STUDY ON THE EFFECT OF TEMPERATURE AND SPEED ON FSW ALUMINIUM WELDS

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Abstract: *Friction stir welding is a recent promising solid state joining technique used to join high strength aluminium alloy. This present work is focused to evaluate the effect of process parameters such as tool rotational speed; welding speed and temperature on tensile strength of friction stir welded aluminium alloy AA 6065 joints The mechanical properties of welded materials are measured in terms of tensile strength, with the help of vertical milling machine create the specimen by friction stir welding (FSW). Universal Testing Machine was used to check tensile testing of the welded specimen. Taguchi method of optimization with design of experiments is used in the present work. Experimental work is carried out to weld the aluminium composites joints to predict tensile strength of the welded joint. After comparison of predicted and practical values of tensile strength it is concluded that with increase in temperature, tensile strength increases. together with high welding speed leads to decrease in tensile strength of the welds work pieces.*

Keywords: Aluminium alloy 6065, Friction stir welding, Tensile, Welded Joints.

1.0 INTRODUCTION:

Friction stir welding (FSW) process is a proven method for joining aluminium alloys. This process is carried out by plunging a rotating tool, containing shoulder and pin, into the interface of two rigidly clamped sheets, until the shoulder touches the surface of the material being welded, and traversed along the weld line. Welding is done with heat generation produced between the tool and sheets. The frictional heat and deformation heat are utilized for the welding under the applied axial force FSW process has many process parameters on which weld quality depends on and hence it is an intricate process to understand. The main parameters are tool materials and its configuration, welding speed, tool rotation speed, axial force and work piece materials. Tool rotation speed is one of the main factors affecting the frictional heat. When the welding speed is small, the frictional heat makes the temperature in the weld too increase considerably. On the other hand, when the welding speed is large, the frictional heat is not enough to plasticize the materials beneath the tool's shoulder and around the probe, the sheets cannot be welded properly This indicates that for fabricating defect free FSW joints, heat generation is one of the major factors. There are few studies on the thermal distribution during the FSW process at different process parameters and their modelling strategies are studied through the thermal distribution in the base material. The present work aims at monitoring the temperature evolution in a friction stir welded joint made of aluminum 6065 under different process parameters like tool rotation speed, welding speed and temperature with a cylindrical tool. This work is a confirmatory test to study the temperature evolution at different process conditions, and is part of an overall research scheme of evaluating the formability of FS welded aluminium sheets.

2.0 LITERATURE REVIEW

Boz, M., et al **[1].** In this study, Al 1080 alloy materials were welded using friction stir welding process. The influence of stirrer design on the welding process was investigated. For this purpose, five different stirrers, one of them square cross-sectioned and the rest were cylindrical with 0.85, 1.10, 1.40- and 2.1-mm screw pitched were used to carry out welding process. Liu HJ, Fujii H et al **[2].** Friction stir welding (FSW) is a new and promising welding process that can produce low-cost and high-quality joints of heat-treatable aluminum alloys. Scialpi A, et al **[3]** The effect of different shoulder geometries on the mechanical and microstructural properties of a friction stir welded joints have been studied in the present paper. The process was used on 6082 T6 aluminium alloy in the thickness of 1.5 mm. The three studied tools differed from shoulders with scroll and fillet, cavity and fillet, and only fillet. Elangovan K **[4].** AA6061 aluminium alloy (Al-Mg-Si alloy) has gathered wide acceptance in the fabrication of light weight structures requiring a high strength-to-weight ratio and good corrosion resistance. Compared to the fusion welding processes that are routinely used for joining structural aluminium alloys, the friction stir welding (FSW) process is an emerging solid state joining process in which the material that is being welded does not melt and recast. Elangovan K **[5].** AA2219 aluminium alloy has gathered wide acceptance in the fabrication of light weight structures requiring a high strength to weight ratio. Compared to the fusion welding processes that are routinely used for joining structural aluminium alloys, friction stir welding (FSW) process is an emerging solid state joining process in which the material that is being welded does not melt and recast. This process uses a non-consumable tool to generate frictional heat in the abutting surfaces. Aydın H, et al **[6].** In this study, the different heat-treated-state 2024 Al-alloys were friction stir welded. The tensile properties of the joints have a tendency to increase with the precipitation hardening of the base material. The peak tensile properties have been obtained in the T6 (100 _C – 10 h) joint. It is observed that the weld zone is strengthened by the friction stir welding process for the 2024-O joint. Patil HS, et al **[7].** Friction stir welding (FSW) is a novel solid state welding process for joining metallic alloys and has emerged as an alternative technology used in high strength alloys that are difficult to join with conventional techniques. Rajakumar S **[8]** The aircraft aluminium alloys generally present low weld ability by traditional fusion welding process. The development of the friction stir welding has provided an alternative improved way of satisfactorily producing aluminium joints, in a faster and reliable manner. Sharma C, et al **[9]** Currently friction stir welding tools are designed by trial and error. Here we propose and test a criterion for the design of a tool shoulder diameter based on the principle of maximum utilization of supplied torque for traction. Prasanna P, et al **[10]** Friction stir welded joints of Al–Zn–Mg aluminium alloy AA7039 were given five different post weld heat treatments in order to investigate their effect on microstructure and mechanical properties. In general, all the applied post weld heat treatments increased the size of an aluminum grains in all zones of friction stir weld joints. Abnormal grain growth was observed in entire zone modified by friction stir welding in case of solution treated joints with and without artificial aging.

