

# Optimization of Friction Stir Welding for AA5052 and AA6061

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**Abstract**— Friction Stir Welding process is widely being used for joining aluminium alloys for aerospace, marine, automotive and many other applications of commercial importance. In this study, the experiments have been conducted on vertical milling machine (model 3KS) on AA 5052 and AA 6061. The tool used for FSW process is of cylindrical shape of H13 high speed steel (HSS) material. From the experiment work it is concluded that the process parameters tool pin profile (cylindrical), rotational speed (1200 rpm) and welding speed (55, 34 and 22 mm/min) which are taken into consideration affects the mechanical properties of the welding joint. In this study there are two output variables are calculated which are Rockwell hardness, tensile strength. Friction Stir welding (FSW) is a fairly recent technique that utilizes a non-consumable rotating welding tool to generate frictional heat and plastic deformation at the welding location, thereby affecting the formation of a joint while the material is in the solid state. The principal advantages of FSW, being a solid-state process, are low distortion, absence of melt-related defects and high joint strength, even in those alloys that are considered non-weld able by conventional techniques. The result for the tensile strength shows that there is a significant amount of effect of tool rotational speed on the welded joint and their mechanical properties. The high tool rotation speed results in improved tensile strength of the welded joint.

**Key words:** AA5052, AA6061, Optimization of Friction Stir Welding

## I. INTRODUCTION

Friction stir welding was invented by a research team led by Wayne M. Thomas at The Welding Institute (TWI) in England (UK) in 1991 and patented in 1999 [1]. Friction stir welding (FSW) is recent technique in welding that utilizes a rotating welding tool to generate frictional heat and plastic deformation at the welding place, resulting in the creation of the joint while the material is in the solid state. Friction welding is a type of forge welding, i.e. welding is done by the application of pressure. Friction generates heat, if two surfaces are rubbed together, enough heat can be generated and the temperature can be raised to the level where the parts subjected to the friction may be fused together. In conventional friction welding, relative rotation between a pair of work pieces is caused while the work pieces are urged together [2]. Typically thereafter once sufficient heat is built at the interface between the work pieces, relative rotation is stopped and the work pieces are urged together under forging force which may be same as or greater than the original urging force. "Friction welding" (FW) is a group of solid-state welding processes using heat generated through mechanical friction between a moving work piece, with the addition of an upsetting force to plastically displace material. It is primarily used on aluminium, and most often on extruded aluminium (non-heat treatable alloys), and on

structures which need superior weld strength without a post weld heat treatment. Friction stir welding is a comparatively new solid state joining process. This joining technique is energy competent, atmosphere friendly and flexible. In particular, it can be used to connect high strength aerospace aluminium alloys and other metallic alloys that are very hard to be weld by conventional fusion welding technique. In comparison to established welding technique, FSW strongly reduces the presence of distortion and left over stresses.

FSW is considered to be the highly significant development in the metal joining in a decade and is a green technology due to its energy effectiveness, atmosphere friendliness and flexibility. As compared to the traditional welding methods, FSW consumes considerably very less energy. There is no use of cover gas or flux, thereby making the process atmosphere friendly. The joining does not involve any use of filler materials and therefore material can be joined without concern for the compatibility of composition, which is an issue in fusion welding. In contrast to be traditional friction welding, which is usually perform on small axis symmetric parts that can be rotated and pushed against each other to form a joint, FSW can be applied to various type of joints like lap joints, butt, joints, T butt joints and fillet joints [3]. Friction stir welding (FSW) is a solid state joining process (the metal is not melted) that uses a third body tool to join two facing surfaces. Heat is generated between the tool and material which leads to a very soft region near the FSW tool. It then mechanically inter mixes the two pieces of the metal at the place of the joint, then the soften metal (due to the elevated temperature) can be joined using mechanical pressure (which is applied by the tool), much like joining clay, or dough. [4]

## II. EXPERIMENTAL DETAIL

### A. Experimental Setup

For the experiment the whole work is done on a vertical Milling Machine with vertical spindle position at the workshop of Geeta Institute of Management and Technology Kurukshetra. The milling machine used for the welding is of rpm ranging from 90 to 2480 rpm. The spindle position of the milling machine is vertical. The longitudinal range is 900 mm. The cylindrical shape tool is used with external vertical pressure. Experiments are conducted with and dissimilar metals. The rotational speed and travelling speed is applied in various steps. The rotational speed of the tool holder is adjusted by changing these pulleys according to the requirements of the speed. There is a driver pulley which is connected to the motor directly and one is driven pulley which is connected to the tool holder. The required speed was achieved by changing the belt from smaller diameter to larger diameter. To change the belt from smaller diameter to larger diameter we have to lose the grip of belts over pulleys with the help of the lever. In condition where

maximum speed is required we set the belt of driver pulley on smaller diameter and the belt of driven pulley on larger diameter.

