# INFLUENCE OF WELDING SPEED AND TOOL ROTATIONAL SPEED ON THE MECHANICAL PROPERTIES OF 5052 ALUMINUM ALLOY FRICTION STIR WELDS

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**Abstract -** This study investigates the influence of welding speed and tool rotational speed on the mechanical characteristics of friction stir welds (FSW) on 5052 aluminum alloy, aiming to enhance the mechanical properties of the welds. Experiments were conducted with varying parameters, including welding speeds (from 23 to 78 mm/min) and tool rotational speeds (from 750 to 1800 rpm). The results indicate that variations in these two parameters affect the tensile strength of the welds. The optimal weld quality was achieved with a moderate rotational speed (approximately 1500 rpm) combined with a moderate welding speed (approximately 57 mm/min), resulting in a tensile strength reaching 81% of the base material. These experimental results provide a basis for selecting optimal technological parameters in the FSW process of 5052 aluminum alloy sheets for applications in the mechanical, marine, and automotive industries.

**Key words -** 5052 aluminum alloy; friction stir welding; welding speed; tool rotational speed; tensile strength

## 1. Introduction

Friction Stir Welding (FSW) [1] is a solid-state joining process where a non-consumable rotating tool is plunged into the interface between two workpieces and traversed along the joint line. The frictional heat generated between the rotating tool and the workpieces softens the material, while the tool mechanically intermixes and forges the materials together, creating a high-strength weld without melting the base materials. FSW offers several advantages, including high weld quality, the absence of arc and welding fumes, no requirement for shielding gases, no need for filler metals, reduced distortion, and crack-free welds, making it particularly suitable for aluminum alloys [2]. The 5052 aluminum alloy is widely used in aerospace, automotive, shipbuilding, construction, and household appliance industries due to its relatively high strength and good weldability [3, 4].

The quality of a weld produced by the Friction Stir Welding (FSW) process is significantly influenced by two key parameters: the tool rotational speed (n) and the welding speed (v). Previous studies have confirmed that appropriate control of v and n is essential to achieve high-quality welds in 5052 aluminum alloy. Optimizing these parameters enhances the tensile strength and corrosion resistance of the welds [5-7]. Previous research has shown that the relationship between the two parameters, *n* and *v*, significantly improves tensile strength, leading to the best weld quality [8-11].

Based on this background, this study experimentally investigates and evaluates the specific effects of *n* and *v* on the tensile strength of FSW joints in 5052 aluminum alloy (AA5052) sheets. The aim is to propose an optimal set of parameters to achieve high-quality welds.

## 2. Experimental Procedure

This research utilized 5052 aluminum alloy as the workpiece material, which measured 5 mm thick, 250 mm long, and 100 mm wide, a configuration depicted in Figure 1. The material properties of the 5052 aluminum alloy are presented in Table 1 [12]. A schematic drawing of the FSW tool is shown in Figure 2.

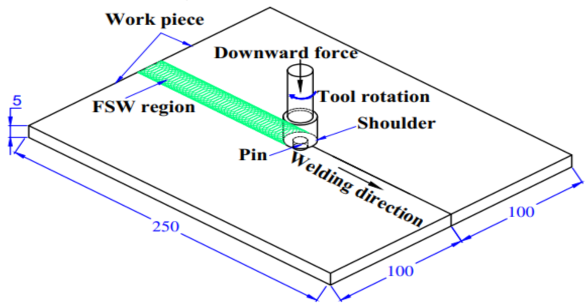


***Figure 1.** The working mechanism of the Friction Stir Welding process*

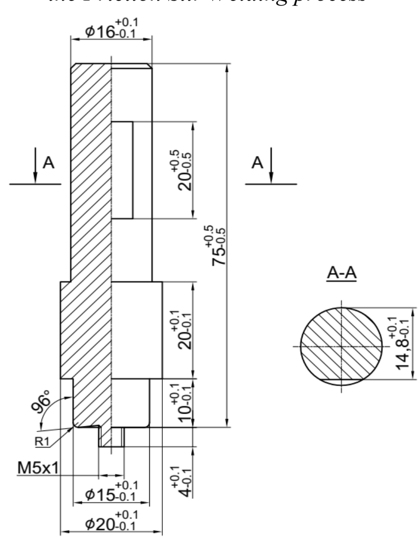


***Figure 2.** Schematic drawing of the FSW tool*

***Table 1.** Properties of AA5052*

| Ultimate Tensile Strength (MPa) | Yield Strength (MPa) | Elongation (%) |
|---|---|---|
| 217 | 168 | 19.5 |

The FSW experimental setup included an FSW machine converted from a universal milling machine, the workpiece, and welding fixtures, as shown in Figure 3.

