ISSN: 2348 - 2117

International Journal of Engineering Technology and Computer Research (IJETCR)
Available Online at www.ijetcr.org
Volume 3; Issue 4; July-August-2015; Page No. 219-224

JOINING OF FERROUS AND NON FERROUS MATERIALS IN FRICTION STIR WELDING

Pratheep Kumar H S[1], Mahaboob Basha D[2].

[1,2,] R & D Centre, Department of Mechanical Engineering, Sir M Visvesvaraya Institute of Technology, Bangalore, Karnataka.

pradeephs52@gmail.com [1], Dmbasha8@gmail.com [2]

Abstract

In this work joining of two dissimilar ferrous and non-ferrous materials was carried out in 5-axis friction stir welding machine. The friction stir welding is a solid state joining process that uses a third body to join two facing surfaces. The high range quality weld can be created by the friction stir welding process. The weld obtained by varying it's rotation speed, tool offset, travel speed, and maintain the constant tilt angle(2▫) and pin diameter 2.7mm. The weld sample viewed under Optical microscope was carried out to study the welding zone at different welded parts. The obtained result shows the better interlocking and bonding of material occurs at 840 rpm, -1.4mm (rotational speed, offset). The Bending strength is better when the tool is offset towards advancing side (-1mm) because of complete fusion of Harder material. The offset towards the retreating side, result in lack of insufficient heat generation on advancing side, so incomplete fusion advancing side. Shoulder diameter, pin diameter and Dwell time has greatest impact on heat generation.

Keywords: FSW, dissimilar materials, microstructure, Bending.

1. INTRODUCTION

Friction Stir Welding transforms the metals from a solid state into a "plastic-like" state, and then mechanically stirs the materials together under pressure to form a welded joint. Fiction stir welding is an innovative solid state material joining method invented by Wayne Thomas and patented by The Welding Institute (TWI) Ltd at UK in December 1991 and has been one of the most significant joining technology developed in the last two decade, Friction stir welding is non-traditional process. FSW is a solid state welding technique which can be used to produce the butt joint ,line joint, tap joint, spot joint and fillet joints as well as the weld hollow objects, like tanks, tube/pipe and many areas used this method with different type thickness of similar and dissimilar materials can be joined successes fully. In the similar materials on friction stir welding method did many researcher and get good result in that but case of dissimilar materials remains not fully researched about on dissimilar materials.

Friction generates heat, if two surfaces are rubbed together, enough heat can be generated and the temperature can be raised to the maximum level where the parts subjected to the friction may be fused together. FSW is a continuous process and this process involving non consumable rotating tool which is harder than the base materials. FSW process is not affected by the environment. FSW process is not producing any kind of smoke, fumes, and it is an eco-friendly process. Energy saving and environmental preservation are important issues for us to resolve. Since reducing the weight of vehicle is of the efficient measure, the use of combination of steel and aluminum alloy has been increasing in fabricating vehicles. This paper contains joining of AA6061T6 and SS404 of 3mm thickness

2. EXPERIMENTAL DETAILS

The FSW process is based on a very simple concept. A method of operating on a work piece comprises offering a probe (tool tip) of material harder than the workpiece material to a continuous surface of the work piece causing relative cyclic movement between the probe and the workpiece while drive forward the probe and workpiece together whereby frictional heat is generated (between work piece and tool) as the probe enters the workpiece so as to create a plasticized region in the workpiece material around the probe, stopping the relative cyclic movement, and allowing the plasticized material to solidify around the probe. This technique, which we refer to as "friction welding" provides a very simple method of joining a probe to a workpiece.

Corresponding author: Pratheep Kumar H S

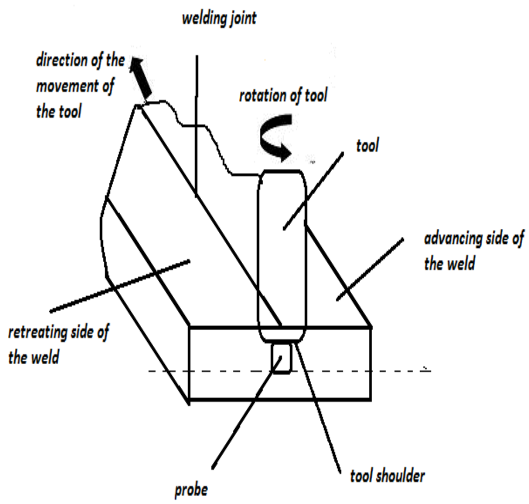

Fig1: schematic of friction stir welding.

