

# Experimental Investigation of Aluminum Alloy 8010 by Friction Stir Welding

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## Abstract

A solid state welding method called friction stir welding (FSW) is used to fuse metals and alloys that are challenging to fuse using traditional fusion welding. The effects of tool pin and shoulder diameter on joining the aluminum alloy Al 8010 were examined in this study. The basis material for combining single butt-welded joints is a plate with a thickness of 6 mm. The welding was carried out on the high-speed steel (HSS) and high carbon high chromium steel (HCHCr) tools. The paper concludes that the axial force, tool pin profile, and shoulder diameter are the major influencing parameters for obtaining the weld quality of aluminum alloys. This study investigates the FSW of Al 8010 aluminum alloy, focusing on the influence of process parameters like tool rotational speed, welding speed, axial force, and tool pin profile on weld quality. Using HSS and HCHCr tools, the experiments aimed to optimize weld integrity and reduce defects. Results highlight that tool rotational speed and axial force significantly impact defect formation, tool wear, and elongation percentage. Findings suggest that HSS tools perform better under high load conditions, improving weld dependability.

**Keywords:** Al 8010 aluminum alloy, friction stir welding, tool wear, axial load

## INTRODUCTION

Aluminum alloys have major applications in manufacturing of space shuttles, rocket fuel tanks, aircrafts, ship building and automobiles due to its light weight and high strength to weight ratio [1]. Joining of metals and alloys is a challenging task for engineers and technologists. The joining difficulties such as oxide layer formation, thermal expansion and solidification time are very difficult to control especially in the fusion welding [2]. Because friction stir welding (FSW) produces minimal distortions, high-quality welds, low residual stresses, fewer weld flaws, and inexpensive joints, it is superior than other traditional processes. Welding characteristics including shoulder penetration, axial force, welding speed, and tool rotational speed all affect the quality of the weld joint. The weld quality is improved through the mechanical properties in order to reduce the defects like tensile and hardness properties. To improve the weld dependability, it would be beneficial to investigate the mechanical or physical characteristics and associated important elements. According to current studies, several grades of aluminum alloys are employed in various applications. Aluminum alloy of grade AA1100 is used for fabrication of light weight

structures and the study discussed the optimal welding condition to maximize the tensile strength and minimize the corrosion rate [3]. Defect-free butt welds of titanium alloy with steel were created by Li et al. [4] using FSW was carried out at tool rotation speed (TRS) with a constant weld speed of 47 mm/min, varying between 600 and 950 rpm. The outcome demonstrated that an increase in TRS thickens the layer of intermetallic compounds. By employing a stationary shoulder, Li et al. [5] enhanced the tensile characteristics of magnesium AZ31 joining by friction stir welding zone.

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Received Date: October 09, 2024

Accepted Date: October 31, 2024

Published Date: November 20, 2024

**Citation:** Jaiganesh. Experimental Investigation of Aluminum Alloy 8010 by Friction Stir Welding. Journal of Materials & Metallurgical Engineering. 2024; 14(3): 14–19p.

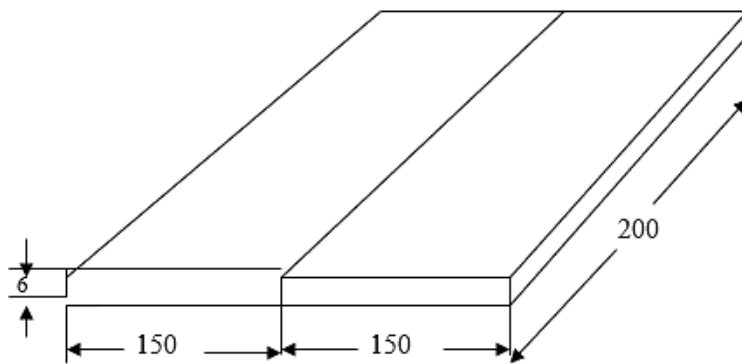
## EXPERIMENTAL WORK

The base material is of rolled plates of Al 8010 aluminum alloys were machined to the required dimensions (150 mm × 75 mm × 6 mm). To produce the Al 8010 welded joints, a square butt joint configuration was utilized, as seen in Figure 1.

