



# *Effect of Friction Stir Welding Parameters on Mechanical Properties of Aluminum Alloy to Austenitic Stainless Steel Lap Joint*

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## **ABSTRACT**

Friction stir welding is a solid state welding process due to the low temperature in the welding zone; prevents from the formation of defect that can occur during fusion welding. In this paper, the effects of three important parameters of rotational speed, welding speed and tool tilt angle on mechanical properties of lap joint of aluminum alloy to austenitic stainless steel have been studied. The results showed that high increasing of the rotational speed or decreasing of the welding speed could be caused the cause for the creation of defects such as flash around the weld zone, cavity and sheet thinning defect which will strongly effect on the mechanical properties of the joint. Maximum fracture load was obtained 7750N in the rotational and welding speed, 1000 rpm and 80 mm/min, respectively. By increasing the rotational speed up to 2000 rpm, it led to reduce the fracture load of joint to 3350 N. It also became clear that strength of the joint increases and then decreases with increasing tool tilt angle. Therefore, increases in the tool tilt angle from 1.5 to 2.5 degree, the fracture strength reduces from 7750 N to 4180 N. In which, due to the increase in the heat input, creation of flash around the weld zone reduces the volume of material under the tool shoulder, and finally the formation of defects in the joint.

## **KEYWORD**

Lap Joint, Aluminum Alloy, Stainless Steel, Friction Stir Welding, Tilt Angle.

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## 1- INTRODUCTION

The need for jointing between dissimilar materials is increasing. As a solid-state welding technology, friction stir welding (FSW) process can be used for joining Al alloys and steels with higher joint quality than the fusion welding technology [1]. In friction welding process, joining is done with the help of frictional heat generated at the faying surfaces of the two sheets to be joined with the specially designed rotating tool. Recently, a few studies have been published on the FSW of Al to steel in a butt joint but for Al-to-steel lap joints only a very few studies have been reported[2]. Chen et al[1], investigated the friction stir lap joints of AC4C Al alloy (top sheet) and steel (zinc-coated steel, brushed finish steel, and mirror finish steel), were produced when the friction stir welding tool did not touch the lower steel surface, They reported that for zinc coat steel, the strength of the joints could reach 97.7% of the strength of the steel; for brushed finish steel, the joints strength was 63.2% of the one of steel; for the mirror finish steel, the joint with Al alloy could not happened. Ogura et al [3] investigated the mechanical properties and interfacial microstructure of friction stir welded aluminum alloy with stainless steel. They reported the strength at the center and the advancing sides of the joint were larger than respect to the retreating side of it. Kimapong et al [4] investigated the effect of a tilt angle and a pin diameter of the tool on the tensile shear load of lap joints between A5083 aluminum alloy and SS400 steel. They reported the shear strength of the joint was reduced by increasing of the tool tilt angle due to the formation of intermetallic compound at the joint interface, and showed that by increasing of a pin diameter of the tool also reduces the shear strength of the joint due to a void defect and a thicker intermetallic compound formed at the interface. A few studies have been published on the other important welding process parameters such as rotation and travel speed. This paper is focused on the effect of the rotation speed, travel speed and joint configuration on the joint shear strength and microstructure.

## 2- EXPERIMENTAL PROCEDURE

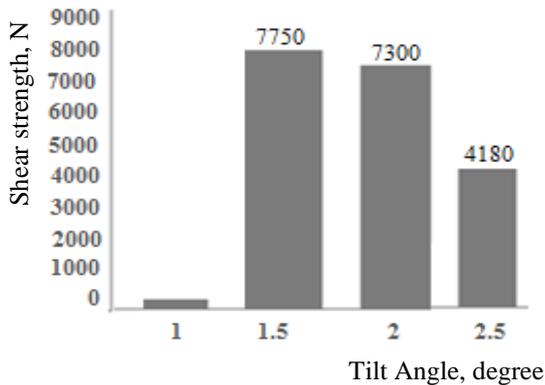
A 150 x 120 mm 5052 aluminum alloy sheet with 2 mm thickness and 304 austenitic stainless steel with 1 mm thickness were used for lap joint by FSW process. According to bonding mechanism in lap welding, the rotating tool was gently pushed to Aluminum sheet until the pin tip entered 0.4 mm into the stainless steel sheet. Then the rotating tool with 1.5° tilt angle moves along the joint. The welding parameters such as rotational and travel speeds of the tool employed varied, and also overlap configuration of the lap joint was investigated.

Tensile shear test was used to evaluate the strength of the joint. The microstructure was observed in the optical microscope, and in the scanning electron microscope (SEM) for closer observations.

