An Experimental Test and Optimization of Friction Stir Welding Process for AA6082 By using GRA

M Senthil kumar, S Venkatesan, C Bright Samuel

Abstract* — Friction stir welding (FSW) is a type of joining process, it uses solid state welding method, also it is widely used in same type and different types of welding like Al, Mg, Cu, Ti, and their alloys. In this study, friction stir welding of two aluminum alloys AA6082 is done with many sets of tool rotation speed, feed and axial force. In this experimental work FSW process was carried out for AA 6082 and optimization of that FSW process parameters were find out for maximum tensile strength values. Taguchi's L_4 orthogonal array was utilized for three parameters – tool rotational speed (TRS), traverse speed (TS), and axial force (AXF) with two levels. Several optimization was carried out with Taguchi method of grey relational tests. During the investigation obtained highest tensile strength value fourth sample 60.887 N/mm^2 and lowest hardness strength value second sample 31HRB and bead appearance found very best surface occurred fourth test plates at the same time angle distortion observed very fine in the fourth test plate. The result was calculated for both ultimate tensile strength and hardness value. The expected grey relational grade was shifted from 0.704 to 0.792, it was the highest value received throughout this experimental results. It was mentioned that the multi-responses of FSW process was improved with this method.

I. INTRODUCTION

The FSW is a special process, which promotes the advantages of solid state type of welding for fabrications like continuous linear welds, the most common form of weld joint configurations that is generally prepared by arc welding processes in current industry. Hence, whereas fusion welding generally results in weld property degradation, FSW can produce a weld with mechanical properties similar or even better than base metal. [1][2]

The content of this work is to make the FSW process to a manufacturing technology which can be utilized over on-site construction of big, complex and critical thick-sectioned shapes which are combination of high performance and high temperature materials (such as high-strength steels, Titanium alloys and super alloys). [3]

Revised Manuscript Received on April 30, 2020.
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It starts to convert the FSW a special welding method to a useful application potential over a large list of industries hence reduction of energy, environmental and economic advantages will be useful. In order to achieve a successful project it required both innovative process concepts and due-diligent engineering efforts to compensate the fundamental shortcomings of current FSW technology. To this end, it is proposed to develop a field-deployable friction stir welding system with the flexibility and affordability for complex structural components. This field-deployable FSW system served as the platform for a concerted effort in this project, to integrate relevant innovative process concepts to enhance field-welding capabilities. [4][5]

II. LITERATURE SURVEY

RajKumar.Va, [1] et.al proved that the characters of FSW dissimilar AA5052 and AA6082, the Tensile test and hardness tests was carried to get the mechanical characters of the materials. It shows that the results of ductility is good while using low weld feed rate, it is achieved by comparing mechanical characters and metallurgical characters.

Sadeesh Pa, [2] et.al shows that accurate parameters were received to joints by the help of statistical methods. Greater efficiency and less defect was achieved by changing the parameters. The factor to consider is the difference of ratio between the tool shoulder diameter and the pin diameter. The results of microscopy structural analysis shows that a material placed over the advancing side dominates the nugget area. The results of hardness test values over the HAZ of AA6082 was very less, similarly areas of welded joints are damaged at the time of tensile tests.

R. K. Kesharwania, [3] et.al were executed the suitable parameters which affects the quality of weld in a tailored FSW butt weld. With this work the experimental data, empirical relations of parameters related to all output which produced with normal regression type method. Good set of parameters are identified using GRA.

M. Ilangovan [4] et.Al were analyzed the welding of two varied grades of aluminum alloys which are need in various less weight military products. The hardness increased which changed the set of perfect grains and other inter metallic grains in stir zone, with this good tensile properties are generated by reduced size of weaker regions like TMAZ and HAZ regions.

K. Kimapong [5] et.al shows that speed of pin rotation, axis of pin and its position along with diameter of pin on the tensile strength and microstructure of the joint. A small quantity of intermetallic compound is formed at the interface between the steel fragments and the aluminum matrix. Hence the region where the intermetallic compounds created seems to be fracture paths in a joint.

III. TOOL TYPES AND FUNCTIONS

The FSW tool has a pin (probe) and a shoulder area. The pin plunges into the mating place of the materials which produces frictional as well as deformational heating then it soft the material connecting with shoulder with the material which increase the material heat after that expands the zone, then softs the work piece then constrains the aligned work piece. The material should have the properties like easy availability, machinability, thermal fatigue resistance and wear resistance. Certain materials like aluminum, magnesium and aluminum matrix and its composites were usually joined with steel tools. AISIH13 is made of chromium molybdenum hot worked air hardening steel and it is widely used everywhere. The various types of tools are i) Fixed ii) Adjustable and iii) Bobb in type tool. PCBN tool results in greater strength and hardness the materials elevated temperatures with high temperature stability. So it is usually preferred as a tool material for FSW process for hard alloys like steels and Titanium alloys .Because of low coefficient of friction a smooth weld surface can be obtained. A very high temperature and pressure were required in the process of manufacturing for PCBN tool, so the production costs for the tool is very high.

