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FRICTION STIR WELDING OF ALUMINIUM ALLOYS AA5052 AND AA6082 USING VERTICAL MILLING MACHINE

[1]M.R.Ananthapadmanaban, [2]S.Sathishkumar, [2]R.Sarathhariharan, [2]T.Ruban, [2]P.Nikilan

[1]Associate Professor, [2]UG Students, Department of mechanical engineering, Saranathan College of engineering, Trichy.

ABSTRACT

Friction Stir Welding is a solid state welding process in which a non-consumable rotating tool with a specially designed shoulder and pin is used to join the workpieces to be welded. In this work Friction Stir Welding of dissimilar aluminium alloys AA5052 and AA6082 has been investigated. The effect of tool pin profile and welding speed on the hardness of the joints were studied. Dissimilar joints were made on 4 mm thick plates with one side single pass of aHCr tool. Parameters used are constant rotational speed of 727 rpm with varying welding speeds of 0.0875 mm/s and 0.1 mm/s. The different pin profiles used are cylindrical pin profile with straight end and chamfered end. It is found that the maximum hardness was achieved with cylindrical pin profile with straight end at rotational speed of 727 rpm and welding speed of 0.0875 mm/s.From the experimental investigation, it can be concluded that the cylindrical pin profile with chamfered end produced maximum results in terms of tensile strength alone. While the hardness and transverse strength was greater with the cylindrical pin profile with straight end. Also it is found that lower the values of welding speed resulted in maximum hardness and tensile values and with increased values of welding speed resulted in increased transverse strength alone.

1. INTRODUCTION

Friction stir welding is a solid state joining process invented at The Welding Institute (TWI) of UK in 1991. The basic concept of Friction Stir Welding is that a non-consumable rotating tool with a specially designed pin and shoulder is inserted into the abutting edges of sheets or plates to be joined and subsequently transversed along the joint line. The tool serves three primary functions as follows, Heating the workpiece, Movement of material to produce the joint, containment of the hot metal beneath the tool shoulder.

Heating is created within the workpiece by friction between both the rotating tool pin and shoulder and by severe plastic deformation of the workpiece.

The localized heating softens the material around the pin and combined with the tool rotation and translation leads to the movement of material from the front to the back of the pin thus filling the hole in the tool's wake as the tool moves forward.

The tool shoulder restricts the metal flow to a level equivalent to the shoulder position. i.e., approximately to the initial workpiece top surface.As a result of tool action and influence on the workpiece, when performed properly, a 'solid state' joint is produced.

In this work friction stir welding was done on the dissimilar aluminium alloys AA5052 and AA6082 by varying the tool pin profiles and welding speed on the vertical milling machine.

2. LITERATURE REVIEW

Z.Zhang et.al,. (2009) have conducted their work on FSW process by using a thermo-mechanical model for predicting the material deformation and temperature changes in the process. The obtained Numerical results shows that the maximum temperature in the FSW process can be increased by increasing the rotational speed. It is found that by increasingthe welding speed results in increased input power for FSW system. Simultaneously, increasing the rotational speed and decreasing the welding speed results in increased stirring effect of the welding tool which can improve the FSW quality. When weld speed becomes higher, the rotational speed must be increased simultaneously to avoid any possible welding defect such as voids. The simultaneous increase of the rotational and translating speeds of the tool can lead to the increase of the residual stress. P.Mehta,et.al,.(2017) have conducted their work on dissimilar friction stir welding of copper and aluminium by 9 different tool designs, while the rest of the process parameters were kept constant. The results obtained from various mechanical and metallurgical tests showed that the maximum joint strength was achieved by the tool of cylindrical pin profile having 8mm pin diameter and polygonal pin profiles were unstable for dissimilar fsw butt joints since they contribute to the major defects in the stir zone. The tensile strength increased as number of polygonal edges increased. The stir zone made by polygonal pin profiles was hard and brittle relative to cylindrical tool pin profiles for same shoulder surface.

