Friction Stir Welding and Optimization of Its Parameters for Maximum Tensile Strength with Two Dissimilar Alloys

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Abstract:- It is solid state welding process which is used in various applications in aerospace, marine, automotive industries. It is used for joining the various similar and dissimilar materials. Friction stir welding has better mechanical properties in comparison with other welding process in the zone. The present work focus to find the optimal combinations of parameters for maximum tensile strength of the weld joint of two dissimilar alloys of Aluminium i.e. Al 5052 and Al 5086. Rotational speed of tool, traverse speed of tool and tilt angle of tool are the important factors or parameters of interest. The present work aims to find out feasibility of process using the two dissimilar alloys i.e. aluminium 5052 and aluminium 5086 and to find out the tensile strength of using different combinations of parameters. A modified vertical milling machine has been used to setup the welding and a group of welding parameters. Various properties of welded joints were evaluated using various tests of mechanical includes the tensile testing. In the present work it is found that the tensile strength is majorly influenced by rotational speed of tool than tool tilt angle than tool traveling speed.

Keywords: *Friction Stir Welding; Charpy test; Tensile Strength; Taguchi Analysis; Welding; Welding of Dissimilar metals;*

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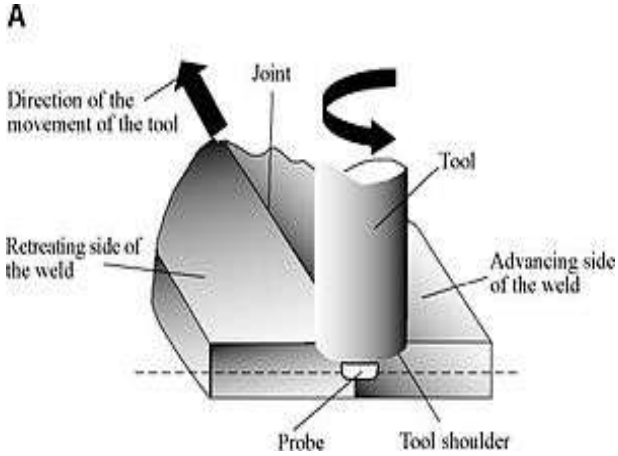
I. Introduction

Some difficult metals are not able to join using conventional methods of welding. So for such metals we can use the friction stir welding such many alloys of aluminium and magnesium which are too soft can be easily welded. The process is basically used in industries like automobile, ship, building etc. The FSW is emerged as new joining solution for welding the number of different combinations of alloys and materials. The friction stir welding a purely mechanical process and as it takes place in totally solid-state phase, in this process the entire solidification problem related to melted material are avoided. So it becomes necessary to optimize the use of this welding. The Welding Institute of UK in 1991 (TWI, 2009). In the Friction Stir Welding a cylindrical non-consumable tool having-shoulder rotates at constant speed with its probe that fed with a constant rate into the butt joint formed by combining two clamped work pieces. The length of tool probe is some shorter than the depth of weld joint required. The shouldered tool rides at the top of the work surface. Due to friction between work piece and wear-resistant welding components heat is generated at the junction. The heat generated due to mechanical intermixing and the adiabatic heat of material melts the stirred material. With the forward movement of the pin, profile of the leading tool face forces the melted plasticized material toward rear end for forged consolidation of the joint to be welded weld. A solid state deformation occurs in the process when tool traversing which results dynamic recrystallization of the base material.



Friction Stir Welding

Haşim Kafali et al. (2011) has observed the processing parameters effect on tensile strength, crack behavior and fatigue of aluminum alloys. It was found that parameters of process in FSW have lot of effects on the temperature, heat input and defects, microstructure and residual stresses of the weld bead. In general, the force of welding decrease with increase in the revolutionary pitch of the tool, the force of welding increases with decreasing in the inclination angle of tool.