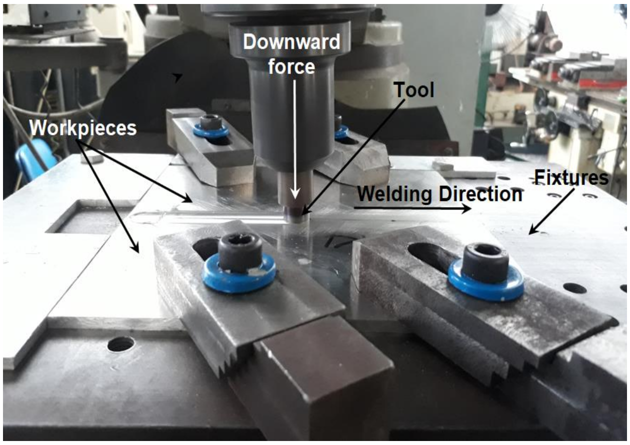


***Figure 3.*** *FSW machine*

The welding process begins with the stirring tool moving downward. The tool descends to a depth equal to the pin length, and the heat generated during this stirring softens the workpiece material into a plastic state. Subsequently, the stirring tool moves along the joint line. At the end of the welding path, the tool stops and retracts (Figure 4).

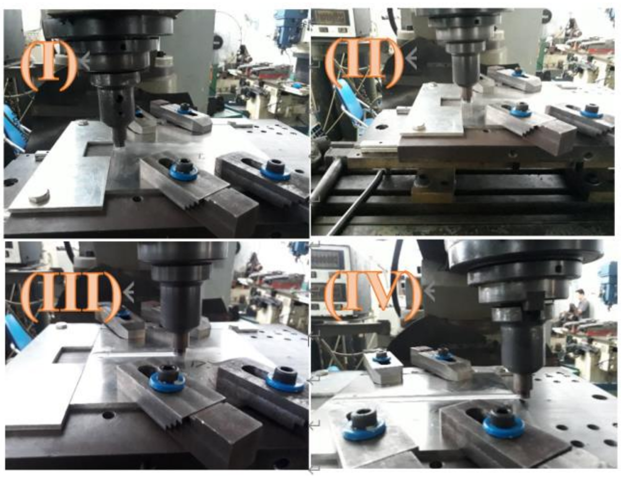


***Figure 4.*** *Stages of the welding process: (I) Plunging stage, (II) Dwell stage, (III) Welding stage, (IV) Retraction/Cooling stage*

This study will investigate the influence of the tool travel speed at different welding speeds of 23.0, 33.0, 40.0, 57.0, and 78.0 mm/min. In addition, different tool rotational speeds of 750.0, 1050.0, 1250.0, 1500.0, and 1800.0 rpm will also be investigated to determine the relationship between these technological factors and the weld quality through tensile testing of the friction stir welds.

Following each welding experiment, the welded plates were sectioned transversely into three specimens, each with a width of 50 mm. From these sections, tensile test specimens were subsequently machined such that the welded region was located within the gauge length. To facilitate data collection, the samples from different welding parameters were arranged in a specific order (from the highest to the lowest $n$, and from the highest to the lowest $v$), as shown in Figure 5. For each welding condition, three specimens were subjected to tensile testing. The tests were performed at room temperature using a Malicet et Blin universal testing machine with a maximum load capacity of 300 kN. The samples after the tensile test are shown in Figure 6.