V.S.Gadakh, et.al.(2013), have conducted their work on heat generation model for taper cylindrical pin profile in Friction Stir Welding. In this work an analytical model modified from the previous analytical models by the literature for heat generation of Friction Stir Welding using taper cylindrical pin profile was developed. A combination of both analytical as well as numerical approach was considered. From the results it is found that less temperature was generated using taper cylindrical pin profile than straight cylindrical pin profile under given set of working conditions. Furthermore, it is found that the increasing the taper pin angle leads to decrease in peak temperature. M.Kolraj et.al.,2012,"Friction stir welding of dissimilar aluminium alloys AA2219 to AA5083 – optimization of process parameters using Taguchi technique", have conducted their experiment on joining of dissimilar AA2219 and AA 5083 plates using friction stir welding technique and the process parameters were optimized using Taguchi L16 orthogonal design of experiments. Here various process parameters were analyzed for defect free and high efficiency welded joints and by using ANOVA method it is found that the ratio between tool shoulder diameter and pin diameter is the most dominant factor in deciding the joint soundness while pin geometry and welding speed also played significant roles and the cylindrical threaded pin tool profile was found to be best among the other profiles considered.

R.Palanivel et.al.,2012,"Effect of tool rotational speed and pin profile on microstructure and tensile strength of dissimilar friction stir welded AA5083 and AA6351 aluminium alloys" have applied their research work to join 6mm thick dissimilar aluminium alloys AA5083 and AA6351 for studying the effect of tool rotational speed and pin profile on the microstructure and tensile strength of the joints. The process is carried out with 3 different tool rotational speeds and 5 different tool pin profiles and found that the joints fabricated using straight tool profiles had no defects while tapered tool profiles caused a tunnel defect at the bottom of the joints under the experimental conditions. It is found that joint fabricated with straight square pin profile yielded highest tensile strength. K.K.Ramachandran, et.al.(2015), have conducted their work on the influence of tool traverse speed on the characteristics of dissimilar friction stir welded aluminium alloy, AA5052 and HSLA steel joints. The joint was performed on 3 mm thick plates by varying the welding speeds in steps of 5 mm/min from 30 mm/min to 60 mm/min while keeping other parameters (rotational speed 500 rpm, axial load 7 kN, tool tilt angle 1.5º) as constant. Also the tool was offset by 2 mm towards the aluminium side. From the results obtained it was found that the highest joint strength was obtained at a tool welding speed of 45 mm/min. Also it was found that both higher and lower welding speed resulted in lower joint strength.

K.Elangovan, et.al.(2008), have conducted their work on the influence of tool pin profile and welding speed on the formation of friction stir processing zone in AA2219 aluminium alloy. In this work five different tool pin profiles (straight cylindrical, tapered cylindrical, threaded cylindrical, triangular and square) have been used to fabricate the joints at three different welding speeds. The formation of the FSP zone has been analysed macroscopically and the tensile properties have been evaluated. From this investigation it is found that the square pin profiled tool produced defect free FSP region, irrespective of the welding speeds. Around 15 joints were fabricated and analysed among which the joint fabricated using square pin profiled tool at a welding speed of 0.76 mm/s exhibited maximum tensile strength, higher hardness and finer grains in the FSP region. Rajkumar et.al.,2014,"studies on effect of tool design and welding parameters on the friction stir welding of dissimilar aluminium alloys AA5052 and AA6061" have performed their study on aluminium alloys AA5052 and AA6061. The metals were friction stir welded using cylindrical pin tool at constant speed of 710 rpm and 2 different feed rates of 28 and 20mm/min and found that friction stir welding between AA5052 and AA6061 sounds good weldability and performance characteristics and cylindrical threaded pin rendered excellent bondage between both alloys by effective friction stir welding.

From the literature review of the previous works it is found that lesser number of works had been performed on the friction stir welding of the dissimilar aluminium alloys AA5052 and AA6082.

Hence this work utilizes these dissimilar aluminium alloys AA5052 and AA6082 for their numerous applications in the fields of marine, automobile, pipelines and structural components.

3. EXPERIMENTAL PROCEDURE

A. Materials used

The workpiece materials used are dissimilar aluminium alloys AA5052 and AA6082. Their chemical composition is shown in Table 1. Plates with dimensions of 200 mm×100 mm × 4 mm each of AA5052 and AA6082 are butt joined using Friction Stir Welding technique. The combined application of the dissimilar aluminium alloys are widely used in the field of marine, automobile, pipelines and structural applications.