N. T. Kumbhar1 et al. (2012) A friction stir welding is used to weld an aluminum alloy having magnesium in steel. In this case, he observed the effects by pin rotation speed of the tool and due to pin offset on the tensile strength after this joint structure was investigated. It is observed that by changing rotating pin position to compensate the hot surface of the steel between steel and an aluminum alloy. The Welding was performed by keeping the alloy of aluminum on the joint retreating side. To make a sound joint he use optimum rotation speed of the pin. A low speed of rotation gives rise to increase in temperature of the weld, therefore the pin of tool wore out in a short time. With increase in rotation speed, the temperature of weld bead increase so excessive that the oxidation of materials take place and resulted in an unsound joint.

Qasim M. Doos et al. (2012) investigated that Aluminum alloy (6061-T6) are weldable using different (FSW) parameters giving different welding efficiencies. FSW defects as indicated on nondestructive tests are related to the welding parameters, defect free weld of FSW obtained by using optimum welding parameter. Fine grain size microstructure obtained on weld nugget of all FSW joints. Microhardness drop was observed in the weld region of FSW joints and an increase in values of microhardness when increasing welding speed.

II. Experimental Setup and Design

In the present work of friction stir welding process, a conventional PACKMILL manufactured vertical milling machine was used which applicable for high duty. Aluminum alloy 5052 and 5086 are the two dissimilar metals to be joined, Table 1 shows the chemical compositions of the work piece materials to be joined, and Table 2 shows the mechanical properties of material in use. Specimens of 127 mm (length) × 72 mm (width) × 5 mm (thick) size were used as work piece material.

Table 1: Nominal Chemical Composition of the Aluminium 5052 and Aluminium5086

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Others
AA5052	0.25	0.40	0.10	0.10	2.2-2.8	0.15-0.35	0.10	–	0.15
AA5086	0.4	0.5	0.1	0.2-0.7	3.5-4.5	0.05-0.25	0.25	0.15	0.15

Table 2: Mechanical Properties of the Aluminium 5052 and Aluminium5086

Material	UTS (MPa)	YS (Mpa)	Elongation %	Hardness
AA5052	214	214	10	80
AA5086	310	276	12	107

Table 3: Specifications of Milling Machine

Specifications	Values
Manufacturer	PACMILL (Semi-Automatic)
Spindle Position	Vertical
RPM range	4650 R.P.M
Diameter of Tool Holder	17 mm
Motor	3 HP, 1430 rpm

First pilot experiments were done on the workpiece using random values and then from those pilot experiments the suitable values of these parameters were selected. Based on observations from the pilot experiments these levels were found suitable for the experimentation.

III. Tool Design

The tool requires a material which can withstand the process and offer enough frictional heat generation. Material to be welded must be considered before selecting a material to manufacture the FSW tool the This tool material must be wear resistant and the material to be welded and must also have a higher melting temperature and sufficiently stronger. A basic and conventional design for a FSW tool is shown in Figure 1. This cylindrical probe design will be compared to other more complex tool variants. FSW tools that follow the same trends in terms of their shapes and geometries. The tool generally comprised of basic three generic

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features: shoulder section, probe and any external features on the probe. Although the probe makes the initial contact with the pre-welded material the shoulder has a larger contact area and produces more friction.

Fig : 1 Friction Welding Tool

Table 4: DOE Factors and Levels

S.N	Factors	Level-1	Level-2	Level-3
1	Tool Rotational Speed	1200	2300	3080
2	Tool Travelling Speed (mm/min)	45	55	65
3	Tool Tilt Angle (^{o})	1.5	2.5	3.5

Based on these observed levels of process parameters welding is done on work material using Taguchi L9 orthogonal array and nine were done using four levels of three parameters.

After a successful welding of the samples at vertical milling machine the sample were analyzed for removal of any defect present. The samples having defects were welded again on the same configuration same as that of defected one. To find the tensile strength, the small samples suitable for UTM were cut from the weld bead.Universal Testing machine was used to calculate the tensile strength of the welded joint.

Table 5: Observation table for Impact Strength and Tensile Strength

Exp No.	TOOL ROTATIONAL SPEED(RPM)	TOOL TRAVELING SPEED MM/MIN	TOOL TILTING ANGLE in Degree	TENSILE STRENGTH HN/mm
1	1200	45	1.5	98
2	1200	55	2.5	102
3	1200	65	3.5	113
4	2300	45	2.5	123
5	2300	55	3.5	114
6	2300	65	1.5	95
7	3080	45	3.5	101
8	3080	55	1.5	77
9	3080	65	2.5	88

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After all the observations done, then all these observations are used for doing analysis and finding the results with the help of Minitab software. The calculations and graph plots for different element are discussed in detail in the next chapter.

