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EFFECT OF PROCESS PARAMETERS OF FRICTION STIR WELDING ON WELDMENT OF ALUMINUM ALLOYS

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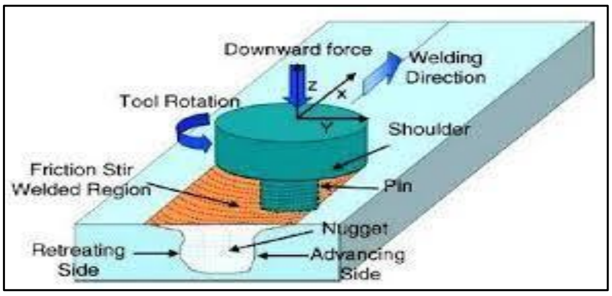
ABSTRACT
This study investigates the effect of key process parameters tool rotational speed, transverse speed, and tilt angle on the friction stir welding (FSW) of dissimilar aluminum alloys AA5052 and AA7075. The welded specimens were analyzed for mechanical properties including tensile strength, hardness, and impact resistance. It was found that increasing tool rotational speed enhances joint strength and hardness due to refined grain structure. FSW proved to be an effective solid-state welding method for dissimilar aluminum alloys, offering superior mechanical characteristics over traditional fusion techniques.

Keywords:
Friction Stir Welding, AA5052, AA7075, Tool Rotational Speed, Mechanical Properties, Tensile Strength, Hardness, Impact Test

INTRODUCTION
Aluminum alloys are widely used in industries such as automotive, aerospace, and marine due to their advantageous properties like high strength-to-weight ratio, corrosion resistance, and ease of fabrication. However, welding these alloys, especially dissimilar ones, is challenging with traditional fusion welding techniques due to the formation of brittle intermetallic compounds, porosity, and distortion.
Friction Stir Welding (FSW) is a solid-state joining process developed to overcome these limitations. In FSW, a rotating non-consumable tool generates frictional heat and plastic deformation, facilitating material mixing without reaching the melting point. This results in joints with improved mechanical and microstructural characteristics. This research focuses on the FSW of dissimilar aluminum alloys AA5052 and AA7075 and evaluates the impact of varying key process parameters on weld quality.



Schematic drawing of Friction stir welding

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OBJECTIVES

The primary objective of this project is to investigate the influence of key process parameters namely tool rotational speed, traverse speed, and tilt angle on the mechanical properties of friction stir welded dissimilar aluminum alloys (AA5052 and AA7075). The study aims to fabricate welded joints using Friction Stir Welding (FSW) and evaluate their tensile strength, hardness, and impact resistance through experimental testing, thereby identifying the optimal welding conditions for improved joint quality and mechanical performance.

Literature Review

1. Tiwari et al. (2013) emphasized the importance of tool rotation rate, traverse speed, and tool tilt angle on weld quality and strength. They observed that high-speed stirring leads to finer grains and better mechanical properties. Rodriguez et al. (2015) highlighted the significance of adequate intermixing and thermal control during dissimilar aluminum alloy welding.
2. Ahmed et al. (2017) demonstrated the role of FSW in overcoming the weldability issues of AA7075 and AA5083. Guo et al. (2014) presented detailed analysis of material flow and mechanical properties in AA6061-AA7075 joints. Rani et al. (2011) studied the influence of tool design and speed in FSW of AA6061. The reviewed literature confirms the critical role of process parameters in determining weld strength, hardness, and durability.
3. Harsha et al. analysed the effect of process parameters by FSW. Aluminium alloys. which exhibits very attractive mechanical, physical and chemical properties have Intensive demand in various areas especially marine structure. In order to join aluminium alloys various welding methods are employed but the recent innovative and environmental friendly techniques is friction stir welding.
4. Patel et al. studied the influence of process parameters on the mechanical properties of friction stir wekled aluminium alloys. They concluded that tool rotation speed and welling speed play crucial roles in determining the well strength. Higher rotation speeds resulted in increased heat inpot, which promoted grain refinement but also led to excessive softening in the weld zone.
5. Sharma and Kumar investigated the effect of tool geometry on weld strength and microstructure. Their findings indicated that pin profile and shoulder diameter significantly affected the material flow and heat generation. A threaded pin profile was found to enhance material mixing, resulting in improved tensile strength and ductility of the welds.
6. Verma et al. analyzed the impact of welding parameters on microstructural evolution in friction stir welded aluminium alloys. They observed that a combination of high rotational speed and moderate traverse speed resulted in fine-grain microstructures in the weld nugget, leading to enhanced mechanical properties. However, excessive heat input caused grain coarsening and reduced hardness in the heat-affected zone.
7. Singh et al. examined the role of process parameters in the formation of defects such as voids and tunnel defects in aluminium welds. Their study revealed that improper selection of tool tilt angle and plunge depth resulted in defect formation, reducing joint integrity. Optimized parameters led to defect-free welds with superior mechanical performance.