The friction stir welded joints of dissimilar AA6061T6 and SS304 were fabricated using a 5-axis friction stir welder at IISC Bangalore. A total of 5 joints were fabricated in this 5-axis FSW machine. The Extruded plate of AA6061T6 and SS304 of 3mm thickness and the size of plate was 200mmx50mm, length and width respectively, were friction stir welded along the butted joints as shown in **Fig1**. The chemical composition of AA6061T6 and SS304 metal was shown in the **Table1** and **Table2** respectively. The steel was in the advancing side and Aluminium was in the retreating side. The tool was made in tungsten carbide and dimension of tool shown in the

Table3

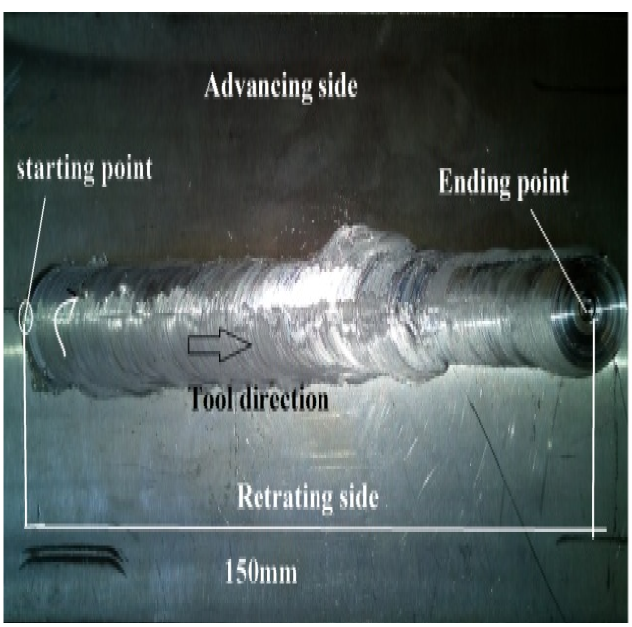

Fig2: Butt joint welding ferrous and non ferrous metal

Table1. Chemical composition of SS304

Material	Min %	Max%
C	-	0.8
Manganese	-	2.0
Phosphorus	-	0.045
Sulfur	-	0.030
Silicon	-	0.75
Chromium	8	20.0
Nickel	8	10.5
Nitrogen	8	1.0
Iron	66.34	74

Table2.Chemical composition of Al6061-T6

Materials	Min %	Max %
Chromium	0.004	0.35
Manganese	0.8	1.2
Copper	0.15	0.4
Iron	-	0.7
Magnesium	-	0.15
Zinc	-	0.25
Titanium	-	0.15

Table3. Tool dimension

Tapered Circular domed (Tungsten Carbide k12)	
Probe length	2.7mm
Upper probe diameter	5.0mm
Lower probe diameter	2.7mm
Shoulder Diameter	20mm
Tool length	28mm

3. RESULTS AND DISCUSSIONS

Bending strength

Table4: Base metal result of Bending strength and % elongation

Base metal	Peak load (N)	% Elongation	bend Strength (Mpa)
AA6061-T6	138.00	10.27	184.o8
SS304	220.0	10.44	293.0

The bending test was carrierd out on base metal AA6061T6 and SS304 % elongation obtained during the bending test was recorded as 10.27 and 10.24. bending sterngth measured for the same time as 184.08Mpa and 293.00Mpa peak load 138N and 220.0N respectivelly its **Table4** shows the recorded bending test result**.**

Table5: Experiment result of Bending strength and % elongation.