IV. RESULT AND DISCUSSION FOR TENSILE STRENGTH

The tensile strength of the welded joint shows the increasing trend as the rotational speed of the tool increases from 1200 rpm to 2300 rpm, a major decrease in the tensile strength is observed as the rotational speed of the tool increases from 2300 rpm to 3080 rpm. Trend is observed to be same for both plots.

Similarly, the tensile strength is largely affected by the tool travelling speed. The tensile strength of the welded joint decreases as the tool traveling speed increase from 45 mm/min to 55 mm/min. the tensile strength shows a slight increasing trend as the tool traveling speed increases from 55 mm/min to 65 mm/min. The trend is observed to be the same for both plots.

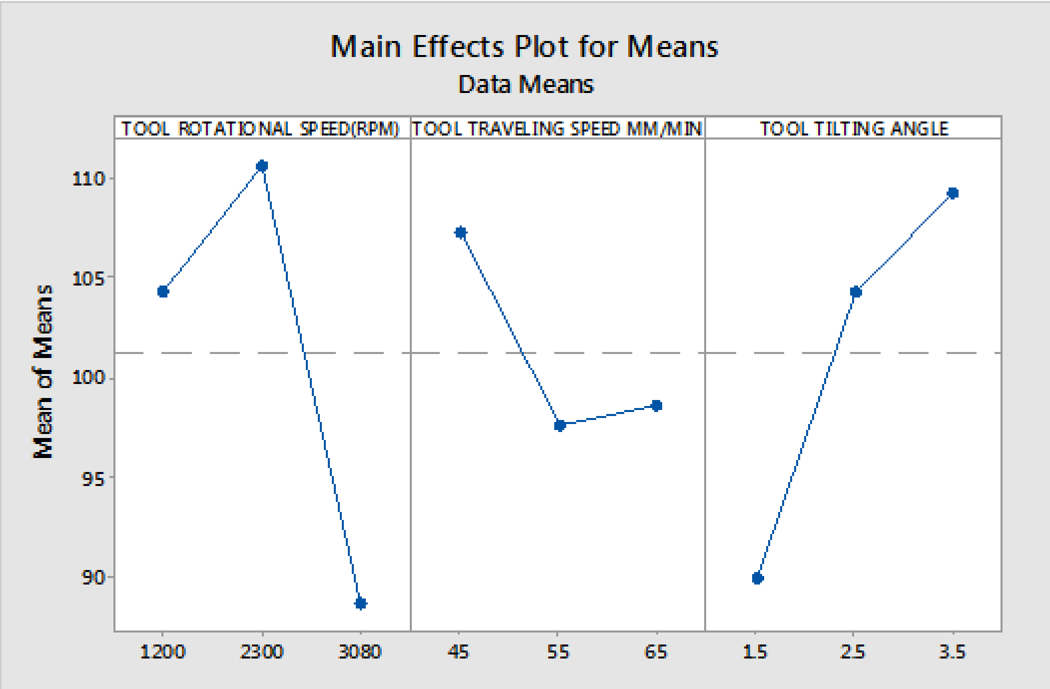

Fig. 2 Main Effects Plot of Means for Tensile Strength

Table 6 Response Table for Means for Tensile Strength

Level	TOOL ROTATIONAL SPEED(RPM)	TOOL TRAVELING SPEED	TOOL TILT ANGLE
1	104.33	107.33	90.00
2	110.67	97.67	104.33
3	88.67	98.67	109.33
DELTA	22.00	9.67	19.33
RANK	1	3	2

V. CONCLSION

- It is concluded that Tensile strength is seemed to be increase up to some extent with increase of tool rotational speed than it starts decreasing.
- Tensile strength is decreasing with increase of tool traveling speed.
- Tensile strength is increasing with increase of the tool tilt angle.

