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A Review of the Friction Stir Welding Process and Parameters

Prashant Pratap Mall[1], Jitender Panchal[2]

Research Scholar[1], Assistant Professor[2]

Department of Mechanical Engineering[2]

Modern Institute of Engineering & Technology, Kurukshetra, Haryana (India)

Corresponding Author's Email: - *prasantpratapmall@rediffmail.com*

Abstract

Weld tensile strength was greatly impacted by welding speed and shoulder diameter in friction stir welding (FSW), but welding speed strongly affected percentage elongation. Friction stirs welding (FSW) modelling with a particular emphasis on heat generation caused by contact circumstances between the FSW tool and the work piece. The thermomechanical conditions observed during FSW differ significantly from those observed during metal welding, resulting in fundamentally distinct material flow processes and weld fault morphologies.

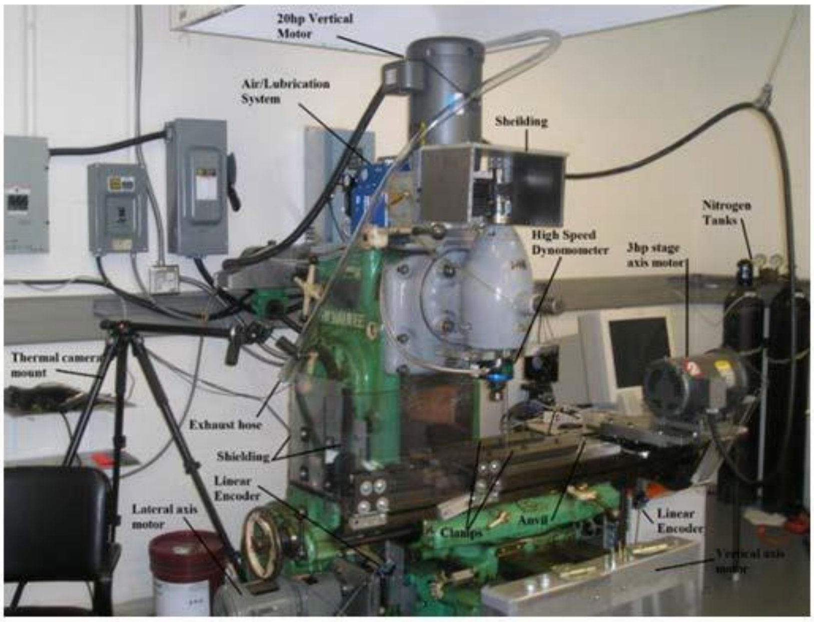
Keywords: *Friction Stir Welding (FSW), Thermomechanical, Welding tool*

INTRODUCTION

Wayne Thomas devised a new welding procedure called "Friction Stir Welding (FSW)" at The Welding Institute in 1991. It eliminates many of the issues associated with traditional joining procedures. FSW input' slow energy may also produce very high strength welds in a wide range of materials at a reasonable cost. The friction stir welding method takes place in the solid phase, below the connecting material's melting point.

WORKING PRINCIPLE OF FSW

The friction stir welding process employs a cylindrical tool with a profile that is rotated and slowly moves into the joint between two pieces joined together with the aid of a butt joint, resulting in the generation of frictional heat between the work piece material and the wear-resistant welding tool. This heat enables the tool to be moved along the weld line without approaching the melting point. The plasticized material is forged by the contact of the shouldered tool and pin profile and is transferred from the front edge of the tool to the rear edge of the tool probe. Friction Stir Welding is used to connect the materials listed below.



PROCESS PARAMETERS

Tool Design

This is an important component since it may affect both weld quality and maximum welding speed. At the welding temperature, a tool material that is sufficiently robust, durable, and hard wearing is required.

Tool Rotational Speed

Friction stir welding is a solid-state joining process in which friction is created between the tool pin profile and the plate. Rotational speed influences friction production. When the tool's rotational speed is increased or lowered, the weld quality will most likely increase or decrease.

Welding Feed Speed

As the welding speed increases, so does the temperature at the local position. The temperature rises when the feed rate is slow.

Axial Force

The axial force increases as the material thickness increases.

There are different weld zone into distinct regions as explained below:

Unaffected material

Heat affected zone (HAZ)

Thermo-mechanically affected zone (TMAZ)

Weld nugget (Part of thermo-mechanically affected zone)

Unaffected material or parent metal

This is material that is removed from the weld, has not been distorted, and has not been altered by heat in terms of microstructure or mechanical characteristics, despite having gone through a thermal cycle from the weld.

Heat affected zone

The material has gone through a heat cycle in this region, which is visibly closer to the weld centre, resulting in changes to the microstructure and/or mechanical characteristics. However, no evidence of plastic deformation has been found in this location. In the former system, this was referred to as the "thermally impacted zone." Because it is a direct parallel to the heat affected zone in other thermal processes, there is little need to label it anything else.