Ex. No.	speed (rpm)	Offset (mm)	% Elongation	Bend Strength (Mpa)
1	800	-1	2.54	72.76
2	830	-1	7.15	77.62
3	880	-1.2	6.79	81.78
4	920	-1.3	6.6	173.76
5	940	-1.4	9.17	119.08

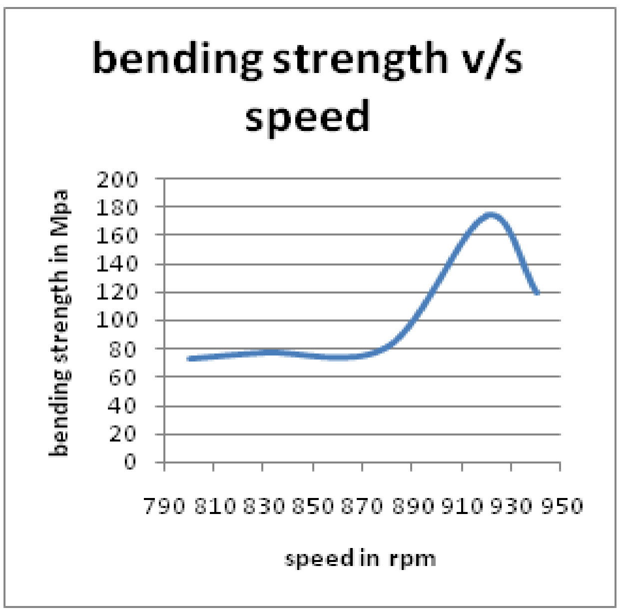

Fig3: The bending strength compare to rotation speed

Fig3 shows the bending test carried out at different rotation speed. At the welding speed of 12 mm/min, rotational speed 920rpm, with the Tapered circular domed tool the temperature did increase enough, so the BMs effectively soften to go higher bending strength. Since the temperature range also less the base alloys are not soften with stirring. The materials are not thoroughly mixed during the welding process. If we go for higher welding speed in the range 12 mm/min and the rotational speed 800 rpm we can get the high bending strength for Tapered circular domed tool pin profiles combinations. The specimens are mostly failing at the HAZ of the advancing side of SS which have the lowest strength. We can see from graph as speed increasing 800,830, 880 and 920rpm the bending strength was increasing in order 72.76,77.67,82.78,173.72mpa but bending strength is decrease at the after 940rpm at BS 119.73Mpa we say that 920rpm is optimum speed. 1000rpm the welded did not getting properly. The rotation speed 920rpm we obtained bending strength is 173mpa its shows in Table5.

Microstructural characterization.

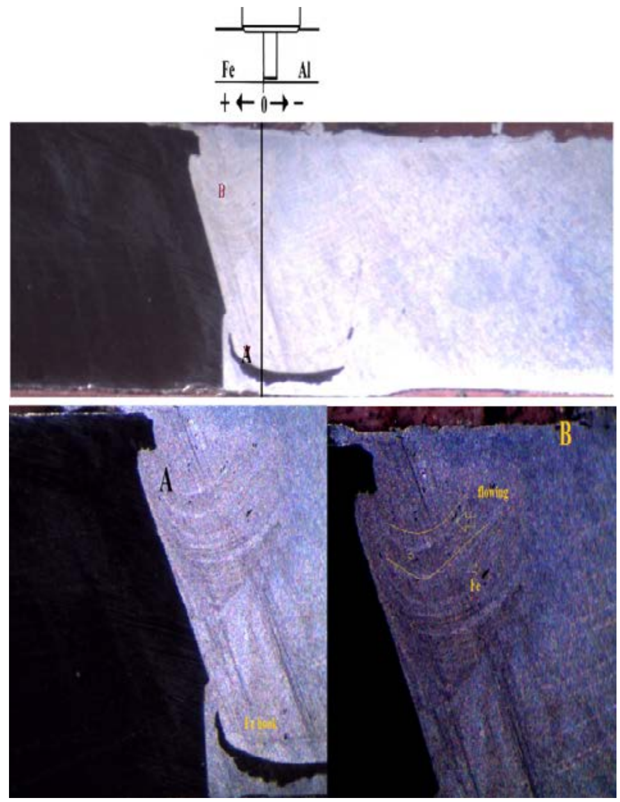

Fig 6: microstructure of parameter (Rotation speed 800rpm, tool offset -1mm, and travel speed 12mm/min)

The cross section weld view in optical microscope the microstructure shows the interface between Fe and Al and consolidation process during stirring, this weld obtained at following welding parameter are speed at 800rpm, offset - 1mm , feed rate 12/mm and plunge depth 2.82mm. The **Fig6** shows the platelet encompassed in nugget zone at steel side, no intermetallic compounds are formed at the interface between the Al and the Fe. The onion rings are formed in nugget region. In nugget region some Fe scraps particles not stirring so its remains same in nugget zone and materials flow towards the advancing side we can clearly shows in above figure. The Fe hook is formed in TAMZ in retreating side it's clearly show material is not mixing properly and the bending strength obtained at 72.62Mpa its very less compare to 920rpm weld.