Table 7 Optimal combination for Tensile Strength

Physical	**Optimal Combination**		
Requirements	Speed(RPM)	Feed Rate (mm/S)	Tool Tilt Angle (^{o})
Maximum Impact Strength	2300	45	3.5
	Level-2	Level-1	Level-3

REFERENCES

[1] C. Meran et al. (2010) [1] “Friction Stir Welding of austenitic stainless steels”, Journal of Achievements in Materials and Manufacturing Engineering”, Volume 43 Issue November 2010, Page: 432-439

[2] D. Muruganandam et al. (2015) [2] “Review Paper on Friction Stir Welding of Aluminium and Magnesium Alloys”, Indian Journal of Science and Technology, Vol 8(35), DOI: 10.17485/ijst/2015/v8i35/86774, December 2015

[3] N. T. Kumbhar1 et al. (2012) [3] “Friction Stir Welding of Al 5052 with Al 6061 Alloys” Journal of Metallurgy Volume 2012, Article ID 303756, 7 pages doi:10.1155/2012/303756

[4] Qasim m. Doos et al. (2012) [4] “Experimental Study of Friction Stir Welding of 6061-t6 aluminum pipe” Int. J. Mech. Eng. & Rob. Res. ISSN 2278 – 0149 www.ijmerr.com Vol. 1, No. 3, October 2012, Page: 143-156

[5] Sivakumar et al. (2014) [5] “ Review Paper on Friction Stir Welding of various Aluminium Alloys” IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e- ISSN: 2278-1684, p-ISSN : 2320 –334X Page: 46-52

[6] K. Kimapong et al. (2004) [6] “Friction Stir Welding of Aluminum Alloy to Steel” Welding Journal Japan Page 277-282

[7] G. H. Payganeh et al. (2011) [7] “Effects of friction stir welding process parameters on appearance and strength of polypropylene composite welds” International Journal of the Physical Sciences Vol. 6(19), Page: 4595-4601

[8] Vukcevic Milan et al. (2009) [8] “Research and Analysis of Friction Stir Welding Parameters on Aluminium Alloys (6082-t6)” Journal for Technology of Plasticity, Vol. 34 (2009), Number 1-2

[9] Smriti Verma et al. (2015) [9] “ Fabrication and Characterization of Friction Stir Welding Using Al 3105” International Journal of Engineering Sciences & Research Technology ISSN: 2277-9655Page 691-703

[10] Bharat K. Jasthi et al. (2015) [10] “Friction Stir Welding of Steel Connections” Department of Civil and Environmental Engineering, SDSM&T, Rapid City, SD USA surovek@sdsmt.edu

[11] Indira Rani et al. (2011) [11] “A study of process parameters of friction stir welded Aa 6061 aluminum alloy in o and t6 conditions” VOL. 6, NO. 2, FEBRUARY 2011 ARPN Journal of Engineering and Applied Sciences Page: 61-66

[12] R. Muthu Vaidyanathan et al. (2015) [12] “Effects of Process Parameters on Friction Stir Welding of 6063 Aluminum Alloy” International Journal of Design and Manufacturing Technology (ijdmt)” Volume 6, Issue 1, January - April (2015), Page- 01-09

[13] Prashant Prakash et al. (2013) [13] “International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 6, June 2013 Page: 2304-2309

[14] A.Suresh Babu et al. (2013) [14] “ An Overview of Friction Stir Welding” International Journal of Research in Mechanical Engineering & Technology IJRMET Vol. 3, Issue 2, May - Oct 2013 Page 259-265

[15] L. Karthikeyan et al. (2012) [15] “experimental studies on friction stir welding of aa2011 and aa6063 aluminium alloys” International Journal of Advanced Engineering Technology IJAET/ Vol.III / Issue IV/Oct.-Dec. 2012/ Page: 144-145

[16] Unnikrishnan et al. (2015) [16] “Friction Stir Welding of Magnesium Alloys -A Review” Advances in Materials Science and Engineering: An International Journal (MSEJ), Vol. 2, No. 4, December 2015

[17] Pasquale Cavaliere (2013) “ Friction stir welding of Al alloys: analysis of processing parameters affecting mechanical behavior” 2nd International Through-life Engineering Services Conference, Procedia CIRP 11 (2013) page:139 – 144