***Figure 5.*** *Samples were arranged in order before tensile testing*

***Figure 6.*** *Samples after the tensile test.*

## 3. Results and discussion

### *3.1. Effect of welding speed*

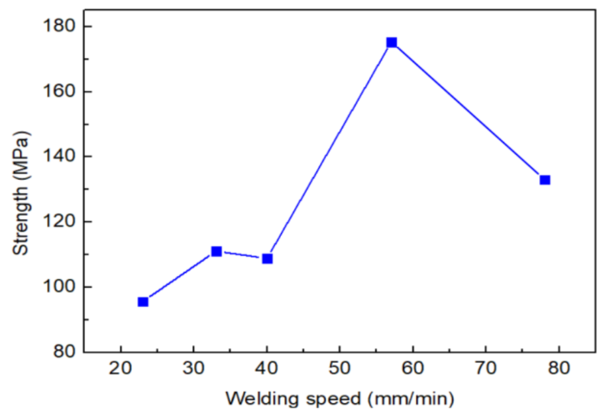


***Figure 7.*** *The correlation between welding speed and the resultant weld strength*

To analyze the influence of the factors on the tensile strength of the welded joint, experiments were conducted with different welding speeds of 23.0, 33.0, 40.0, 57.0, and 78 mm/min; the rotational speed was kept at a level of 1500 rpm. After testing the tensile strength of the specimens, the single-factor experimental results point out that when the welding speed changes, the tensile strength has a maximum value at a speed of approximately 57.0 mm/min, as exhibited in Figure 7. The relationship between welding speed and weld strength demonstrates a non-linear trend, with a distinct peak observed at 57.0 mm/min, indicating an optimal welding speed for maximizing strength under the given parameters. At lower welding speeds (20-40 mm/min), the reduced strength can be attributed to a combination of excessive heat input, potentially leading to grain growth and over-dwell, which may hinder effective material flow and promote defects. On the other hand, employing faster welding speeds (80 mm/min) led to a reduction in strength, potentially stemming from insufficient heat introduction and inadequate material intermingling, thereby promoting weak bonding and a greater occurrence of defects. The peak at 57 mm/min signifies a critical balance, where sufficient heat input and adequate material flow are achieved, minimizing detrimental microstructural effects and ensuring optimal weld integrity.

### *3.2. Influence of tool rotational speed*

To examine how the tool rotational speed influences the tensile strength of the welded joint, experiments were performed using various tool rotational speeds: 750, 1050, 1250, 1500, and 1800 rpm. A constant welding speed of 57 mm/min was chosen for these tests. The single-factor experimental results show that when the rotational speed changes and is around 1500 rpm, the tensile strength has a maximum value, as shown in Figure 8. The effect of tool rotational speed on weld strength exhibits a non-monotonic relationship, with a peak strength observed at approximately 1500 rpm, indicating an optimal rotational speed under the given conditions. Lower rotational speeds (750-1200 rpm) are associated with a decrease in weld strength, likely due to insufficient heat generation and inadequate material flow, hindering proper bonding and potentially leading to defects. In contrast, rotational speeds exceeding the optimum (1600-1800 rpm) also result in reduced strength, possibly due to excessive heat input causing grain growth or other defects, and turbulent material flow. The peak at 1500 rpm represents a balance between sufficient heat generation for material plasticization and adequate material flow for effective mixing and bonding, thereby optimizing the weld's microstructure and mechanical properties.

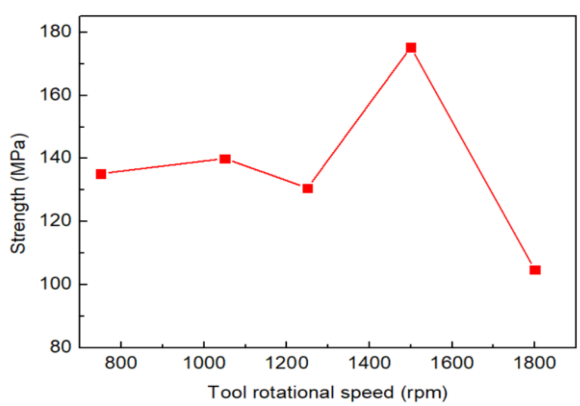


***Figure 8.*** *The correlation between the tool rotational speed and the weld strength.*

The findings reveal that both welding speed and tool rotational speed exert a considerable impact on the tensile strength of the weld. Specifically, when employing friction stir welding on 5052 aluminum alloy, the maximum weld strength is achieved at a welding speed of 57 mm/min and a tool rotational speed of 1500 rpm.

## 4. Conclusion

The single-factor experimental results in this study identified the individual effects of *v* and *n* on the weld. The results indicate that when friction stir welding 5052 aluminum alloy, the weld strength reaches its highest value corresponding to a welding speed of 57 mm/min and a tool rotational speed of 1500 rpm. The FSW process on flat aluminum plates, under the experimental conditions of the parameters (v and n), resulted in a maximum tensile strength of the weld reaching 81% of that of the base material (217 MPa). This tensile strength value is a critical parameter that significantly affects the weld quality.

In the reality of the FSW process, the strength of the weld is not only influenced by *v* and *n* but also by a number of other factors. Therefore, experiments with the simultaneous participation of these factors are necessary to observe the influence of the factors acting concurrently. This is precisely the purpose of the full-factor experiment section, and this is the direction of further research.

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