

Full Length Article

## Impact Of Tool Profile And Material On Mechanical And Microstructural Behaviour Of FSSW Joints

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### Abstract

Friction Stir Spot Welding (FSSW) is an advanced solid-state joining process widely used for lightweight materials such as aluminum alloys and brass. In this study, similar and dissimilar joints of Aluminum 6061 and Brass IS319 were fabricated using FSSW with EN31 tools having taper square and diamond pin profiles. The weldments were produced using a vertical milling machine at a rotational speed of 900 rpm, feed rate of 25 mm/min, and depth of cut of 2.8 mm. Mechanical performance of the joints was evaluated through tensile testing using a Universal Testing Machine (UTM). Experimental results revealed that the taper square profile produced superior joint strength compared with the diamond profile for all material combinations. The highest ultimate tensile load of 16.92 kN was obtained for Brass–Brass joints fabricated using the taper square profile tool, while Aluminum–Aluminum joints achieved a maximum load of 3.82 kN. The study demonstrates that tool geometry significantly influences heat generation, material flow, and weld quality in FSSW.

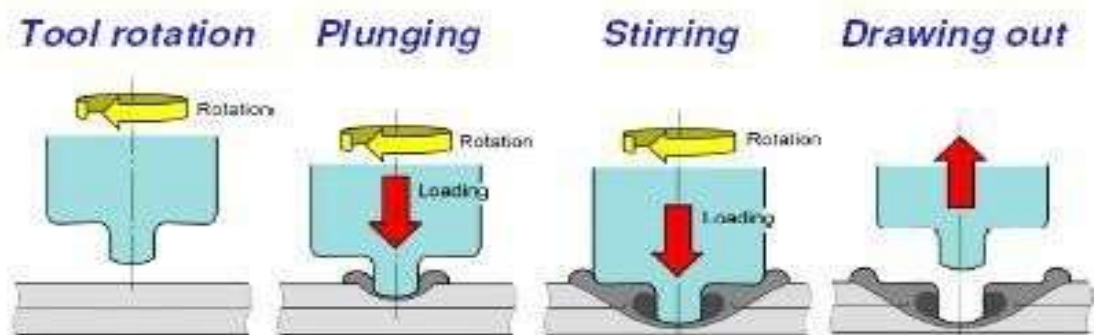
**Keywords:** Friction Stir Spot Welding, Aluminum Alloy 6061, Brass IS319, EN31 Tool, Tool Geometry, Tensile Strength.

### Introduction

Friction Stir Welding (FSW) is a solid-state joining process developed for joining aluminum alloys without melting the base material. Friction Stir Spot Welding (FSSW) is a modified form of FSW used mainly for spot joining applications in the automotive and aerospace industries. In this process, a rotating non-consumable tool generates frictional heat at the tool–workpiece interface, softening the material and enabling plastic flow without reaching the melting temperature.

Compared with conventional fusion welding techniques, FSSW offers several advantages such as

low distortion, improved mechanical properties, minimal residual stresses, and elimination of filler materials and shielding gases. These benefits make FSSW highly suitable for lightweight structural applications involving aluminum and brass alloys. The quality of FSSW joints is influenced by process parameters such as rotational speed, plunge depth, feed rate, tool geometry, and dwell time. Among these parameters, tool pin profile plays a critical role in determining heat generation and material flow behavior. Therefore, the present work investigates the effect of taper square and diamond profile EN31 tools on the mechanical performance of similar and



dissimilar joints of Aluminum 6061 and Brass IS319.

**Literature Review**

Several researchers have investigated the influence of process parameters and tool geometry on friction stir spot welding.

Kai Chen et al. (2016) studied the effects of process parameters on FSSW of aluminum alloy to advanced high-strength steel and reported cross-nugget failure as the dominant failure mode.

Lakshminarayanan et al. (2015) identified optimum FSSW parameters for low carbon automotive steel joints and analyzed tensile shear behavior.

Hande Güler et al. reported that tool geometry strongly affects weld strength and hardness in aluminum alloy FSSW.

Gholinia et al. (2012) demonstrated successful rapid joining of aluminum alloy to steel using friction stir spot welding.

Mustafa Kemal Bilici applied the Taguchi method to optimize FSSW parameters and observed significant improvement in weld strength.