METHODOLOGY

The experimental work was conducted using AA5052 and AA7075 aluminum alloy plates (150 mm x 25 mm x 5 mm). A vertical milling machine was modified to act as a FSW setup. The H13 tool steel was selected for the rotating tool due to its high wear resistance and strength. The tool had a cylindrical profile and plunge depth of 5 mm.

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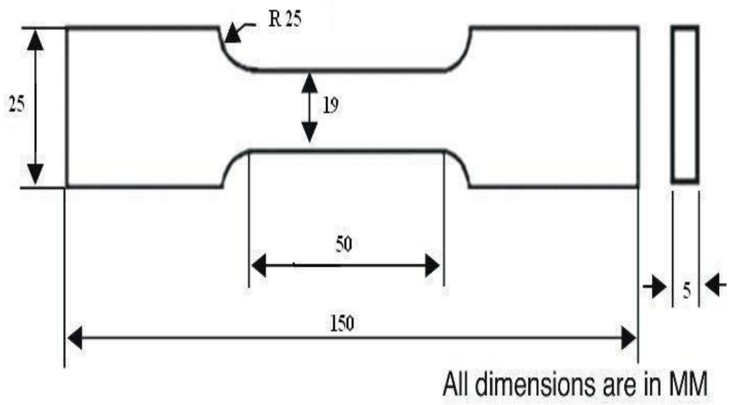

Dimensions of Tensile test specimen

Process parameters included:
- Tool Rotational Speeds: 710, 900, and 1120 RPM
- Traverse Speed: 40 mm/min (constant)
- Tool Tilt Angle: 1° (constant)

After welding, the specimens were subjected to mechanical tests including tensile, hardness, and impact tests. Microstructural observations were also performed to study grain structure and defect formation.

Experimental Procedures

Tensile tests were carried out using a Universal Testing Machine (UTM) with a capacity of 1 kN. Standard specimens were cut perpendicular to the weld line using wire EDM.

Universal Testing machine

Hardness was measured using a Brinell Hardness Testing machine (RAB250) with a 5 mm steel ball under a load of 250 kgf. Measurements were taken across the weld nugget, heat-affected zone (HAZ), and base metal.

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Brinell hardness testing machine

Impact tests were conducted using a Charpy impact testing machine (KI-300). V-notch sub-size specimens were prepared as per standard dimensions (55 mm x 10 mm x 5 mm).

Charpy impact test machine

RESULTS AND DISCUSSION

Tensile Test Results

The tensile strength and elongation of the weldments increased with tool rotational speed. This is attributed to higher heat input and better mixing of materials.

Specimen 1 (710 RPM): UTS = 80.34 MPa, Elongation = 5.56%
Specimen 2 (900 RPM): UTS = 131.87 MPa, Elongation = 17.76%
Specimen 3 (1120 RPM): UTS = 143.76 MPa, Elongation = 16.40%

Tensile test specimen after testing

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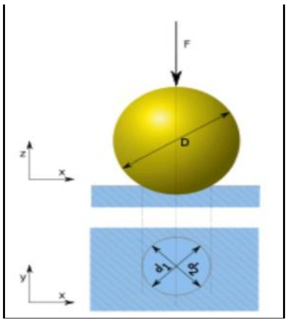
Hardness Test Results

The Brinell hardness number (BHN) increased with tool speed due to finer grain formation and reduced voids. However, HAZ showed slightly reduced hardness compared to the weld nugget.

Specimen 1: 56.30 HBW
Specimen 2: 61.84 HBW
Specimen 3: 65.54 HBW



Indentation of sphere ball

Impact Test Results

Impact energy absorption varied with speed. Maximum energy was recorded at 900 RPM (28 J), indicating optimum material mixing and ductility at this speed.

Specimen 1: 14 J
Specimen 2: 28 J
Specimen 3: 24 J

Specimens after testing

CONCLUSION

Dissimilar AA7075 and AA5052 alloys have been friction stir welded with a variety of different process parameters. At a variant tool rotation speed, the effects of materials position and welding speed on materials flow, hardness and tensile properties of the joints were investigated. Based on the above results and discussion, the following conclusions are discussed

1. Highest Tensile strength of 193.574MPa is obtained at highest cutting tool speed 1120RPM
2. The process parameters (speed, tilt angle and transverse speed) of Friction Stir Welding are better than other conventional welding processes by observing the testing results (tensile, hardness and impact tests).
3. Deformation of the specimens increases by the increase in speed of the cutting tool. Maximum deformation 2.7mm occurs at the 1120RPM. But rate of deformation is fluctuating by the increase in tool rotational speed
4. By observing the hardness test results, when speed will increase than hardness will decreases.
5. By observing the impact test results the impact more at high speed that is 28. joules

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