## 3- RESULTS AND DISCUSSION

In order to investigate the effect of rotational and travel speeds on mechanical properties of a lap joint in FSW process, a number of experimental tests have been established. Heat generation and heat transfer to the weld zone and surface are increased by increasing on tool rotation speed. This heat generation is actual proportional to the square of rotational speed respect to the travel speed ( $\omega^2/V$ ). Material on the weld zone (HAZ) are melted, flew around, formed more flash around weld zone and consequently caused more cavities on welding stir zone by increasing heat generated due to high rotational speed of the welding tool. Difference on thermal properties of two dissimilar materials such as melting points, shrinkage coefficients is the other sources for cavities formation at the weld zone. The results of the joints by different tool rotational and travel speeds have shown that the shear strength of the lap joint is reduced by high increasing of the tool rotational speed or decreasing of the weld travel speed for a certain values lead to some defects in weld zone due to high heat generation on the weld zone. Some experimental tests performed to concern the effect of tool tilt angle on performance of the lap joints of Al alloy to austenitic stainless steel. The experimental results have shown that the shear strength of the joints increases and then decreases by increasing tool tilt angle. As shown in Fig. 1, by increasing the tool tilt angle from 1.0 to 1.5 degree, shear strength increases up to 7750, after that, for tool tilt angle from 1.5 to 2.5 degree; shear strength reduces from 7750 N to 4180 N. At the 1.5 degree tool tilt angle, as shown in the SEM image in Fig. 2 (a), the quality of the joint is relatively good and there is no any cavities in the weld zone. By increasing the tool tilt angle to 2 degree, the appearance of the joint was not change drastically and the shear strength of the joint is also reduced a little as 7300 N. As shown in Fig. 2 (b), with the 2 degrees tool tilt angle a few cavities appear in weld zone and could be as a stress concentration and crack propagation zone which are the cause of the shear strength in lower values. At 2.5 degrees tool tilt angle, in spite of good appearance of the joint, due to increase of the forging force of the tool and heat input, create flash around the weld zone and consequently reducing the volume of material under the tool shoulder, and finally formation of more cavities in the weld zone as shown in Fig. 2 (c). At this tool tilt angle, the volumes of the cavities in weld zone are increased higher and reduce the

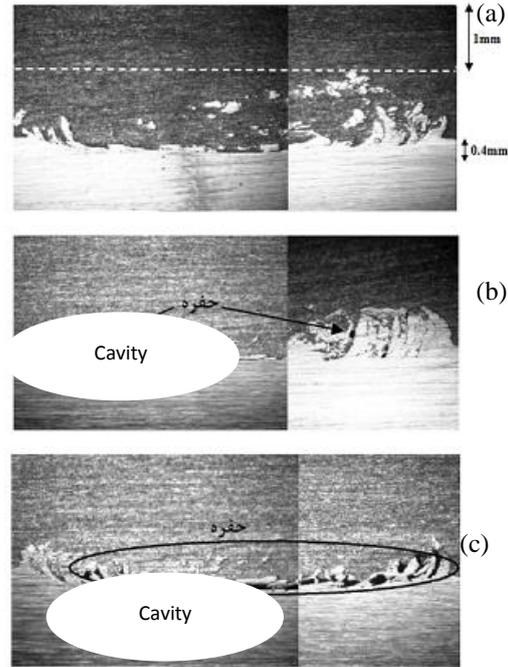
shear strength of the joint drastically. Micro-hardness of the joints has been investigated for different tool tilt angles. Micro-hardness of the Al alloy in weld region is about the same (63 Vickers) for different tool tilt angles and it was less than the base metal due to grain grows by welding heat. But hardness value of the austenitic stainless steel is increased from 305 Vickers for the base metal to 365 Vickers in weld nugget by tool tilt angles due to increasing forging force under the tool pin region and consequently high plastic deformation of the region and local work hardening.



**Fig. 1: Shear Strength of the joints at different tool tilt angles**

#### 4- CONCLUSION

The performance of the lap joint of Al alloy 5052 with austenitic stainless steel by friction stir welding is investigated. The results have shown that the shear strength of the lap joint is reduced by high increasing of the tool rotational speed or decreasing of the weld travel speed for a certain values lead to some defects in weld zone due to high heat generation on the weld zone. In addition for a certain value of tool tilt angle, the shear strength of the lap joint is also reduced due to high plastic deformation of the weld zone. Hardness in Al alloy side of the joint is about the same as base metal but in austenitic stainless steel one is increases twice as base metal due to high plastic deformation, work hardening and intermetallic phases.



**Fig. 2: Cross- section of the joints at different tool tilt angles (a) 1.5 degrees, (b) 2.0 degrees, (c) 2.5 degrees.**

#### 5- REFERENCE

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