AN EXPERIMENTAL APPROACH TO STUDY THE EFFECTS OF FRICTION STIR WELDING ON 1050 H8 ALUMINIUM ALLOY

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ABSTRACT

In this study an attempt has been made to investigate the effects of friction stir welding on mechanical and metallurgical parameters of 1050 H8 Aluminum Alloy. The alloy has been welded by friction stir welding process and then the strength of the joint was tensile tested. Further the microstructure was studied.

Keywords: Breaking Load, Friction Stir Welding, Stir Zone, Weld Pitch

I. INTRODUCTION

In the present market scenario and cut-throat competition, to stand in the market new techniques are evolving day by day; friction stir welding (FSW) is also attractive technology for welding of a wide variety of metallic materials. Especially for aluminum and magnesium alloys. It is the welding process in which the heat required for welding is obtained by friction between the ends of the two parts to be joined for similar and dissimilar metals (soft metals). One of the parts to be joined is rotated at a high speed near about (3000 - 4000) rpm and the other part is axially aligned with the second one and pressed tightly against it. The friction between the two parts raises the temperature of both the ends. Then the rotation of the part is stopped abruptly and the pressure on the fixed part is increased so that the joining takes place. FSW was invented and patented in 1991 by TWI (The Welding Institute) in UK. Initially FSW was invented for joining Aluminum, but now-a-days plastics are also joined through FSW. Importance of FSW: very ease of automation, less residual stresses, good mechanical properties in region of joining. FSW is widely used for several applications where it is important to keep the original characteristic of material. It consists of non-consumable rotating tool, with profiled-pin plunged into joint lines between two pieces of sheet.

II. AIMS AND OBJECTIVES OF WORK

The aim of the present work is to investigate the mechanical properties and micro structural of butt joints friction stir welded specimens of Al Alloy 1050 H8 material.

III. EXPERIMENTATION

The material selected for the study was Aluminum alloy 1050 H8 is an Al-based alloy contains a minimum of 99.50% Aluminum, is a member of 'Commercially Pure Wrought' family. It is commonly used in the electrical and chemical industries, on account of having high electrical conductivity, corrosion resistance and workability. It has low mechanical strength compared to more significantly alloyed metals. It can be strengthened by cold working, but not by heat treatment. The Chemical composition and Mechanical properties of Aluminum alloy 1050 H8 are presented in Table1 and Table 2 respectively.

Table 1 : Chemical Composition of Al Alloy 1050 H8

Elements	Al	Cu	Fe	Mn	Mg	Si	Ti	V	Zn
Percentage	99.95 min	0.05 max	0.4 max	0.05max	0.05max	0.25 max	0.03 max	0.05max	0.05 max

Table 2: Mechanical Properties of Al Alloy 1050 H8

Material	Micro Hardness(HV)
1050 H8	44

The material received from supplier was 6 mm thick sheet and the specimen having dimensions 125 mm x 64.5 mm was prepared for friction stir welding. Eighteen plates of size 125 mm x 64.5 mm were prepared to obtain nine frictions stir welded joints of size 125 mm x 125 mm with different welding parameters. The milling operation was performed so that interfaces can be properly matched. The schematic diagram of Aluminum Alloy 1050 H8 alloy plates is shown in Fig. 1.

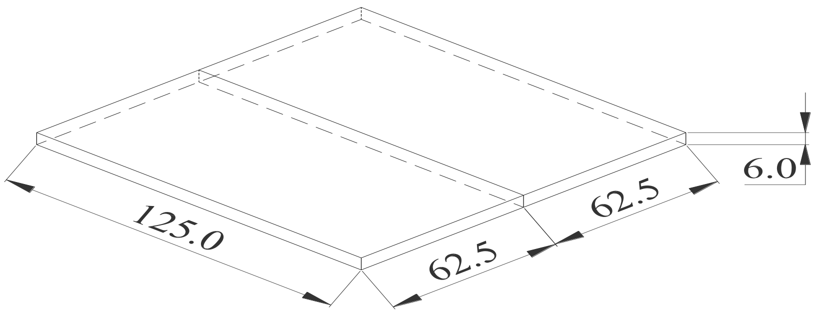


Fig. 1: The Schematic Diagram of Aluminum Alloy1050 H8 Plates

The experiment was carried out in Vertical milling machine with a table size of 254 X 1370 mm and a spindle speed ranging from 600-4600 rpm with a feed range of 10-60 mm/min. Fig. 2 shows the experimental setup of the semi automatic Friction Stir Welding machine.

