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A REVIEW ON FRICTION STIR WELDING OF ALUMINIUM

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ABSTRACT

Aluminium alloy has gathered wide acceptance in the fabrication of light weight structures requiring a high strength to weight ratio. Compared to the fusion welding processes that are routinely used for joining aluminium alloys, Friction Stir Welding (FSW) process is an emerging solid state joining process in which the material that is being welded does not melt and recast. Friction Stir Welding is the most remarkable welding technology that has been invented and developed in last two decades. This process uses a non-consumable tool to generate frictional heat in the abutting surfaces. The welding parameters such as tool shoulder diameter, tool rotational speed, welding speed, axial force play a major role in deciding the joint strength. In presen study an attempt has been made to develop a mathematical model to predict tensile strength of the friction stir welded AA8011 aluminium alloy by incorporating FSW process parameters. Four factors, five levels central composite design has been used to minimize number of experimental conditions.

KEYWORDS: Friction Stir Welding; Aluminium alloy; Design of experiments; Tensile strength.

1. INTRODUCTION

The unique combination of light weight and relatively high strength makes aluminium the second most popular metal that is welded. Aluminium is the most widely used non-ferrous metal in the modern world, and the uses of the metal are extremely diverse due to its many unusual combinations of properties. No other metallic element can be used in so many ways across such a variety of domains, like in the home, in transport, on land, sea and in air, and in industry and commerce. The welding of aluminium and its alloys has always represented a great challenge for designers and technologists. As a matter of fact, lots of di_culties are associated to this kind of joining process, mainly related to the presence of a tenacious oxide layer, high thermal conductivity, high coe_cient of thermal expansion, solidi_cation shrinkage and, above all, high solubility of hydrogen, and other gases, in molten state. Further problems can arise when attention is focused on heat-treatable alloys, since heat, provided by welding process, is responsible of the decay of mechanical proper ties, due to phase transformations and softening induced in alloy. The e_ect of process parameters such as rotational speed, traverse speed, tool geometry and axial force on weld properties is major topics for researchers. Most of the papers published on FSW are focusing on the effect of FSW parameters and tool profiles on tensile properties and microstructure formation. Hence, here an attempt has been made to develop a mathematical model to predict tensile strength of the friction stir welded aluminium alloy by incorporating FSW process parameters.

2. OBJECTIVE

The main objective of present study on " Friction Stir Welding of aluminium" is to predict tensile strength of friction stir welded AA8011 aluminium alloy incorporating FSW parameters using statistical tool response surface methodology (RSM). The developed model can be effectively used to optimize the friction stir welding process parameters which produce mechanically sound and metallurgically defect free welds.

3. SUMMARY

- Compared with the fusion welding processes, such as metal inert gas welding (MIG) or tungsten inert gas welding (TIG), which are routinely used for joining aluminium alloys, Friction StirWelding (FSW) is an emerging solid state joining process in which the material that is being welded does not melt and recast since any problems associated with cooling from the liquid phase are avoided.

- Friction stir welding has been used to weld all wrought aluminium alloys, across the 2xxx, 5xxx, 6xxx, 7xxx and 8xxx series of alloys, some of which are bordering on being classed as virtually unweldable by fusion welding techniques.
- A conventional milling machine can be successfully modified in to a Friction Stir Welding machine which is capable of producing defect free aluminium welds.
- The FSW process parameters such as tool shoulder diameter, tool rotation speed, welding speed and axial force play major role in deciding the weld quality.

Table 1: Important process parameter or process variables of FSW

Sr. No.	Author Name	Aluminium Alloy	Rotational Speed (rpm)	Welding Speed (mm\min)	Shoulder Dia. (mm)	Axial Force (KN)
1.	Cavaliere et al. [10]	AA6082 4 mm plate	1600	40 56 80 115 325 460	14	9
2.	Jayaraman et al. [11]	A319 A356 A413 6 mm plate	800 1000 1200 1400 1600	12 24 48 72 96	18	3 4 5 6 7
3.	Elangovana et al. [12]	AA6061 3 mm plate	1200	75	15 18 21	7
4.	Elangovana et al. [13]	AA2219 6 mm plate	1600	22.2 45.6 75	18	12
5.	Leal at al. [14]	AA5083 AA6063 3 mm plate	800 1000	400 550	15	9

4. FRICTION STIR WELDING

Friction Stir Welding (FSW) is a solid-state joining process and is used for applications where the original metal characteristics must remain unchanged as far as possible. This process is primarily used on aluminium, and most often on large pieces which cannot be easily heat treated post weld to recover temper characteristics. It was invented and experimentally proven by Wayne Thomas and a team of his colleagues at The Welding Institute, UK in December 1991.

Friction Stir Welding Process

Friction stir welding (FSW) process a cylindrical, shouldered tool with a profiled probe is rotated and slowly plunged into the joint line between two pieces of sheet or plate material, which are butted together. The parts have to be clamped on to a backing bar in a manner that prevents the abutting joint faces from being forced apart. Frictional heat is generated between the wear resistant welding tool and the material of the workpieces. This heat causes the latter to soften without reaching the melting point and allows traversing of the tool along the weld line. The plasticised material is transferred from the leading edge of the tool to the trailing edge of the tool

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probe and is forged by the intimate contact of the tool shoulder and the pin profile. It leaves a solid phase bond between the two pieces. The process can be regarded as a solid phase keyhole welding technique since a hole to accommodate the probe is generated, then filled during the welding sequence.