IV. MATERIALS AND METHODS- AA6082

Al 6082 has the properties like smooth finishing of surface, good resistance for corrosion, then readily available to weld and also has the tendency of anodized. In the T4 condition the formability is good. Friction stir welding operation is done using the Czechoslovakian vertical milling machine shown in Figure 1. The weld quality were ascertained by visual inspection of weld bead and defect free joints along the weld region

Figure 1: Vertical Milling Machine

The experimental setup is to be carryout by friction stir welding is shown in Figure 2

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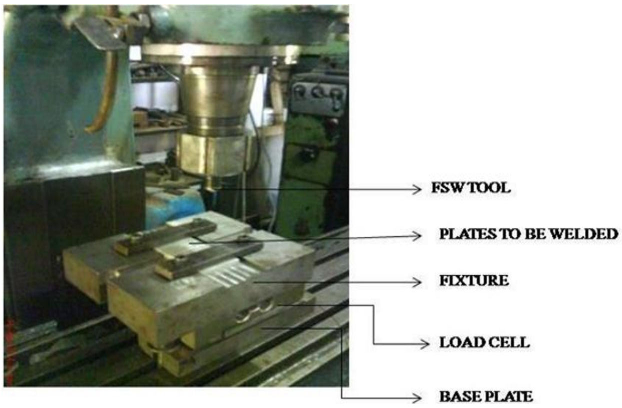

Figure 2: Friction stir welding setup

The working parameters with the stages are tabulated in the table 1

Table 1: Process specification and their stages.

STAGE	PROCESS SPECIFICATION		
	SPEED RPM	TOOL-TR Mm/min	TOOL PROFILE
1	800	20	TP
2	1000	30	SQ

V. FINITE ELEMENT ANALYSIS

Finite Element analysis of a 3-D model is carried out by three major steps. 3 type of al-sic composite is analyzed by ANSYS

- Pre-Processer
- Solution
- Post-Processer

The pre-process range has engineering data, geometry and discretization, with all this data a 3-D model is designed. The solution stage gives the analysis types, location of forces and fixation of parts. The post process stage consists of viewing of data files generated by the software at the time of solution phase. The figure 3 and figure 4 shows the stress levels of Square pin and Taper cylindrical pin.

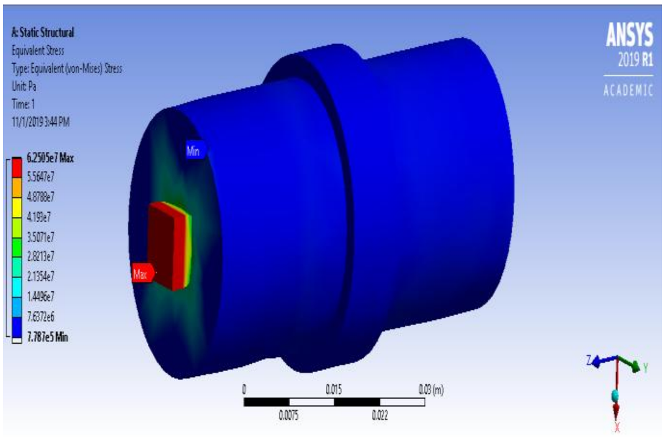

Figure 3: Stress Distribution of FSW Tool with Square Pin

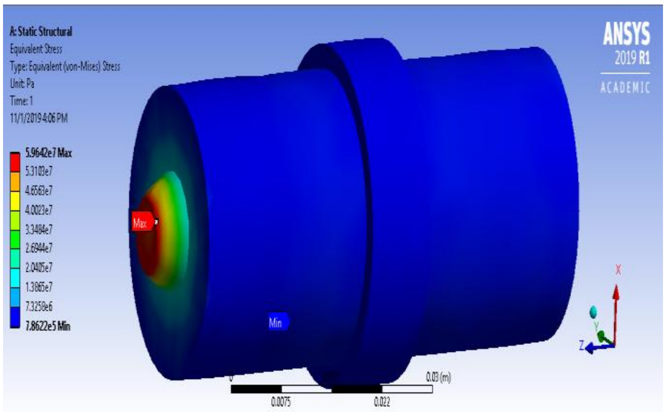

Figure 4: Stress Distribution of FSW Tool with Taper cylindrical Pin

The use of FSW tools gives a set of contact stresses. These range of contact stress and deformed were used in the opting of material in various areas. The advantage of several types of tools in FSW tools results in contact stresses. This range of contact stress and deformation were useful in selection of FSW tools in various areas.