Fig. 2: The Experimental Setup of the Semi Automatic Friction Stir Welding Machine

In the present study experimentation was conducted using the different parameters to select the range of the welding parameters. A proper selection of tool material and tool design plays a vital role to achieve good mechanical as well as micro structural properties with friction stir welding process. The FSW tool affects the heat generation, material flow, power input, and weld quality. Tool pin profiles play a major role in improving the quality of the weld and the maximum possible welding speed. A cylindrical pin tool was used with shoulder diameters of 20 mm, keeping pin diameter and pin length of 6 mm and 5mm respectively. The tool configuration is presented in Table 3. The appropriate clamps were used to hold the fixture on machine table. .

Table 3: Tool Configuration

S. No.	Parameters	Dimensions (mm)
1	Shoulder Diameter	20
2	Pin Diameter	6
3	Pin Length	5

Fig. 3: The Tool Used in the Experiment

There are miscellaneous process parameters of friction stir welding machine affecting the welding characteristics. In present investigation; the study was divided into two stages; firstly the joining process as shown in the Fig. 4 and secondly, the testing of specimen for strength of joint and to measure the hardness of specimen surface at interface and at various distances from interface.

Fig. 4: Joint Prepared by FSW

The experimental ranges for parameters were determined in such a way that acceptable welds were produced. The Fig. 5 shows the schematic view of tool and plates.

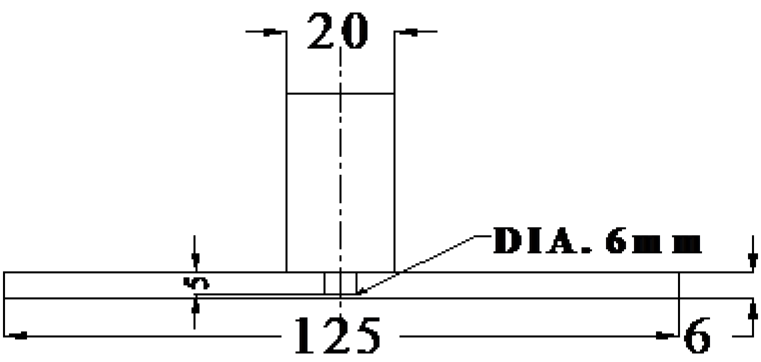


Fig. 5: The schematic View of Tool and Plates

Standard metallurgical procedure was followed to prepare the metallurgical specimens. All polished specimens were etched by dipping in a standard regent known as accetic-picral [10 ml acetic acid (99%), 4.2 gram picric acid, 10 ml H2O, 70 ml ethanol (95%)] for about 40 seconds and then dried in blast of air after rinsing in ethanol. Specimens were snapped at 100 X magnification at stir zone and thermo-mechanical affected zone. Micro indents were made on the welded zone at centre of the joint of each specimen at load of 0.5 Kg. The values for the micro hardness of each specimen were calculated and average of the result is presented in Table 4.