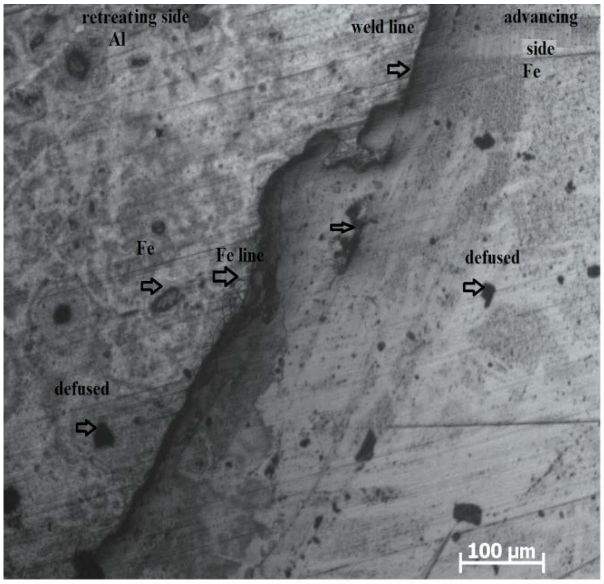

Fig7: microstructure of parameter (Rotation speed 830rpm, tool offset -1mm, and travel speed12mm/min)

Fig7 The study of Cross-sectional joint Microstructure Perpendicular to a We1d Interface, a Cross-sectional microstructure magnified 100µm. The microstructure shows the improper intermixing of material occurs at negative tool offset in advancing side and tool move in clockwise direction. The Fe particles are dispersed in small numbers in retreating side at 2.7mm plunge depth and tilt angle 2^0. The large amount of Fe defused particles are obtained at 830rpm. The negative offset -1.0mm in advancing side less heat generation in advancing side so material not mixed proper position in nugget region and bending strength is increase 4.86% compare to 800prm weld. The speed increase 800rpm to 830rpm the bending strength of weld also increase.

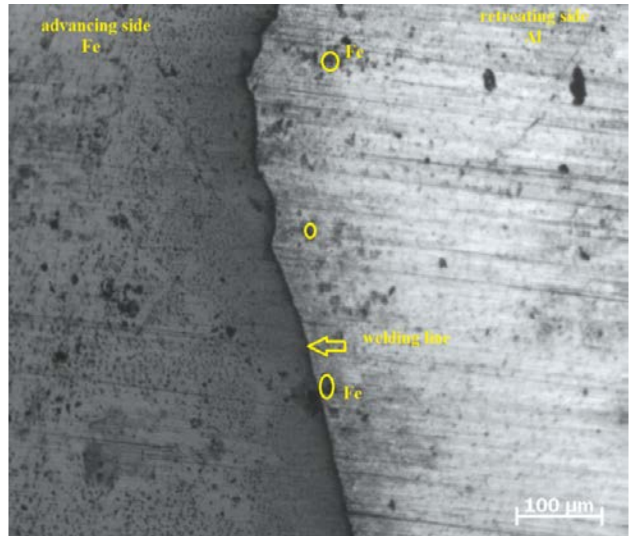

Fig8: microstructure of parameter (Rotation speed 880rpm, tool offset -1.2mm, and travel speed12mm/min)

The study of Cross-sectional joint Microstructure Perpendicular to a We1d Interface, a Cross-sectional microstructure magnified 100µm. The **Fig8** microstructure obtained at 880rpm rotation speed and tool offset increase -1.0mm to -1.2mm and travel speed maintain 12mm/min and plunge depth also increase 2.7mm to 2.82mm in entire welding and the partial intermixing interface are obtained due to less heat produced in advancing side so the Fe is very less amount mixed in stir region because of effects welding parameter. The retreating side of small amount of Fe and Al particles dispersed and good quality microstructure compare previous microstructure at 830rpm. The bending strength also increase 9.02% compare to 800rpm and maintain the 2^0 tilt angle entire weld. The obtained bending result for 880rpm weld sample is 81.7Mpa.