### B. Experimental Procedure

The rolled plates of 5 mm thickness, AA5052 and AA 6062 aluminium, were cut out into the size (73 x 150 mm) by the hand cutter and finally shaped by the shaper machine tool. The initial joint configuration was obtained by securing plates in position using mechanical clamps. The work piece sheets were held on a fixture made of mild steel material on the bed of the milling machine. The clamping was done in a way that during the process spindle of the machine was clear of the way and clamps did not obstruct the spindle. The total three experiments are done on different plates of two alloys one by one. The experiments are performed according to the design of experiment prepared by Taguchi approach. During the welding process there are many conditions are seen when the welding becomes hard because of low speed of spindle due to the improper heating of materials. It is also found that the heat is also effect the type of chips which are produced in the welding process. The weld plates are properly clamped in the suitable fixture for the welding which can hold the plates in such a manner that both the plate cannot divert from their position during the weld. The fixture also provides a base to place the plates so that they are weld in the proper flat position. After clamping the work pieces the spindle motor is started and the centre of the plates is ensure in respect of tool then the tool is made in contact with the work plates. When the rotating tool comes in the contact of the plates the bed is made to move in forward direction by giving the required feed. And in the end tool is made to move up to remove the clamps and remove the welded plate from the fixture.

### C. Tool, Materials and Process Parameters

The tool used is of cylindrical shape of material HSS with tool shoulder diameter 18mm. The diameter of the pin is 5.5 mm and the length of the pin is 4.8 mm slightly less than the thickness of the welding plates which have the thickness of 5 mm. This slightly difference in the pin length and plate thickness is maintained for the proper welding process so that the pin do not strike the bed surface during welding of two dissimilar plates. The shape of the tool is shown in the figure 1.



Fig. 1: Straight Cylindrical Welding Tool

The work pieces that are welded by this process are in the form of two plates of Aluminium having AA-5052 and AA-6062 grade quality. The specimen plates of aluminium alloy are cut from the big size plates in the required size which is 153mm x 63mm x 5mm by the hand cutters. The chemical composition of aluminium alloys AA-5052 and AA-6061 is shown in the table I.

Material	Cr	Zn	Mn	Cu	Mg	Fe
AA5052	0.15	0.01	0.01	0.02	2.40	0.20
AA6061	0.15	0.25	0.06	0.20	0.95	0.70

Table 1: Chemical Composition of Materials

The experiments are done in the three different parts. First experiment is done on the rotational speed of 1200 and feed rate of 22mm/min. Second experiment is done on the rotational speed of 1200 rpm and feed rate of 34mm/min. Third experiment is done on the rotational speed of 1200 rpm and feed rate of 55mm/min. The tool is used of cylindrical shape with pin length of 4.8 mm as the thickness of work piece is 5 mm. The design of the process parameter is prepared on the basis of the taguchi approach. The design of the experiment is shown in the table II.

Sample No	Rotational Speed (rpm)	Feed Rate (mm/min)
1	1200	22
2	1200	34
3	1200	55

Table 2: Process Parameters

### III. RESULT AND DISCUSSION

This chapter provides the results of the mechanical tests. The values of the ultimate strength, percentage elongation and hardness have been recorded. Initially the testing for the hardness is taken in to the consideration and after the Rockwell hardness testing the tensile strength is calculated on the universal testing machine.