Table 4: Experimental Results

Specimen No	Tool Rotational Speed (RPM)	Welding Speed (mm/min)	Welding Pitch (mm/rev)	Tool Shoulder Dia.(mm)	Breaking Load (N)	Microvicker Hardness (HV)
1	1200	20	0.016	20	5300	36.5
2	1200	30	0.025	20	5600	37.5
3	1200	40	0.033	20	6300	38.5
4	1950	20	0.01	20	6900	40.5
5	1950	30	0.015	20	7300	41
6	1950	40	0.02	20	7600	41.5
7	3080	20	0.006	20	7800	32.5
8	3080	30	0.009	20	7900	36.5
9	3080	40	0.012	20	7900	47.5

The Fig. 6 shows the welded Al 1050 H8 specimen after tensile test. Tensile Strength test were conducted in Research and development centre for bicycle & sewing machine Lab, Ludhiana. This test was conducted to determine the breaking load of specimen in friction stir welding.

Fig. 6: The welded Al 1050 H8 Specimen After Tensile Test

IV. RESULTS AND DISCUSSION

The results of this study have fundamental importance for the understanding and comprehension of the main characteristics of friction welding process, the bonding mechanisms between similar materials and the feasibility of applying this process in the production of structural joints that will be used in engineering applications**.** Bringing the optimized process parameter is always a very complicated task. Various experimentation were conducted to obtain best suitable rotation speed and feed rate for the same tool profile and following points were observed:

4.1 Effect of Weld Pitch or Combined Effect of Welding Speed and Tool Rotational Speed on Breaking Load

The specimens were tensile tested and Microvicker Hardness tested. Three specimens were tested at each condition and average of the results is presented in Table 4. It has been seen that tensile strength increases with welding speed and tool rotational speed. The combined role of both parameters could be better represented by welding pitch (Welding pitch was calculated by dividing welding speed to tool rotational speed). The relationship between breaking load and welding pitch is represented in Fig. 7. It can be seen from the Fig. that the breaking load increases as the welding pitch increases keeping constant shoulder diameter of tool. The maximum breaking load of 7900(N) for welding pitch of 0.012 mm/rev was observed.

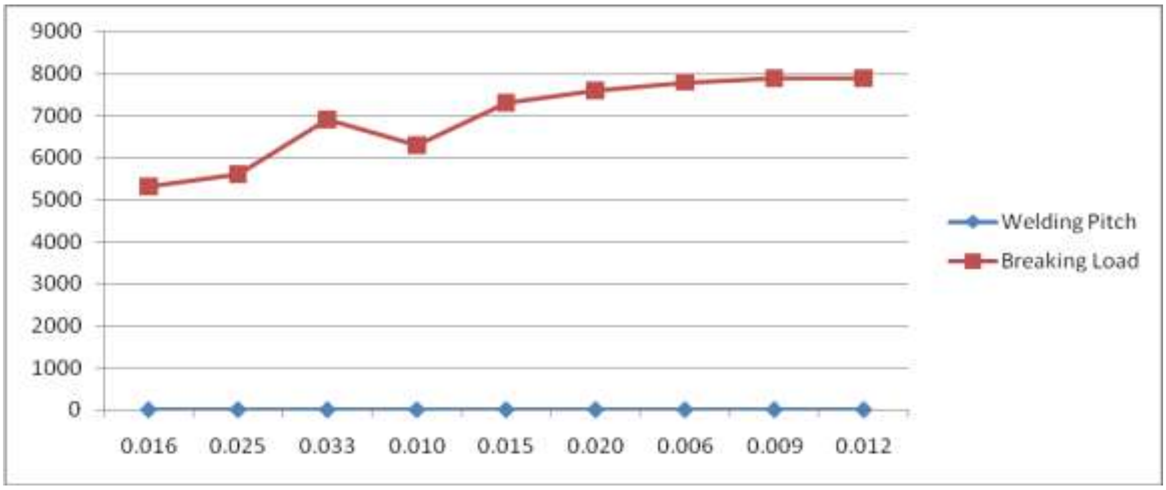


Fig. 7: The Relationship Between Breaking Load and Welding Pitch

The entire tensile test specimen fractured between Stir Zone (SZ) and Thermal Mechanical Affected Zone (TMAZ) of the advancing side with increase in the welding pitch, breaking load of the joints enhanced due to the sufficient heat generation during FSW which lead to the formation of fine and equi-axed grains. It has also been observed that the grain size decreases with increase in welding pitch with constant tool shoulder dia.