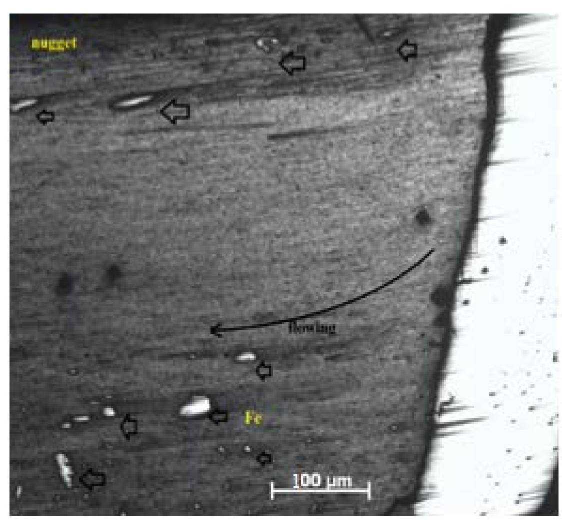

Fig9: microstructure of parameter (Rotation speed 920rpm, tool offset -1.3mm, and travel speed10mm/min)

Fig9 The study of Cross-sectional joint Microstructure Perpendicular to a We1d Interface, a Cross-sectional microstructure magnified 100µm.The onion layer in the microstructure formed because of the flow of materials, it is observed in microstructure the tool is rotated the materials flowing towards the direction of the tool. Pin diameter 5mm and increase the negative tool offset -1.3mm and 2drgree tilt angle at the center line of the weld the stirring of material did not take place completely due to the lacking of heat generation in advancing side. The interface region, both materials exhibited similar quality even with the no exact mixing of the materials in the stir zone. Welding is done successfully on 920rpm of dissimilar materials the micro structural studies recommended that there clearly evidence of no exact mixing of both materials in the nugget region and TAMZ. The bending strength was obtained in max in 920rpm compare to previous rotation speed. The microstructure revels that the materials had flowing till end. The onion rings was appealing clear so it revels the complete stirring of material has obtained when tool offset of -1.3mm towards to Fe side is given 920rpm gives the better bending strength. The %10decrease bending strength compare to the base metal AA6061T6

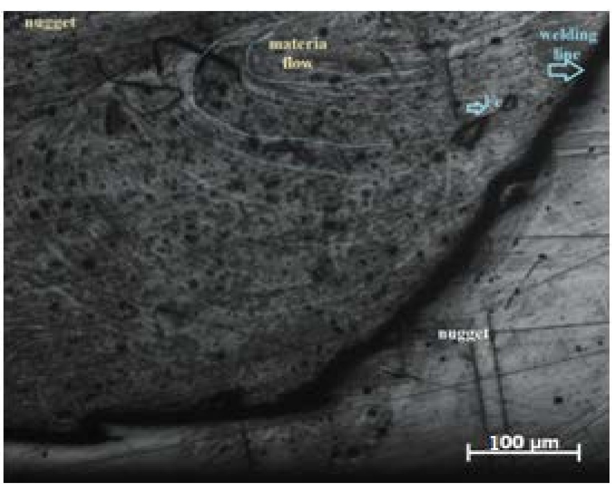

Fig10: microstructure of parameter (Rotation speed 940rpm, tool offset -1.4mm, and travel speed10mm/min)

The study of Cross-sectional joint Microstructure Perpendicular to a We1d Interface, a Cross-sectional microstructure magnified 100µm **Fig10** the microstructure shows the nugget zone a significantly mixed structure reveals that difficult thermo mechanical process and consolidation process during stirring microstructure the magnified viewed of a platelet encompassed in nugget at the steel side. Increase the tool offset -1.4mm the bending strength also drop at 940rpm. The microstructure shows the Fe particles are dispersed large amount compare 800rpm obtained microstructure, advancing side is less stirring process happens so material not exactly mixed and retreating side good mixing. The nugget zone shows the flow of materials in retreating side to advancing side and more defused particles are formed. The bending strength was obtained in the weld joint made underneath the following welding conditions are feed rate 10mm/min, -1.4mm pin offset and 940rpm tool rotation speed. The obtained bending strength is decreasing at 54.68% its compare to 920prm.