The FSW joints were fabricated using a non-consumable rotating tool composed of high-speed steel (HSS) and high carbon high chromium steel (HCHCr). The influencing parameters which affect the weld quality such as tool rotational speed, welding speed, shoulder penetration and axial force are taken in order to optimize the defect free joints. The experiment was conducted on HURCO VM20 Vertical Machining Center of X, Y, and Z axis travel of 1016 × 508 × 508 mm. The capacity of the spindle motor is of 20 HP 15 kW. Trial experiments were conducted to identify the visible weld defects. The weld conditions and process parameters are shown in Table 1. The chemical composition of base metal is presented in Table 2.

### Selection of Tool Material

The effects of axial force and tool pin profile on the development of the friction stir processing zone in 8010 aluminum alloy. In contrast to other tool pin profiles, the square profile yields welds that are both mechanically sound and free of metallurgical defects [6].



All dimensions are in 'mm'

**Figure 1.** Dimensions of square butt joint configuration.

**Table 1.** Process parameters and welding conditions.

S.N.	Process Parameters	Weld Conditions
1	Tool rotational speed (rpm)	800–1200
2	Welding speed (mm/min)	40–120
3	Axial force (kN)	6–8
4	Shoulder penetration (mm)	0.02–0.08
5	Shoulder diameter (mm)	20
6	Tool pin profile	Left hand thread
7	Pin diameter (mm)	6.5
8	Pin length (mm)	5.86

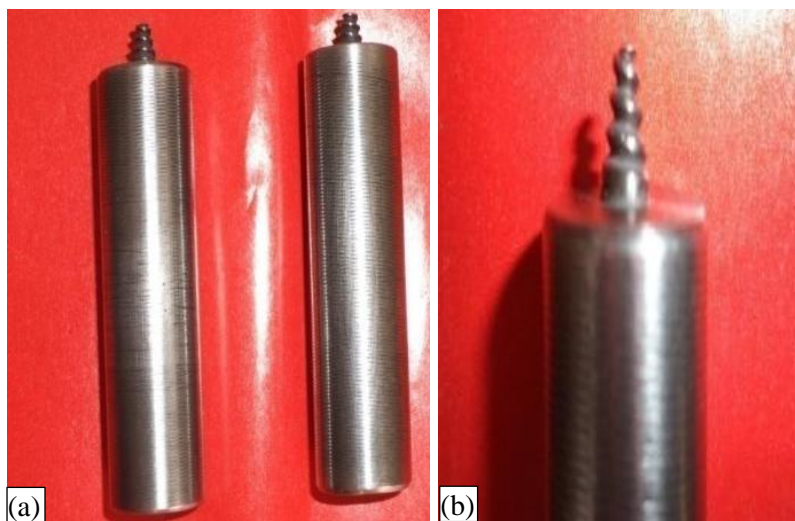
**Table 2.** Chemical composition of the 63400 alloy (wt%)

Reference	Si	Fe	Cu	Mn	Mg
Typical actual batch	0.30–0.70 0.445	0.60 Max 0.405	0.10 Max 0.097	0.30 Max 0.110	0.40–0.90 0.508
Reference	Cr	Zn	Ti	Al	-
Typical actual batch	0.10 Max 0.007	0.20 Max 0.175	0.20 Max 0.011	Remainder 98.20	-

The material of the work item to be welded determines which tool is best. In this paper, the HSS tool and HCHCr tools are used for fabricate the weld joints. The tool material is also hardened above 950°C for increasing the harden ability. The tool has the shoulder and pin with left hand thread and a pitch size of 1 mm. The cylindrical shoulder measures 60 mm in length and 20 mm in diameter. The pin has a cylindrical threaded taper shape with length of 5.85 mm (Figure 2).