#### A. Hardness Measurement

The hardness is measured by the Rockwell-Brinell technique. Rockwell hardness is simply defined as the resistance to indentation and it is determined by measuring the depth of the indentation. In this, a fixed load is used to intend the surface of the work piece, low the depth of the indentation, harder the material. A ball of high speed steel (HSS) of diameter 1/16 inch with a load of 60 kgf is impacted on the surface of aluminium alloy welds and Rockwell hardness is measured on scale-B. From the measurement it can be seen that the ratio is increases as feed rate increases. This means that at the speed of 1200 rpm and feed rate of 22 mm/min the welded part is not very harder and proper mixing of two alloys does not takes place that means the welding surface remains rough. But as we increases the feed rate from 22 mm/min to 34 mm/min to the welding part the welding speed increases which results in the proper mixing of two alloys then the surface obtained at 22 mm/min and hence we obtained the better hardness. And from the experiments it can be calculated that we obtained the best hardness at the speed of 1200 rpm and feed rate of 55 mm/min due to the proper mixing of two alloys takes place. The measured value of hardness is shown in table III.

Sample No	HRB1	HRB2	HRB3	HRB Average
1	72.0	73.2	73.1	72.76
2	70.2	72.3	78.9	73.80
3	69.3	71.0	72.3	70.86

Table 3: Hardness Test Results

#### B. Tensile Measurement

The welded specimens after Rockwell hardness were put under tensile testing and the values of the ultimate tensile strength, percentage elongation were noted. A universal testing machine (UTM), also known as universal tester, materials testing machine or materials test frame, is used to test the tensile stress and compressive strength of materials. Tensile testing, also known as tension testing, is a

fundamental materials science test in which a sample is subjected to a controlled tension until failure. Properties that are directly measured via a tension test are ultimate tensile strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined like young's modulus, yield strength and strain-hardening characteristics. For anisotropic materials such as composite materials and textiles, biaxial tensile testing is required. Uniaxial tensile testing is the most commonly used for obtaining the mechanical characteristics of isotropic materials. From the measurement as shown in the table IV it can be seen that the ratio is increases as feed rate increases.

Sample No	Load (KN)	Stress (KN/mm <sup>2</sup> )	Elongation (%EL)
1	13.33	0.175	10.30
2	16.29	0.169	10.05
3	12.51	0.152	4.20

Table 4: Tensile Test Results

This means that at the speed of 1200 rpm and feed rate of 22 mm/min the welded part is not very harder and proper mixing of two alloys does not takes place that means the welding surface remains rough. But as we increases the feed rate from 22 mm/min to 34 mm/min to the welding part the welding speed increases which results in the proper mixing of two alloys then the surface obtained at 22 mm/min and hence we obtained the better hardness .And from the experiments it can be calculated that we obtained the best hardness at the speed of 1200 rpm and feed rate of 55 mm/min due to the proper mixing of two alloys takes place. The tensile test specimen after tensile testing is shown in Fig.2.

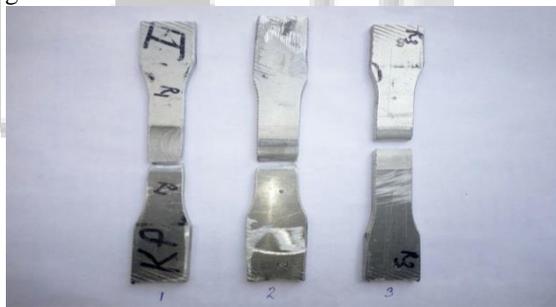


Fig. 2: Specimens after Tensile Testing

#### IV. CONCLUSIONS

Dissimilar AA6061 and AA5052 alloys have been friction stir welded with a variety of different process parameters. At a constant tool rotation speed of 1200 rpm, the hardness distributions and tensile properties of the joints were investigated. Based on the above results and discussion, the following conclusions can be drawn accordingly.

- 1) The parameters which are taken in the accounts are affects the mechanical properties of the welding joint. It is also to be noted that some of the parameters have significantly affect the mechanical behaviour of welded joint and some of the parameters have not so much effect on the properties like tensile strength and hardness.
- 2) The result for the tensile strength shows that there is a significant amount of effect of tool rotational speed on the welded joint and their mechanical properties. The high tool rotational speed results in improved tensile

strength of the welded joint. Also the low tool rotational speed decreases the tensile strength of the welded joint.

- 3) The maximum Rockwell hardness and the maximum tensile strength are obtained at 1200 rpm and 55 mm/min.
- 4) There is also a considerable effect of tool traverse speed on the tensile strength when feed is increased the tensile properties are improved but not in much amount as in tool rotational speed. It is due to the fact that the high feed rate increases the amount of friction which is further results in high heat. So the proper mixing of two metals takes place. In this way the tensile properties are improved also with hardness.

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