4.2 Effect of Weld Pitch on Micro Hardness with Tool Shoulder Diameter Constant

The effect of welding pitch on micro hardness in friction stir weld joint of aluminum alloy with 20mm shoulder diameter is illustrated in Fig. 8. The high value of micro hardness 47.5 HV was achieved at weld pitch of 0.0120 mm/rev. The micro hardness of the base material was 44 HV and as compared with the base metal the micro hardness of the welded samples comes out to be 32.5 to 47.5 HV in stir zone, when tested for its Microvicker hardness test. The micro hardness increases due to reduction in grain with increase in welding pitch. The grain boundaries become the main obstacles to the slip of dislocation and the material with small grain size would have higher micro hardness as it would impose restriction to the dislocation movement.

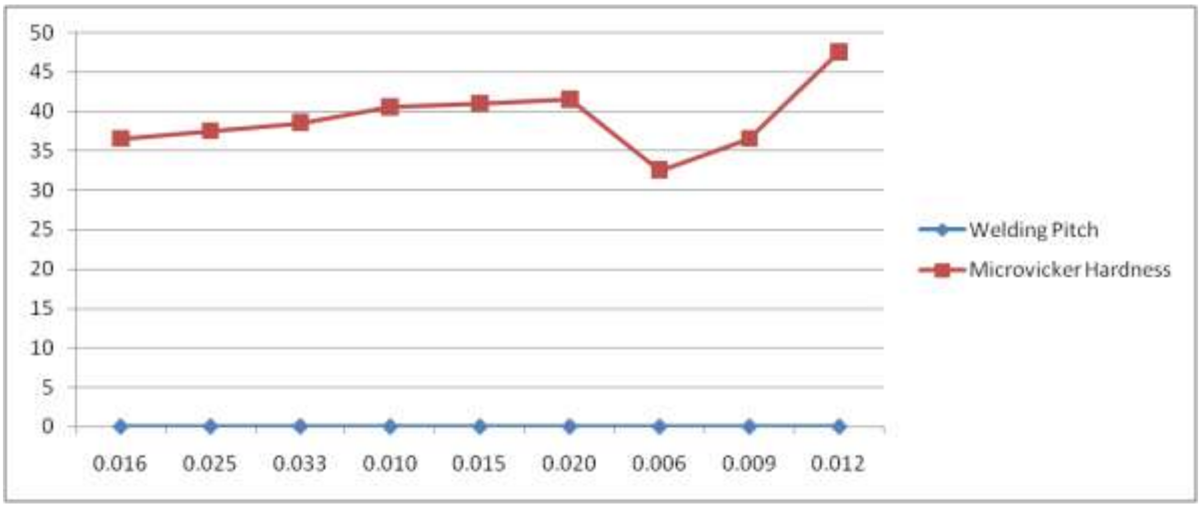
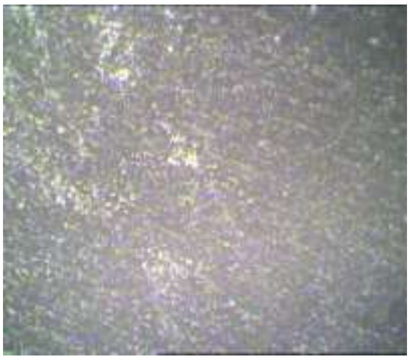


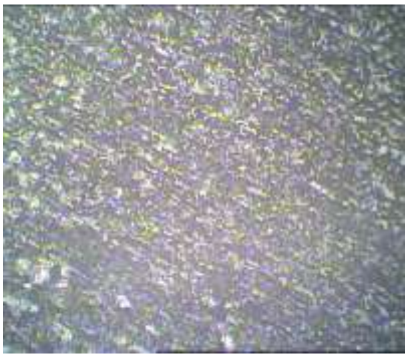
Fig. 8: The Relationship Between Microvicker Hardness and Welding Pitch