Table 1

Alloy composition	AA5052 (weight %)	AA6082 (weight %)
Mg	2.2-2.8	0.6-1.2
Cr	0.15-0.35	0.25
Cu	0.1	0.1
Fe	0.4	0.5
Mn	0.1	0.4-1.0
Si	0.25	0.7-1.3
Zn	0.1	0.2
Others each	0.05	Tt 0.1
Others total	0.15	0.15
Remainder	Al	Al(95.2-98.3)

The tool used is made of HCr with shoulder diameter of 20mm and pin diameter of 4mm with pin length of 3.8mm. Of the two pin profiles, first one is the cylindrical pin profile with straight end and another one is cylindrical pin profile with chamfered end.

B. Fixture preparation

During the Friction Stir Welding process, due to tool rotation, plunging and advancement of the tool various forces are exerted on the work piece by the tool. Hence it is necessary to clamp the work piece rigidly during the welding process against these forces.

In this work a fixture is prepared for holding the work piece on to the milling machine table.

The CREO model of the fixture is shown in the figure 1.

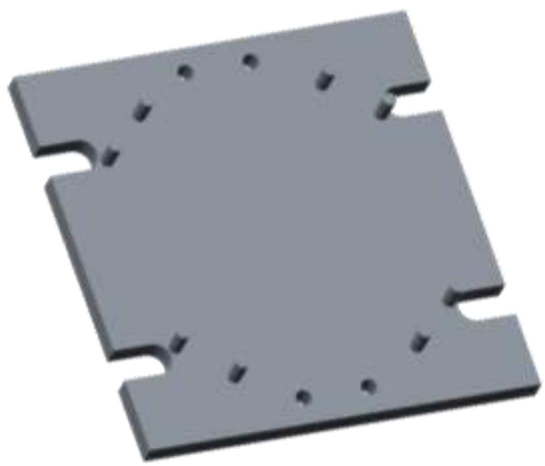

Figure 1

The fixture is made of a Mild Steel plate of dimensions 300 X 300 X 4 mm as a base material. The plate is drilled and made into a shape for accommodating the bolted joints. By using these bolted joints the fixture is fixed on the slots of milling machine table.

To arrest the movement of the work piece materials due to the force generated by the tool on the work piece, around 8 stopper pins of dimensions of diameter 10 mm and length 35 mm and 4 clamps with bolted joints are used to hold the work piece.

The stopper pins are used to constrain the horizontal movement of the work piece materials and clamps are used to constrain the vertical movement of the work piece materials during welding process.

C. Experimental work

The two dissimilar alloy plates AA5052 and AA6082 were to be butt joined using vertical milling machine. First the workpieces were made upto the required dimensions of 200mm X 100mm X 4mm. Then the workpieces were rigidly clamped with the help of a fixture on the milling table. The purpose of the fixture is to avoid the movement of the workpieces due to lateral forces developed during the welding process.

Then the tool is fixed on the spindle and it is positioned on the joint line of the workpieces were the welding has to be made.

Four welding joints have been made by considering the following process parameters. For all the joints the tool rotational speed of 727 rpm was kept constant. For the first two joints the cylindrical tool pin profile with straight end was used with varied welding speeds of 0.0875 mm/s and 0.1 mm/s. The next two joints are made using the cylindrical tool pin profile with the chamfered end by using the welding speeds of 0.0875 mm/s and 0.1 mm/s.

Table 2

Process parameters	Sample 1	Sample 2	Sample 3	Sample 4
Rotational speed (rpm)	727	727	727	727
Welding speed (mm/s)	0.0875	0.1	0.1	0.0875
Tool pin profile (Cylindrical pin with)	Straight end	chamfered end	Straight end	chamfered end

D. Hardness test

Hardness test was performed on the welded specimen using the Rockwell hardness apparatus. The test was performed using 1/16" steel bar intendor with applied load of 100 kg on five different places on the welded specimen. The readings are shown in table 2.