### Selection of Base Material

The work piece should be placed on the vice so that only it can withstand maximum axial load. If the clamping is not fixed correctly defects will occur. As seen in Figure 3, the work piece is fastened to the table using a nut and a bolt arrangement. The FSW experiment was first performed in the United Kingdom's Welding Institute (TWI), which pioneered FSW back in 1991 to join solid state aluminum alloys [7].



**Figure 2.** Friction stir welding (FSW) tool materials: (a) high-speed steel (HSS) and high carbon high chromium steel (HCHCr) tool and (b) tool shoulder with threaded pin.



**Figure 3.** Welding fixture.

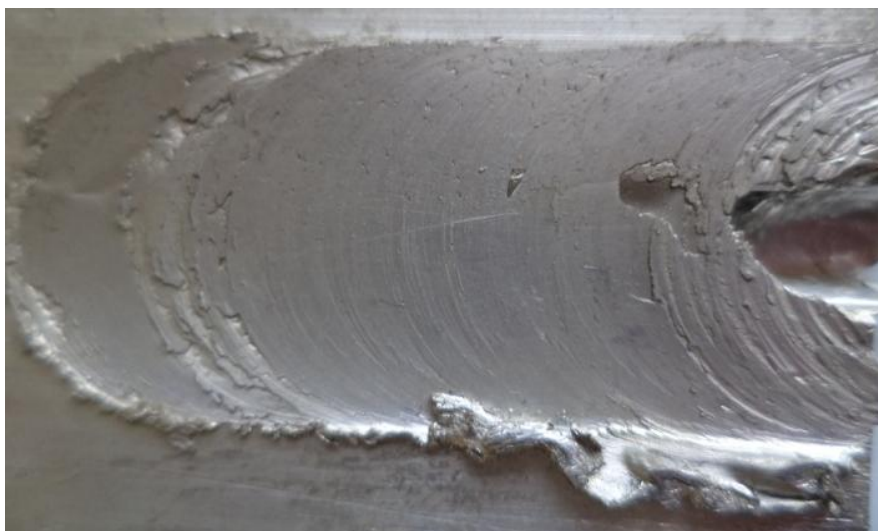
## RESULTS AND DISCUSSION

### Defects due to Axial Load

The common defects that occur in fusion welding of aluminum alloys are porosity, slag inclusion, solidification cracks, etc. and these defects affect the weld quality and joint properties. The FSW technique may be employed to eliminate the defects like porosity, micro-fissuring, hot cracking, etc. [8]. The defects occurred in welding of Al 8010 is mainly due to many reasons; the axial force required to withstand the weldment and the tool holder should be strong enough to withstand the tool when it penetrates the base metals. In this experiment, the holder allowed the tool to get into the holder sleeve which results the base material would not experiencing the plastic flow. Figure 4 shows the improper weldment takes place on the base alloying element. Through specialized experiments, the process of FSW creation and the function of the FSW tool to comprehend the material flow pattern in the weld were discovered, and it was found that the FSW tool's interaction with the base material is constantly increasing [9]. The weld fusion zone of aluminum alloys exhibit coarse columnar grains due to prevailing thermal conditions during the weld metal solidification. The result shows the advancement on the weld mechanical properties and poor resistance towards the hot cracking surfaces [10]. In this paper, Figure 4 depicts that additional axial force was employed that leads to excess heat input of the shoulder surface of the base material as well as the pin shaped profile on the reverse side of the welded region due to lack of heat.