4.3 Effect of Weld Pitch on Micro Structure with Tool Shoulder Diameter Constant

The effect of weld pitch on microstructure at stir zone in friction stir welding joint are shown in the Fig. 9 at the optimized parameter fine and equiaxed recrystalised grain structure observed in stir zone due to dynamic recrystalisation in this study at the weld pitch of 0.012mm/rev uniform fine structure with uniformly distributed fine lumps of alloys silicides and at this weld pitch the max breaking load and mocrovicker hardness was observed in stir zone and findings are presented in the table 5.



Specimen 1



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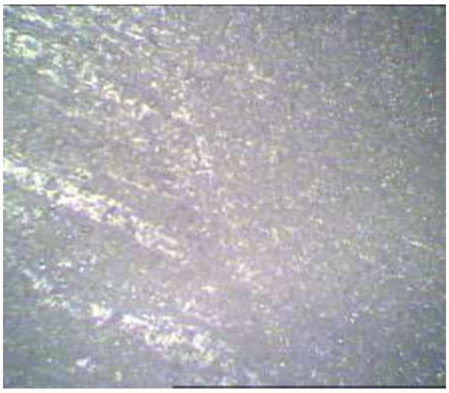
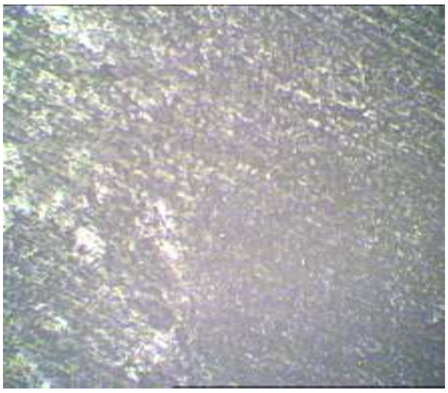


Specimen 3



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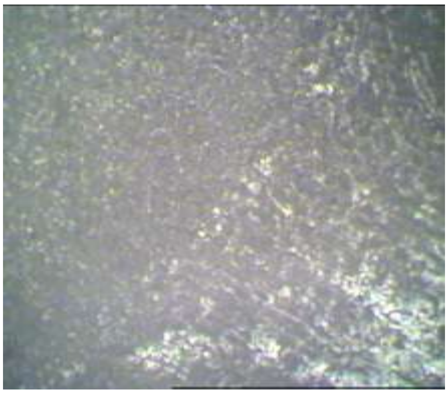
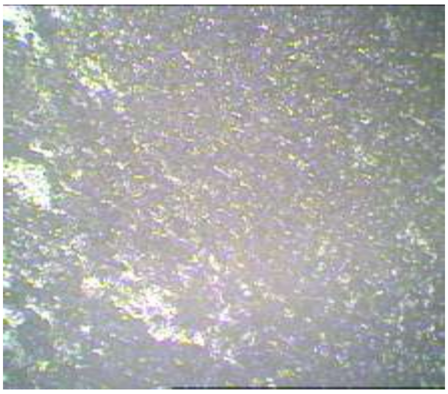
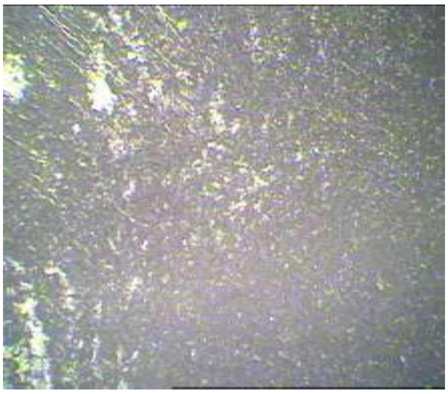


Specimen 5



Specimen 6

Specimen 7



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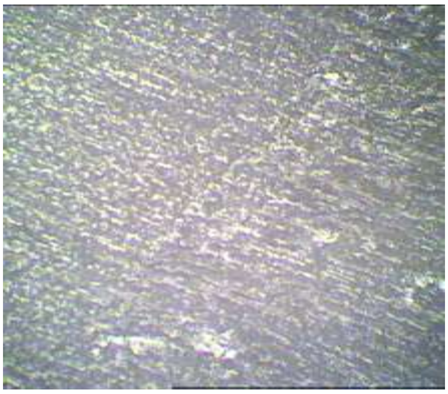

Specimen 9

Fig. 9: Microstructure of the FSW joints at SZ with 20 mm tool shoulder diameter at 100X.