Previous studies indicate that tool geometry greatly influences material flow, heat generation, and mechanical properties of welded joints. However,

**4.1.1 Chemical Composition of Aluminum 6061**

Element	Composition (%)
Aluminum	Balance
Magnesium	0.8–1.2
Silicon	0.4–0.8
Copper	0.15–0.4
Chromium	0.04–0.35

**Tool Material**

EN31 alloy steel was selected as the tool material due to its high wear resistance, toughness, and hardness.

Element	Composition (%)
Carbon	0.36–0.44
Silicon	0.10–0.40

**Tool Profiles**

Two different tool pin profiles were fabricated:

Taper Square Profile

Parameter	Value
Shoulder Diameter	18 mm
Pin Diameter	1.2 mm

**Experimental Setup**

The welding experiments were conducted using a vertical milling machine. The EN31 tool was

Parameter	Value
Rotational Speed	900 rpm
Feed Rate	25 mm/min

limited research has been conducted on the effect of taper square and diamond profile tools in joining Aluminum 6061 and Brass IS319 combinations.

**Objectives of the Study**

The objectives of the present investigation are:

To fabricate similar and dissimilar joints of Aluminum 6061 and Brass IS319 using Friction Stir Spot Welding.

To investigate the influence of taper square and diamond profile EN31 tools on weld quality.

To evaluate the tensile strength of the fabricated weldments.

To compare the mechanical performance of different tool profiles.

To identify the optimum tool geometry for achieving stronger weld joints.

**Materials and Methods**

**Base Materials**

The materials selected for the present investigation are Aluminum 6061 and Brass IS319 plates of thickness 1.6 mm.

**Chemical Composition of Brass IS319**

Element	Composition (%)
Copper	56–59
Lead	2–3.5
Iron	0.35–0.39
Zinc	Balance

**EN31 Composition**

Manganese	0.70–1.00
Chromium	0.90–1.20
Molybdenum	0.25–0.35

**Diamond Profile**

**Tool Dimensions**

Probe Height	2.5 mm
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mounted on the spindle and welding was performed under controlled process parameters.