Thermo-mechanically affected zone

The material has been plastically deformed by the friction stir welding tool in this location, and the heat from the operation has also had an effect on the material. In the case of aluminium, sufficient plastic strain may be obtained without re-crystallization in this region, and there is usually a clear border between the re-crystallized zone and the deformed zones of the TMAZ. These two sub-zones were formerly classified as different micro structural areas. However, further research on other materials has revealed that aluminium behaves differently than most other materials in that it may be substantially deformed at high temperatures without re-crystallization. Other materials lack the characteristic re-crystallized portion (the nugget), and the entire TMAZ looks to be re-crystallized.

Weld nugget

In aluminium alloys, the re-crystallized region in the TMAZ is known as the nugget. Although descriptive, this word is not scientific. However, its use has expanded, and because there is no other word that is as straightforward and has as much scientific worth, this phrase has been embraced. The accompanying Figure depicts a schematic diagram that clearly distinguishes the various sections. It has been recommended that the area immediately below the tool shoulder (which is obviously part of the TMAZ) be given its own category since the grain structure is frequently different here. Rubbing by the back face of the shoulder determines the microstructure here, and the material may have cooled below its maximum. This area is proposed to be classified as a discrete sub-zone of the TMAZ.

APPLICATIONS

1. Shipping and Marine: The shipbuilding and marine industries were the first to use the method for commercial applications. The procedure is appropriate for the following applications: decking panels, sides, and floors Extrusions of aluminium Superstructures and hulls Marine and transportation infrastructure Masts and booms, such as those used in sailing vessels

2. Aerospace Sector: At the moment, the aerospace industry uses friction stir welding to weld prototype and production parts. Welding skins to spars, ribs, and stringers for use in military and civilian aircraft is possible. Friction stir welded longitudinal butt welds in Al alloy fuel tanks for space spacecraft have been successfully employed. As a result, the friction stir welding procedure may be used to forewings, fuselages, and empennages. Cryogenic fuel tanks for spacecraft. Tanks for aviation fuel. Rockets for military and scientific purposes. There are several basic and secondary structural components.

3. Railway Industry: A patent for the commercial manufacture of high-speed trains composed of aluminium extrusions that can be bonded by friction stir welding has been issued. High-speed trains are one example of an application. Rolling equipment for railways, subway cars, and trams. Tankers and freight waggons on the railway. Container shells

4. Other Industry Sectors: Friction stir welding can also be used for the following applications: electric motor housings (in production), refrigeration panels, cooking equipment and kitchens, gas tanks and gas cylinders, and connecting aluminium or copper coils in rolling mills.

ADVANTAGES OF FRICTION STIR WELDING:-

- It increases strength
- This process improves sealing. Completely void- free, leak proof joints with greater strength than fusion-welded joints the weld is in principle flush with the parent material
- It reduces heat distortion
- It improves repeatability. The FSW operation comprises a small number of variables which it is easy to monitor: tools, feed rate, rpm, and position of tool. This also permits close tolerances.

ENVIRONMENTAL ASPECTS OF FRICTION STIR WELDING

Today, there is a need to evaluate new industrial processes in terms of their environmental effect. The importance of HSE (Health, Safety, and Environment) problems in the workplace cannot be overstated in any business. Manufacturers frequently track the environmental effect of their products throughout their life cycles. When compared to alternative joining technologies, friction stir welding has significant environmental benefits.

Furthermore, "green thinking" is cutting-edge in the industrial sector and has significant marketing value.

Weld-seam preparation is simplified.

The principal weld applications for the FSW technique include butt, overlap, and blind welds. Work items with thicker walls frequently need an unique cutting or milling technique to establish the proper bead arrangement.

Fewer resources

As long as low melting temperature materials such as aluminium are used, the FSW Process requires no shielding gas and hence no investment in pressure tanks, pipe connections, or gas regulators. There is no need for consumables, which eliminates the requirement for their storage and transportation within the manufacturing area, as well as the necessity for their creation.

Noise, an underestimated health threat

MIG-pulse or TIG square-wave welding methods are often employed for aluminium. Both need a lot of energy when used on work pieces of medium thickness. Furthermore, the pulse or square-wave frequencies necessitate worker noise protection, which is often overlooked.

An FSW unit consistently produces less noise than a normal milling machine due to its electric spindle drive and hydraulic unit for axial pressure.

Energy saving FSW process

When calculating energy consumption, three elements must be considered: how much energy is necessary to execute the weld, how much energy is required to operate the machinery and ancillary equipment, and how much energy is required for post-processing (grinding and cleaning). In general, FSW requires less energy to weld than MIG and TIG, but more than laser welding. Total energy input is determined by the size of the equipment and the thickness of the joint, as well as whether single-pass or multipass welding is employed. FSW is always single pass, providing the maximum energy savings at thicker walls.