Table 3

Hardness	Sample 1 (RHN)	Sample 2 (RHN)	Sample 3 (RHN)	Sample 4 (RHN)
AA5052	74	80	87	74
Near 5052	91	88	87	83
Weldment center	95	92	90	86
Near 6082	99	80	87	80
AA6082	132	130	132	129

E. Tensile Test

Tensile test was performed on the Universal Testing Machine of 40 ton capacity. The test specimens were cut down to the ASTM E8/E8M-09 standards. Then the specimens were loaded on the UTM machine and the tensile testing was performed.

The tensile test readings are given below:

Data	Sample 1	Sample 2	Sample 3	Sample 4
Load at yield (kN)	5.48	4.88	4.78	10.78
Elongation at yield (mm)	1.10	0.010	0.04	5.280
Yield stress (N/mm^2)	18.221	81.333	79.667	179.667
Load at peak (kN)	15.10	12.58	10.66	13.74
Elongation at peak (mm)	7.250	4.910	5.05	7.540
Tensile strength (N/mm^2)	50.208	209.667	177.667	229
Load at break (kN)	4.32	3.66	3.45	4.36
Elongation at break (mm)	8.120	7.930	8.450	15.090

4. RESULTS AND DISCUSSION

From the detected hardness values it is found that the hardness values gained at the weld center regions are found to lie between the ranges of the hardness values of the parent alloys AA5052 and AA6082 which implies appropriate mixing of the materials in the weld zone. The maximum hardness value is obtained for the sample 1as 95 RHN with the rotation speed of 727 rpm and welding speed of 0.0875 mm/s. The tool used was cylindrical tool pin profile with straight end.

The minimum hardness value is obtained for the sample 4 as 86 RHN with the rotation speed of 727 rpm and welding speed of 0.0875 mm/s. The tool used was cylindrical tool pin profile with chamfered end. The comparison of the hardness values of the samples are given in the chart 1.

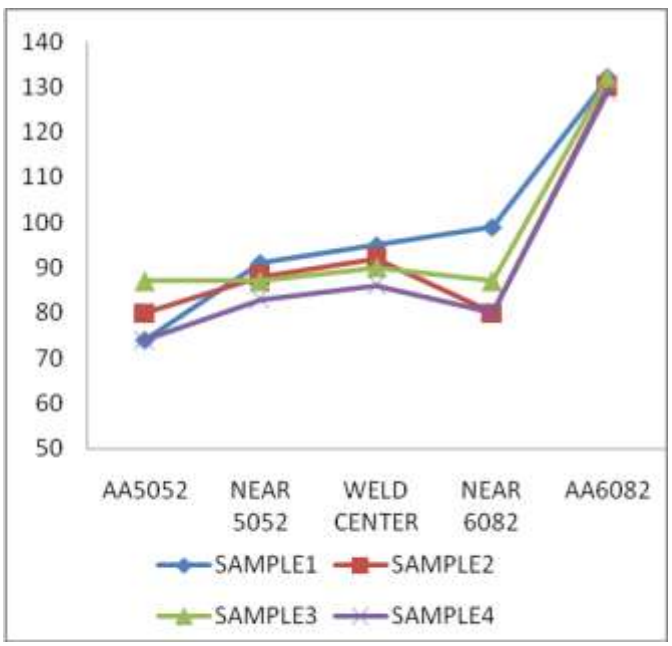

Chart 1

- From the tensile values it is found that Sample 1 has the lowest tensile strength of 50.208 N/mm^2 which was given the input process parameters of cylindrical pin with straight end of 727 rpm rotational speed and welding speed of 0.0875 mm/s.
- It is also found that Sample 4 has the highest tensile strength of 229 N/mm^2 with the input process parameters of cylindrical pin with chamfered end of 727 rpm rotational speed and welding speed of 0.0875 mm/s.

5. CONCLUSION

- From the hardness values obtained it is found that the maximum hardness was obtained for the process parameters of tool rotation speed of 727 rpm and welding speed of 0.0875 mm/s by using the cylindrical pin profile with straight end.
- It is also found that the cylindrical tool with chamfered end has no effect on increasing the hardness of the workpiece.
- But the chamfered end has produced higher tensile values in comparison with the straight end.

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