor adalah berkadar songsang. Eksperimen tesis ini termasuk cadangan untuk usaha penyelidikan masa depan.

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LIST OF SYMBOLS AND ABBREVIATIONS

FSW	-	Friction Stir Welding
UFSW	-	Underwater Friction Stir Welding
AISI D2	-	Tool steel
6061-T6	-	Aluminium Alloy 6061
HRB/HRC	-	Value hardness in Rockwell
Mpa/Gpa	-	Megapascal/Gigapascal
°	-	Degree
Rpm	-	Rotation per minute
PFD	-	Process flow diagram
AZ31B	-	Magnesium alloys
Mm/min	-	Milimeter per minute
AA5083	-	Aluminium Alloy 5083
AISI H13	-	Tool Steel
kW	-	Kilowatt
Kg/mm3	-	Kilogram per cubic milimeter
Mpa	-	Mega Pascal

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CHAPTER 1

INTRODUCTION

1.1 Background

As a result of the Fourth Industrial Revolution (Industry 4.0), there is a significant difficulty in ensuring that the process used is in optimal condition, whether in terms of productivity or quality. The optimal plan must be implemented in order to achieve the best possible outcome on the market. Improving the manufacturing industries will eventually result in the creation of new jobs and economic growth across the country. A number of different versions of Friction Stir Welding (FSW) have gained popularity during the last two decades. In the case of conventional FSW, various researchers improved auxiliary energy sources in order to achieve better welding speeds and tool life at a reduced cost. When it comes to joining different materials such as aluminium and steel, FSW has an advantage over conventional welding techniques. As a result of its great performance and long-term durability, friction stir welding (FSW) is widely employed across a wide range of industries. It is widely utilised in the automobile, aerospace, shipbuilding, and railway sectors, among other fields.

Friction stir welding (FSW) is a non-consumable rotating device used to attach two plates in a specially designed pin. Welding of aluminium alloys previously thought to be unweldable with no flaws and excellent mechanical properties has been demonstrated to be possible. With friction stir welds, porosity, alloy segregation, hot cracking, and welding would not be an issue (FSW). No post-welding cleaning is necessary due to the robustness and improved surface quality. When compared to a few of the more frequently used fusion

welding processes for structural metals. Friction Stir Welding (FSW) is a novel solid-state joining process that eliminates the need for melting and recasting the material being welded. Additionally, it is commonly employed in industries due to the several benefits it may provide, including less distortion, lower cost, and no toxic airborne emissions.

Despite the numerous advantages of friction stir welding, there are some drawbacks. The hot cycles used in FSW result in a deterioration in the material's mechanical characteristics. Underwater Stir Welding (UFSW) is advantageous in this situation. UFSW is one of the most sophisticated welding methods currently accessible. This process is less expensive than shielding gas welding since it does not require filler material or shielding gas. It conserves energy and improves mechanical properties. Additionally, it enables well-defined grain size variation between zones inside the created high-quality weld joint. Underwater Friction Stir Welding (UFSW) is a state-of-the-art welding technology that has surged in popularity over the last several years. Underwater friction stir welding (UFSW) is a method of friction stir welding that occurs underwater rather than at ambient temperature in the air.

1.2 Problem Statement

In the last two decades, friction stir welding (FSW), a stable solid-state joining method, has emerged as a breakthrough welding technology owing to the high-quality joints it produces, the efficiency with which it operates, and the environmental friendliness it exhibits. (Meng et al., 2021). There are numerous joining weldabilities that can be formed throughout the welding process, the best quality of joining weldability after welding process, such as the material's tensile strength.

Dry Friction Stir Welding (FSW) and Underwater Friction Stir Welding (UFSW) are the two types of FSW welding. Given the same parameter, dry and underwater stir welding most likely offer different quality of the weld because of the condition where it is performed. Given the varying quality of the welding product, multiple parameters of Friction Stir Welding (FSW) are used. Furthermore, the varied quality of the product throughout the welding process is according to the state of friction stir welding.

The general problem is there are not much research has been done on Underwater Friction Stir Welding focusing on morphology and tensile strength as well as for lap joint welding. Underwater Friction Stir Welding (UFSW) product commonly seen to be rougher on metallic material like aluminium rather than perform in dry condition. The parameter of Underwater Friction Stir Welding (UFSW) used when using metallic material is also most likely different for when performed in wet and dry condition.

1.3 Research Objective

The main objective of this study and research are:

a) To study the weldability of aluminium alloy AA6061 material using lap joint in FSW.

b) To investigate the parameter on Friction Stir Welding (FSW) on aluminium alloy AA6061 in both dry and underwater condition.

c) To understand the relationship of welding morphology to tensile strength for when using Friction Stir Welding (FSW) in both condition on aluminium alloy AA6061.