Table 5: Specimen Findings

Specimen No.	Weld Zone	Base Metal	Heat Affected Zone
1	Microstructure shows uniform fine grain structure with some fine nuggets of alloy silicides. No cavity/discontinuity/cracks observed.	Uniform fine grain structure observed having distribution of alloy silicides	No Heat Affected Zone observed.
2	Uniform fine grain structure observed along with some nuggets of alloy silicides. No cavity/discontinuity/cracks observed.	Mixed grain structure observed with uniformly distributed alloy silicides.	No Heat Affected Zone observed at X100.
3	Microstructure shows uniform fine grain structure with some fine nuggets of alloy silicides. No cavity/discontinuity/cracks observed in the weld zone.	Mixed grain structure observed with some alloy silicides.	No Heat Affected Zone observed at X100.
4	Uniform fine grain structure with fine lumps of alloy silicides observed. No cavity/discontinuity/cracks observed.	Uniform grain structure with distribution of alloy silicides.	No Heat Affected Zone observed.
5	Uniform grain structure with fine lumps of alloy silicides observed. No cavity/discontinuity/cracks observed.	Uniform grain structure with distribution of alloy silicides.	No Heat Affected Zone observed at X100
6	Fine grain structure along with distorted grains observed in weld zone. Some fine lumps of alloy silicides observed. No cavity/discontinuity/cracks observed in the weld zone.	Uniform grain structure observed with some alloy silicides.	No Heat Affected Zone observed at X100.
7	Uniform fine grain structure observed along with some nuggets of alloy silicides observed. No cavity/discontinuity/cracks observed.	Mixed grain structure observed with uniformly distributed alloy silicides.	Distorted grains observed in the Heat Affected Zone.
8	Microstructure shows equiaxed fine grain structure with some fine nuggets of alloy silicides. Cavity observed in the weld zone	Uniform grain structure having distribution of alloy silicides.	No Heat Affected Zone observed.
9	Uniform fine grain structure with uniformly distributed fine lumps of alloy silicides. No cavity/discontinuity/cracks observed.	Uniform grain structure with some distribution of alloy silicides.	No Heat Affected Zone observed at X100.

V. CONCLUSIONS

The solid-state nature of FSW leads to several advantages over fusion welding methods such as:

- Problems associated with cooling from the liquid phase are avoided.
- Issues such as porosity, solute redistribution, solidification cracking and liquation cracking do not arise during FSW. In general, FSW has been found to produce a low concentration of defects and is very tolerant of variations in parameters and materials.
- FSW does not rely on specialized welding skills; indeed manual intervention is seldom required.
- No shielding gas or filler wire is required for Aluminium alloys.

- The process is remarkably tolerant to poor quality edge preparation: gaps of up to 20% of plate thickness can be tolerated, although this leads inevitably to a reduction in local section thickness since no filler is added.
- Excellent mechanical properties, competing strongly with welds made by other processes.
- The energy required at the weld for FSW lies between laser welding (which requires less energy) and metal inert gas (MIG) welding (which typically needs more).
- Various mechanical and thermal tensioning strategies can be applied during welding to engineer the state of residual stress in the weld.
- High welding speeds and joint completion rates: in single pass welds in thinner materials, FSW competes on reasonable terms with fusion processes in terms of welding speed; in thicker materials, FSW can be accomplished in a single pass whereas other processes need multiple passes. This leads to higher joint completion rates for FSW, even though the welding speeds may be lower. Thick plates can also be joined by FSW on either side.
- Can operate in all positions (horizontal, vertical, etc.), as there is no weld pool.