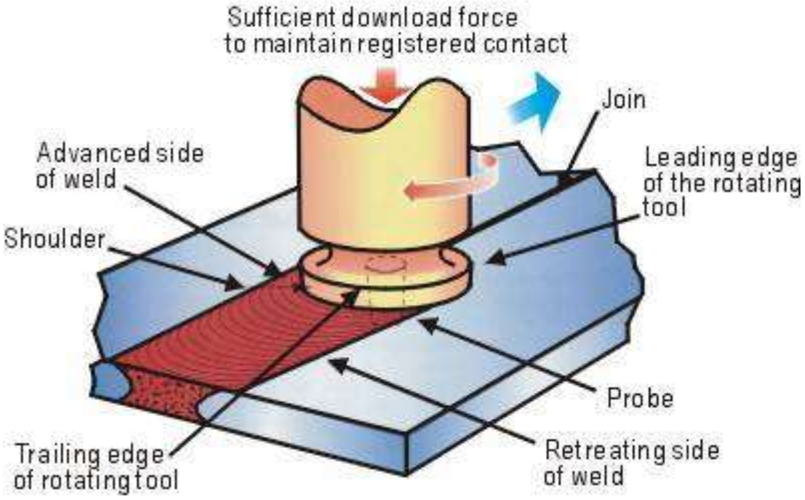

Figure 1: Schematic of the friction stir welding process

Various researchers has studied the material ow during FSW. From these studies and other experiments, three effective zones with different material ow and associated temperature changes have been identified.

Unaffected base metal
This is material remote from the weld, which has not been deformed, and which although it may have experienced a thermal cycle from the weld is not affected by the heat in terms of microstructure or mechanical properties.

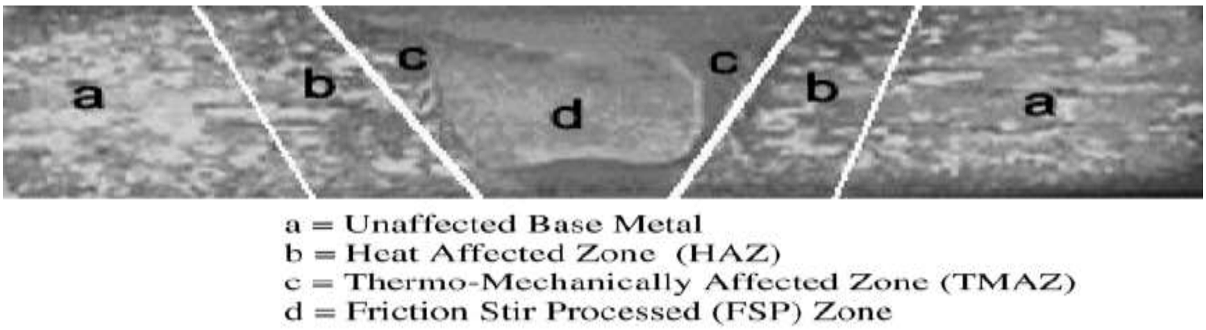

Figure 2: Different regions of FSW joint

Heat Affected Zone (HAZ)
In this region, which clearly will lie closer to the weld centre, the material has experienced a thermal cycle which has modified the microstructure and/or the mechanical properties. However, there is no plastic deformation occurring in this area. In the previous system, this was referred to as the "thermally affected zone". The term heat affected zone is now preferred, as this is a direct parallel with the heat affected zone in other thermal processes, and there is little justification for a separate name.

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Thermo-Mechanically Affected Zone (TMAZ)

In this region, the material has been plastically deformed by the friction stir welding tool, and the heat from the process will also have exerted some inuence on the material. In the case of aluminium, it is possible to get significant plastic strain without recrystallization in this region, and there is generally a distinct boundary between the recrystallized zone and the deformed zones of the TMAZ. In the earlier classification, these two sub-zones were treated as distinct microstructural regions. However, subsequent work on other materials has shown that aluminium behaves in a different manner to most other materials, in that it can be extensively deformed at high temperature without recrystallization. In other materials, the distinct recrystallized region (the nugget) is absent, and the whole of the TMAZ appears to be recrystallized.

Friction Stir Processed (FSP) Zone or Weld Nugget

The recrystallised area in the TMAZ in aluminium alloys has traditionally been called the nugget which is consist of a very fine grained, 1-10 micron, microstructure. The width of the FSP zone depends on the combination of tool design, welding parameter, and alloy composition. As for the microstructure of the FSW weld, the mechanical property of the joint in weld condition also varies from nugget to base metal.

5. PROCEDURE

The procedure described below has been used to obtain the objective of present work:

Experimental set-up

- Fixture design and development which secure the aluminium plates in position during welding.
- Design and development of non-consumable tool, made of high carbon steel to fabricate the joints.

Experimental investigation

- Different different combination of input parameters used to fabricate the joints keeping direction of welding normal to the rolling direction.
- Prepare tensile test specimens from welded joints as per guideline of American Society for Testing of Materials (ASTM) using ASTM-E8 M-04.
- Evaluate ultimate tensile strength by performing tensile test on universal testing machine.

Process parameter optimization

- Develop mathematical model using response surface methodology (RSM).
- The developed mathematical model can be effectively used to predict the tensile strength of FSW joints and optimize the process parameters.

6. CONCLUSION

A conventional milling machine has been demonstrated, capable of performing friction stir welding and producing defect free welds with good mechanical properties. As a part of a project work, friction stir welding fixture has been developed. An extensive experimental study has been conducted to investigate the effect of the process parameters namely tool shoulder diameter, rotational speed, welding speed and axial force on friction stir welded joints of AA8011 aluminium alloy. Tensile strength of the welded joints prepared by friction stir welding has been considered as response.

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