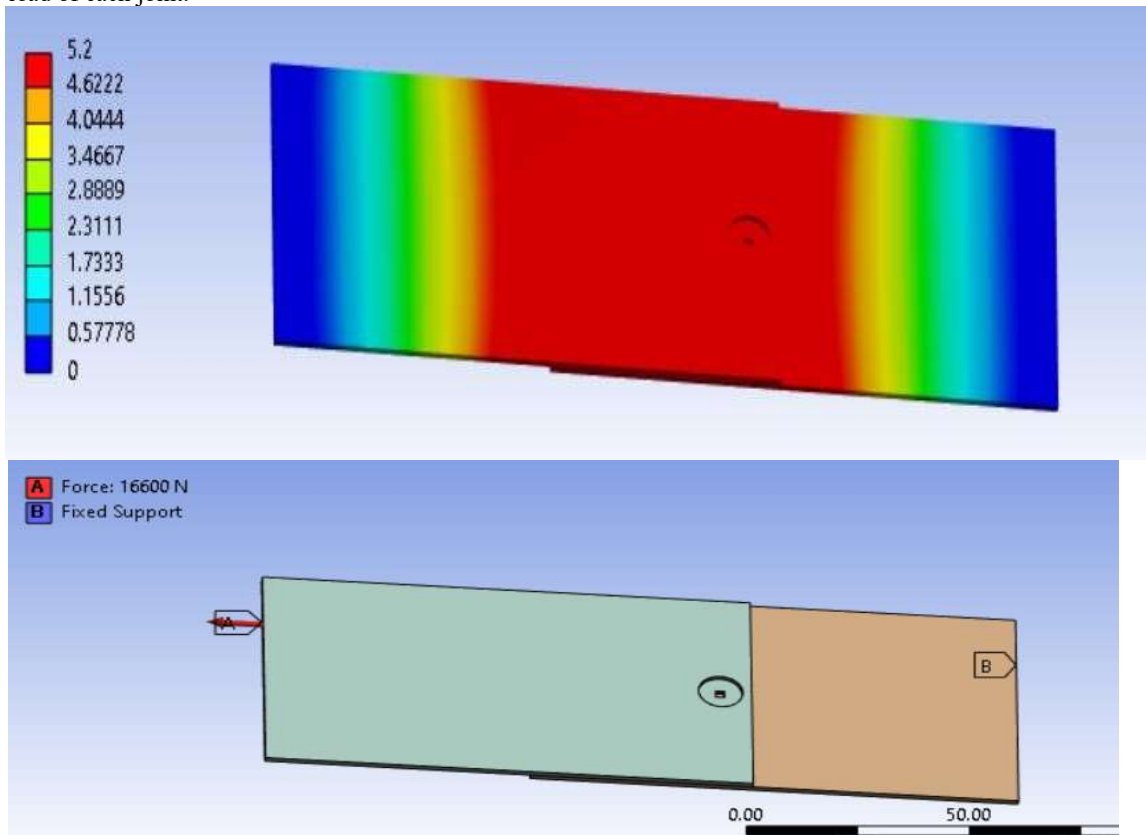
**Process Parameters**

Depth of Cut	2.8 mm
Tool Tilt Angle	0.5°



**Tensile Testing**

The fabricated weldments were tested using a Universal Testing Machine (UTM) to determine the ultimate tensile load of each joint.



**Results and Discussion**

**Weld Strength Results**

Sl. No	Material Combination	Tool Profile	Ultimate Load (kN)
1	Al6061–Al6061	Taper Square	3.82
2	Brass–Brass	Taper Square	16.92
3	Brass–Al6061	Taper Square	9.62
4	Al6061–Al6061	Diamond	1.98
5	Brass–Brass	Diamond	14.02
6	Brass–Al6061	Diamond	8.82

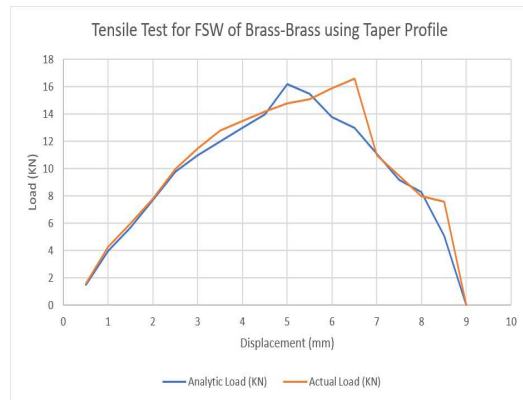
### Effect of Tool Geometry

The taper square profile tool produced superior weld strength compared with the diamond profile tool for all material combinations. The improved performance can be attributed to enhanced material stirring and better heat distribution generated by the taper square geometry.

For Aluminum–Aluminum joints, the taper square tool achieved an ultimate load of 3.82 kN, whereas the diamond profile achieved only 1.98 kN.

Similarly, for Brass–Brass joints, the taper square profile produced the highest tensile load of 16.92 kN compared with 14.02 kN for the diamond profile.

The dissimilar Brass–Aluminum joints also exhibited higher strength with the taper square tool due to improved material mixing at the interface.



### Heat Generation and Material Flow

During FSSW, frictional heat generated between the rotating tool and workpiece softened the surrounding material. The rotating pin facilitated material flow in both axial and radial directions, producing a metallurgical bond between the sheets. The taper square profile generated stable heat input and improved plastic deformation, resulting in defect-free welds and enhanced tensile strength.

### Conclusions

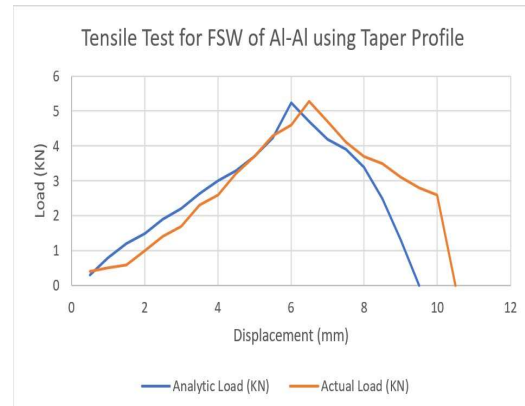
The present investigation on Friction Stir Spot Welding of Aluminum 6061 and Brass IS319 using different EN31 tool profiles led to the following conclusions:

Friction Stir Spot Welding successfully joined similar and dissimilar combinations of Aluminum 6061 and Brass IS319.

Tool geometry significantly influenced weld quality and mechanical properties.

The taper square profile tool produced better tensile strength compared with the diamond profile tool.

The maximum ultimate tensile load of 16.92 kN was achieved for Brass–Brass joints using the taper square profile.



Enhanced material flow and heat generation contributed to improved weld performance with the taper square tool.

FSSW is an effective solid-state joining technique for lightweight engineering applications requiring high-strength welds.

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