However, FSW is associated with a number of unique defects. Insufficient weld temperatures, due to low rotational speeds or high traverse speeds. This may result in long, tunnel-like defects running along the weld which may occur on the surface or subsurface. Low temperatures may also limit the forging action of the tool and so reduce the continuity of the bond between the materials from each side of the weld. The light contact between the materials has given rise to the name "kissing-bond". This defect is particularly worrying since it is very difficult to detect using nondestructive methods such as X-ray or ultrasonic testing. If the pin is not long enough or the tool rises out of the plate then the interface at the bottom of the weld may not be disrupted and forged by the tool, resulting in a lack-of-penetration defect. This is essentially a notch in the material which can be a potential source of fatigue cracks. Exit hole left when tool is withdrawn, large down forces required with heavy-duty clamping necessary to hold the plates together. Less flexible than manual and arc processes. Often slower traverse rate than some fusion welding techniques, although this may be offset if fewer welding passes are required.

A brief investigation was carried out on Friction stir welding of Al 1050 H8. The mechanical properties and the resultant microstructure for friction stir welded A Al 1050 H8 were investigated. The results can be drawn as follows:

- A maximum breaking load of 7900 N was exhibited by the FSW joints fabricated with the optimized parameters of 3080 rpm rotational speed, 40 mm/min welding speed and joint material hardness of 47.5 HV.
- From micro structural analysis uniform fine grain structure were observed in SZ due to dynamic recrystalisation and welding pitch 0.012mm/rev. Grain size decreased with increase in weld pitch.

Although it is only 14 years since FSW technology was invented at The Welding Institute (Cambridge, UK) in 1991, quite a few successful industrial applications of FSW have been demonstrated. The process has demonstrated its capabilities and been approved as a novel method for joining aluminum and other metals. The future scope of work may include:

- Design of experiment can be used to characterize the new friction spot weld process.
- Mathematical model can be developed to predict shear strength of spot welding.

- Finite element analysis of new friction spot welding process can be done to optimize the weld strength.

REFERENCES

[1] Inderjeet Singh, Gurmeet Singh Cheema, Amandeep Singh Kang, An experimental approach to study the effect of welding parameters on similar friction stir welding joint of AZ313-0 Mg alloy, Procedia Engineering 97 (2014) 837-846.

[2] S.Rajakumar, C. Murlidharan, V. Balasubramanian, Influence of friction stir welding process and tool parameters on strength properties of AA 7075-T6 Aluminum alloy joints, material and design 32, (2011) 535-549.

[3] M.Movahedi, A.H. Kaba, S.M. Seyed Reihani and H.Najafi, Mechanical and micro structural characterization of aluminum 50083/St -12 lap made by friction stir welding, Procedia Engineering 10 (2011) 3297-3303.

[4] C. Elanchezhian, B.Vijaya Ramnath, P. Venkatesan, S. Sathish, T.Vignesh,R.V. Siddharth, B. Vinay, k. Gopinath , Parameter optimization of friction stir welding of AA 8011-6062 using mathematical method. Proceedia Engineering 97 (2014)775-782.

[5] R. Padmanabnan, V. Ratna Kishore and V. Balusamy, Numerical simulation of temperature distribution and material flow during friction stir welding of dissimilar aluminum alloys. Procedia engineering 97 (2014)854-863.

[6] S. Ugender, A Kumar, A. Somi Reddy microstructure and mechanical properties of AX313 Magnesium alloy by friction stir welding .Procedia Engineering 6(2014) 1600-1609.

[7] Z. Shen, Y.Chen, M. Haghshenas, AP Gerlich, role of welding parameters on interfacial bonding in dissimilar steel\ aluminium friction stir welds. Engineering science and technology an international Journal. XXX (2015)1-8.