1.4 Scope of Research

The scope of this research are as follows:

- The material use for workpiece is aluminium alloy AA6061.
- Welding process will be run on Conventional Milling Machine.
- SOLIDWORKS software is used to draw and design all the equipment needed for this project.
- Jig and fixture applied in this project.
- The test analysis is to study the relationship of welding morphology to tensile strength of the material welded.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter portrays an overview about this project based on related article about studies of Friction Stir Welding in dry condition and Friction Stir Welding in underwater condition (UFSW). The objective of this chapter is to provide better understanding about Underwater Stir Friction Welding (UFSW) used for aluminium alloy material. Apart from that, this chapter also focus on the related tool material and different jig & fixtures used in the industries.

2.2 Dry Friction Stir Welding

In the solid-state welding technology, the "Friction Stir Welding" (FSW) joining process is a well-known procedure. In this method, a spinning tool is used to physically combine the edge zones of two clamped metal species using a spinning tool. Based on (Mishra & Ma, 2005) Because of its energy economy, environmental friendliness, and versatility, FSW is considered a "green" approach by some. It is widely regarded as the most significant advancement in metal joining technology in a decade. When compared to typical welding processes, FSW consumes a disproportionately less amount of energy.

Because no cover gas or flux is used, the approach is environmentally friendly. Due to the absence of filler metal in the joining process, any aluminium alloy may be linked without regard for composition compatibility, which is a concern with fusion welding. When needed, dissimilar aluminium alloys and composites may be bonded with equal ease. It is an

aluminium alloy solid-state joining method that creates high-quality welds.(Choudhary et al., 2019)

(Nataliia et al., 2019) stated in her research that There have been a number of papers published on the FSW process since it was established in 1991, in an effort to better understand and enhance it. The vast majority of them use numerical methods such as finite element and finite difference techniques to solve specific problems such as temperature deformation distribution and heat transport processes in order to address these difficulties. Coulomb friction is used by the instrument to warm the contact surface between the workpiece 24 and its surface during the first stages of the FSW process. An investigation on the persistence of Coulomb's involvement and viscous friction throughout the pre-immersion stage of the FSW process is presented in this paper. In the welding process, the pre-immersion step is critical because it prepares the instrument for the following penetration of the weld.

2.3 Underwater Friction Stir Welding (UFSW)

Underwater Friction Stir Welding (UFSW) is a sophisticated solid state welding technology that uses a non-consumable high rotation tool to efficiently perform welding underwater. The use of the UFSW technique will make connecting the two metals underwater much easier (Ikram et al., 2016). This process uses a non-consumable tool that runs over the substrates under water without emitting any fumes. It uses less electricity. It improves the mechanical qualities of the product (Garg et al., 2014). It provides a very effective joint. In the realm of UFSW, there has been very little research. Researchers and academicians can benefit much from studies in this sector. According to (Dong et al., 2020) The average grain size of the stir zone was significantly finer than ordinary friction stir welding because to the enhanced cooling rate.

As stated by (Zhang et al., 2013) The thermal modelling of underwater friction stir welding (UFSW) was conducted with a three-dimensional heat transfer model. The vaporising properties of water were investigated in order to determine the underwater FSW boundary conditions. The modelling took into account the material's temperature-dependent properties. To validate the calculated findings, FSW experiments were conducted, and the calculated findings were found to be in good agreement with the experimental data. Although the surface heat flow of the shoulder is greater during the underwater FSW than during the normal FSW, the findings indicate that the underwater joint's greatest peak temperature is much lower than that of the regular joint. In comparison to a conventional joint, the region of high-temperature distribution is significantly decreased for underwater joints, and welding heat cycles in various zones are effectively managed.

Corresponding to (Fathi et al., 2019) no study in the published literature has taken into consideration the influence of water cooling on the distribution of residual stress. This is based on a prior work in which an aluminium alloy 6061-T6 was fused underwater utilising friction stir welding (UFSW). We investigated the impact of tool rotation and welding rate on joint quality, microstructures, hardness distributions, and tensile parameters. As previously stated, no data on the distribution of residual stress over the thickness of welded samples has been published until far.

2.3.1 Working Principle of USFW

UFSW (Underwater Friction Stir Welding) is a method for solid-state welding. It occurs at temperatures below the melting point of the substance. In this procedure, a non-consumable rotating tool is employed to run over the substrates. the water, which generates heat as a result of friction (Garg et al., 2014). The tool serves two fundamental functions: (a) heating the workpiece and (b) material movement to create the connection. Friction between