Less post-treatment and impact on the environment

Most other welding procedures need weld and root reinforcement. Grinding, in the latter situation, has a detrimental influence on the workplace environment, as well as greater energy consumption and extra equipment investment.

LITERATURE SURVEY

Kumaran and colleagues (2011) Numerous improvements in the field of materials processing have occurred as a result of this study. Friction welding is a popular solid-state joining method. Friction welding of tube-to-tube plate using an external tool (FWTPET) was accomplished in this research project, and process parameters were prioritised using Taguchi's L27 orthogonal array. The welding process parameters are optimised using a genetic algorithm (GA). The practical importance of using GA in the FWTPET process has been proven by computing the difference between expected and experimentally obtained welding process parameters.

Elangovan and colleagues (2012) The researchers in this work employ response surface methodology (RSM) in conjunction with a genetic algorithm to establish an effective approach for determining the ideal welding settings that enhance the strength of ultrasonic welding connections (GA). RSM is used to develop an effective analytical model for welding strength based on welding characteristics such as pressure, weld time, and amplitude. Experiments were carried out in accordance with the core composite design of experiments on 0.3- and 0.4-mm-thick Al specimens for spot and seam welding. Using experimental results, an effective second-order response surface model is built. The response surface model is then used in conjunction with GA to optimise the welding circumstances for the required weld strength. The optimal welding settings generated by GA are validated with experimental findings and found to be in good accord.

Mariano et al. (2012) give a review of the literature on friction stir welding (FSW) modelling, with a particular emphasis on heat generation owing to contact conditions between the FSW tool and the work piece. The physical process is detailed, and the key process parameters important for modelling are noted. The contact circumstances (sliding/sticking) are described, as well as an analytical model for calculating the accompanying heat generation. The modelling of the FSW process necessitates understanding of heat loss processes, which are presented primarily in terms of the more often used formulas. Different ways to investigating material flow are described, and their benefits and downsides are examined. The careful tweaking of some process and material parameters is required for successful FSW process modelling. Typically, these characteristics are determined via experimental data. The numerical modelling of the FSW process can assist in achieving such parameters with less work and at a lower cost.

ZHANG (2012) investigated the thermal modelling of underwater friction stir welding (FSW) using a three-dimensional heat transfer model. The vaporising properties of water were investigated in order to shed light on the boundary conditions of underwater FSW. The modelling took into account the material's temperature-dependent characteristics. To validate the calculated findings, FSW experiments were performed, and the calculated results agreed well with the experimental data. The findings show that the highest peak temperature of the underwater joint is much lower than that of the regular joint, despite the fact that the surface heat flow of the shoulder during the underwater FSW is more than that during the normal FSW. In comparison to a regular joint, the underwater joint's high-temperature distribution region is considerably reduced, and the welding heat cycles in various zones are efficiently managed.

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Simoes a, (2013) their study outlines the thermo-mechanical conditions during Friction Stir Welding (FSW) of metals have previously been topic of significant investigation and comprehensively explored in literature, but information on FSW of polymers is still quite sparse. This study examines the material flow and thermo-mechanical processes that occur during the FSW of polymers. The study is based on a review of the literature as well as an assessment of friction stir welds performed on polymethyl methacrylate under various FSW settings (PMMA). Because of this polymer's extreme transparency, it was possible to analyse easily the morphological changes induced by the welding process on it. Results of the weld morphologic analysis, of the residual stress fields in the different weld zones and of temperature measurements during welding are shown, and its relation with welding conditions is discussed. From the study it was possible to conclude that, due to the polymers rheological and physical properties, the thermo-mechanical conditions during FSW are very different from that registered during welding of metals, leading to completely different material flow mechanisms and weld defect morphologies.

Thin sheets of aluminium alloy 6061-T6 and one type of Advanced high strength steel, transformation induced plasticity (TRIP) steel were effectively butt linked utilising the friction stir welding (FSW) technology, according to Ni (2014). The greatest ultimate tensile strength can be up to 85% of the basic aluminium alloy. At the Al-Fe interface on the advancing side, an intermetallic compound (IMC) layer of FeAl or Fe3Al with a thickness of less than 1 lm was created, which can really contribute to joint strength. Tensile testing and scanning electron microscopy (SEM) results show that the weld nugget is an aluminium matrix composite reinforced by distributed sheared-off steel fragments encased by a thin inter-metallic layer or simply inter-metallic particles. The effects of process factors on the evolution of the joint microstructure were investigated using mechanical welding force and temperature measurements taken throughout the welding process.

CONCLUSIONS

This study aims to describe the Friction Stir Welding Process Principle and the different factors involved with it. It also aids in describing the various Zones, as well as the environmental concerns of Friction Stir Welding (FSW) and the numerous benefits of friction stir welding.

Some FSW research articles have also been studied in order to shed sufficient light on this problem.

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