Tool breakage and wear normally occurred due to sudden penetration of tool advances the base metal. The tool should be hardened in order to withstand the axial load directly. The other parameters like tool rotational speed, tool travel speed, peak temperature and mechanism and design of tool decides the quality of weldment. The impact of FSW tool profiles on weld material flow and temperature. They displayed the material flow and weld tool profile temperatures in relation to several probe profiles. The findings indicate that the temperatures displayed were below the melting point of the aluminum alloy and in close proximity to experimental values [11]. The primary causes of the base metal joints' enhanced tensile qualities are the optimal degree of heat generation, the development of finer grains, and the increased hardness of the joints made on magnesium alloy with a tool rotational speed of 1600 rpm (Figure 5) [12].

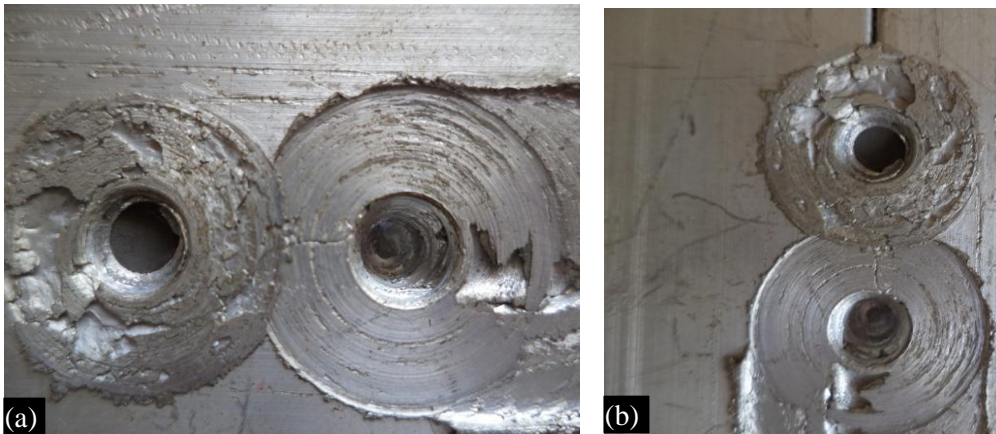
The parameters like quality, shape, residual stress and distortion of workpiece and microstructure of the processed zone are depends mainly on amount of heat gone to the tool dictates the life of the tool and the capacity of the tool to produce good processing zone (Figure 6a and b) [4, 5, 7, 13, 14].



**Figure 4.** Defect surface on Al 8010 base material. Figure depicts that additional axial force was employed that leads to excess heat input of the shoulder surface of the base material as well as the pin shaped profile on the reverse side of the welded region due to lack of heat.



**Figure 5.** Blended tool.



**Figure 6.** (a and b) Tool tip with broken base material.



**Figure 7.** Improved condition of weldment Al 8010 sample.

The FSW joints also have defects like pin holes, tunnel defects, piping defects, kissing bonds, cracks, etc. These are due to improper plastic flow and inadequate accumulation of metal in the friction stir processing region [15]. The above problems are rectified after conducting a number of trials and the weld quality have improved as shown in Figure 7. Weld sample results shown in Figure 4 indicate the

weld defects of Al 8010 aluminum alloy. Tool breaking conditions due to improper tool holders and weld defects in different forms of weldment. This paper discusses the effect of tool pin profile and axial force on the FSW weld joints using Al 8010 aluminum alloy.

## CONCLUSION

The most important component in FSW for reducing the percentage of elongation is the tool's rotation speed; welding speed comes in second, and tool pin diameter comes in third. Tool rotational speed is the most efficient metric in relation to percentage elongation. On the other hand, the percentage elongation was significantly impacted by both welding speed and tool pin diameter. The percentage of elongation first rises and then falls when the tool rotation speed is increased. The percentage of elongation increases as the welding speed increases. The percentage of elongation first reduces and then increases as the tool pin diameter increases. From this experimental trial the parameters such as tool wear, defects in base materials on weld surfaces are visually identified and reported. The above defects are mainly due to improper selection of axial force and tool pin profile. The HSS tool withstands more weld samples than the HCHCr tool. But the factors that influence the quality of weld are also concerned with axial force, tool rotational speed, welding speed, and pin profile.

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