Table 2: FEA result of tool

TOOL PROFILE	Total deformation m		Equivalent Stress pascal		Equivalent elastic strain mm	
	Min	Max	Min	Max	Min	Max
Square	0	$3.7338e^{-6}$	$7.787e^{5}$	$6.2505e^{7}$	$4.2318e^{-6}$	$2.9911e^{-4}$
Taper cylindrical	0	$3.2917e^{-6}$	$7.8622e^{5}$	$5.9642e^{7}$	$4.5491e^{-6}$	$2.8566e^{-4}$

Based on the results FSW WITH TAPER CYLINDRICAL PIN having better results. Also deformation, stress, strain are analyzed by ANSYS 19. FSW WITH TAPER CYLINDRICAL PIN is selected for the manufacturing.

VI. RESULT AND DISCUSSION EXPERIMENTAL & MECHANICAL BEHAVIOUR ANALYSIS

Table 3: FSW parameters for Al6082

SPEED (Rpm)	TOOL-TR (Mm/min)	AXIAL FORCE (KN)
800	20	10
800	30	10
1000	20	10
1000	30	10

The above mentioned parameters are executed in FSW process on **LML-KODI** 40 machine, along with this Hardness tests, Tensile test and Elongation tests are also taken into consideration for finding out mechanical behavior of the material

Figure 5: FSW with Taper Cylindrical Pin Full Plates images

The results of Hardness test and the Tensile strength test for the work piece were calculated and tabulated below

Table 4: Hardness value

TEST. NO	SPEED (Rpm)	TOOL-TR (Mm/min)	AXIAL FORCE (KN)	HARDNESS HRB
T_1	800	20	10	37
T_2	800	30	10	31
T_3	1000	20	10	39
T_4	1000	30	10	30

Table 5: Tensile strength

TEST. NO	SPEED (Rpm)	TOOL-TR (Mm/min)	AXIAL FORCE (KN)	TENSILE STRENGTH (N/mm^2)
T_1	800	20	10	43.73
T_2	800	30	10	51.76
T_3	1000	20	10	60.18
T_4	1000	30	10	66.87

GREY RELATIONAL ANALYSIS

This special type of analytical method is depend on the theory named as grey system, it is helps in finding several problems of interfered problems in a responses with very effective way. In this special method, certain data are known and some data are not known. So this method were mostly involved in the development of FSW work with various tool profiles involved during the operation with multi-responses. The first stage of the GRA process is data pre-processing since the range and unit in one data sequence may be varied with the others. Data pre-process refers that transferring the original order to a new comparable order. Depending on the characteristics of data sequence, there are various methods of data pre-process were available for this kind analytical work.

Table 6: Grey grade value

S NO	NORMALIZATION		SEQUENCE VALUE		GREY RELATIONAL CO-EFFICIENT		GREY GRADE VALUE
	Hardness HRB	Tensile Strength N/mm^2	Hardness HRB	Tensile Strength N/mm^2	Hardness HRB	Tensile Strength N/mm^2	
1	0.222	1.000	0.778	0.000	0.391	1.000	0.696
2	0.889	0.653	0.111	0.347	0.818	0.590	**0.704**
3	0.000	0.289	1.000	0.711	0.333	0.413	0.373
4	1.000	0.000	0.000	1.000	1.000	0.333	0.667

In this experiment very fine finish obtained at test plate-4 parameter of speed-1000RPM, tool traverse-30mm/min and axial force-10KN. In test plate-5GRA (speed-800RPM, tool traverse-30mm/min and axial force-10KN) were very smooth bead appearance, no crack & porosity. Friction stir speed increases fine holes produced on the top of the weld bead

Table 7: Weld appearances

SL.NO	SPEED (Rpm)	TOOL -TR (Mm/ min)	LOAD (KN)	RESULT
T_1	800	20	10	Coarse bead appearance, no crack & porosity
T_2	800	30	10	Coarse bead appearance, no crack & porosity
T_3	1000	20	10	Coarse bead appearance, no crack & porosity but angle deviation higher than others
T_4	1000	30	10	Very smooth bead appearance, no crack & porosity
T_5 GRA SAMPLE	800	30	10	Very smooth bead appearance, no crack & porosity

VII. CONCLUSION AND FUTURE SCOPE

All the researchers went with the work on changing a particular parameter at a time and with no consideration is given to interaction effect of two or more parameters. All the researcher used cylindrical tool but taper cylindrical tool, taper threaded tool and square type of tool profile were limitedly used, so in this research work taper cylindrical and square tool were used and it to be compared with each other tools and find out the tool profile which has higher tensile strength and related bead properties. Based on the FEA results FSW with Taper cylindrical Pin having less deformation, stress, strain were analyzed by ANSYS 19. During the investigation obtained highest tensile strength value fourth sample 60.887 N/mm^2 and lowest hardness strength value second sample 31HRB. And bead appearance found very best surface occurred fourth test plates at the same time angle distortion observed very fine in the fourth test plate. The expected results are changing from 0.704 to 0.792, which is the highest value obtained in all the test results. It shows that a multi-responses in the FSW process is increase by using this method. In future these parameters are taken into consideration and Grey grade value can be improved by changing the properties of materials.

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