Conclusion

1. Result showing that good bonding of material occurs at -1.3mm tool offset and speed 920rpm.
2. Optical microscope study was carried out to uniform Stirring the material not good in low speed.
3. In AA6061T6-SS304 weld with tungsten carbide tool at 800rpm the mechanical properties were too much weaker than the base material.
4. Higher speed 1000rpm tool fails while welding SS304 with AA6061T6 as it was not strong enough to plasticized SS304.
5. Tungsten Carbide tool was able to join SS304 - AA6061T6 in 800rpm to 940rpm and exceed the more than 940rpm welding is improper and tool breaks.
6. The bending strength is not good when tool negative offset towards advancing side because of less fusion take place of harder material side.
7. The heat input too low sustainable plastic condition prevented that causing voids during welding and high speed causes the tool break may break

References:

1. M.Jayaraman."Influences of process parameters on tensile strength of friction stir welded cast A319 aluminium alloy joints", Metals and Materials International, 04/2009
2. Chen,C. "Joining of Al 6061 alloy to AISI 1018steel by combined effects of fusion and solid state welding", International Journal of Machine Tools and Manufacture, 200409
3. Venukumar.S, Bibin Baby, S. Muthukumaran, and Satish V. Kailas. "Microstructural and Mechanical Properties of Walking Friction Stir Spot Welded AA 6061-T6 Sheets", Procedia Materials Science, 2014.
4. Britto Joseph, G., G. Murugesan, R. Prabhaharan, and Tariq Mohammad Choudhury. "Investigations on the Effect of Tool Geometries on Friction Stir Welded 5052 H32 Aluminium Alloy", Applied Mechanics and Materials, 2015.
5. Gopalakrishnan, S.. "Prediction of tensile strength of friction stir welded aluminium matrix TiC"p

particulate reinforced composite", Materials and Design, 201101

6. Zhao,Y.-H., Lin, S.-B., Wu, L., and Qu, F.-X. (2005). "The influence of pin geometry on bonding and mechanical properties in friction stir weld 2014 Al alloy." Materials letters 59(23): 2948-52.

7. Mishra,R.S. and Ma, Z. Y. (2005). "Friction stir welding and processing." Materials Science & Engineering. R, Reports 50(1): 78-78.

8. Tang, W., Guo, X., and McClure, J. C. (1998). "Heat input and temperature distribution in friction stir welding." Journal of materials processing & manufacturing science 7(2): 163-172.

9. Indira Rani M, Marpu R. N, and A. C. S. Kumar " A study of process parameter of friction stir welding AA 6061 Aluminium alloy in 0 and T6 condition" ARPN Journal of Engineering and Applied Sciences . Volume 6, Number 2, February 2011,ISSN 1819-6608

10. Thomas, W. M., Nicholas, E. D., Needham, J. C., Murch, G., Temple-Smith, P., and Dowes, C. J. (1991). "Friction stir butt welding."

11. C.M Chen R Kovacevic(2014)." Joining of 6061 to AISI1080 by combined effects of fusion and solid state welding " manufacture 44(2004)1205-1214

12. Mukuna P,(2013) Friction stir welding of dissimilar materials: An overview Industrial and enginerring vol:7 no:4

13. Emel Taban,(2010) "Dissimilar friction welding of 6061-T6 aluminum and AISI 1018 steel: Properties and microstructural characterization" Materials and Design 31 (2010) 2305–2311

14. S. Ravikumar, Evaluation of bending strength for Dissimilar Friction stir welded AA6061T651 - AA7075 T651 aluminium alloy butt joint Industrial and Mechanical Engineering (ICTIME'2013) Sept 17-18, 2013

15. Ramulu, P. J., and R. Ganesh Narayanan. "Weld zone representation during the formability prediction of friction stir welded blanks with similar thickness sheets", The Journal of Strain Analysis for Engineering Design, 2011.