3.0 MATERIALS AND METHODS

The material used in this study was 6065 aluminum alloy with a butt joint configuration. The chemical, mechanical, properties of this material are depicted in Table respectively. The welding sheet was cut off parallel into the rolling direction with a dimension of 101.6 mm × 20 mm × 5 mm using a hand hacksaw to minimize the residual stresses that will occur during the cutting operations. In addition, the tensile strength test samples were prepared accordingly.

Table 1. Chemical composition of AA 6065 material.

Material %	Mg	Si	Fe	Cr	Cu	Al
AA6065	0.93	0.6	0.33	0.18	0.25	97.7

Table 2: Mechanical properties of AA 6065 material

Material %	Yield Strength (Mpa)	Tensile Strength (MPa)	Hardness (HRA)
AA6065	0.93	0.6	40

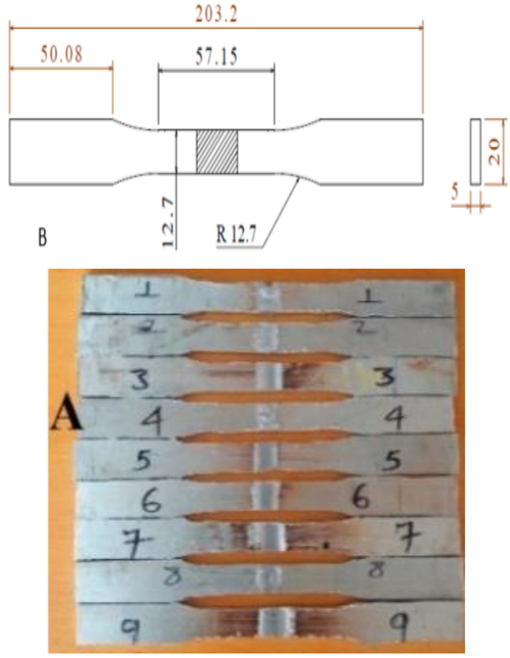


Figure1: Welded specimen

Taguchi Method:

Taguchi method is one of the quality enhancement approaches developed by Dr. Genechi Taguchi in Japan in 1940. The technique is simple, capable, and a systematic quality improvement method that allows independent estimation of the response with a minimal number of trials This method involves two major tools: Orthogonal array (OA) and S/N ratio. Based on Latin Square an orthogonal array is employed to reduce variance and optimize process parameters. On the other hand, the signal-to-noise-ratio is used to measure process robustness and to evaluate deviation from desired values based on the selected quality characteristics.

4.0 Results and Discussions

From the experiments performed it is very much evident that the heat generated during the friction stir welding is directly proportional to the temperature. The experiments were conducted to study the effect of process parameters over the output response characteristics of tensile strengths and are summarized as shown in Table. Cylindrical profile tool was selected for the present experimental approach.

Table 3: Taguchi L9 orthogonal array parameter setting and experimental tensile strength

S. No	Rotational Speed (RPM)	Traverse speed (mm/min)	Tool Temperature	UTS (Mpa)	HV
1	900	30.5	350	220	71.6
2	900	42.5	400	244	79.8
3	900	45.2	450	261	81.2
4	1000	30.5	400	254	77.8
5	1000	42.5	450	270	85.4
6	1000	45.2	350	254	79.2
7	1200	30.5	450	269	83.1
8	1200	42.5	350	247	72.4
9	1200	45.2	400	290	86.8

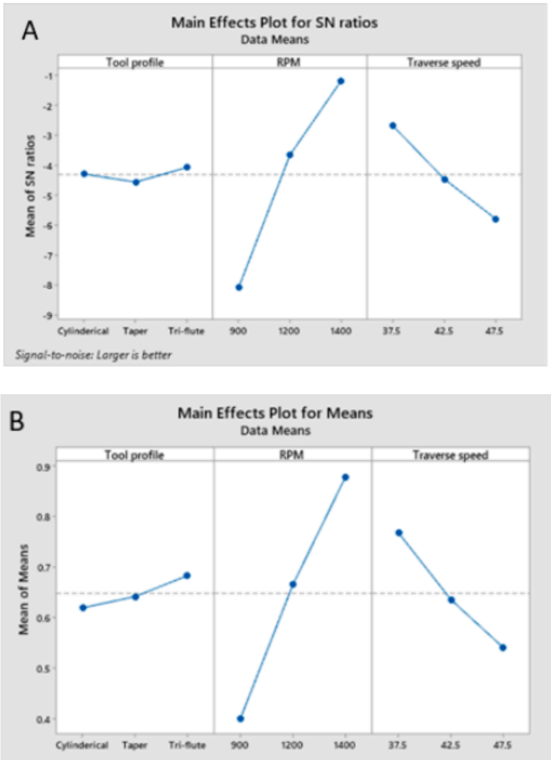


Figure 2: (A) Signal to noise ratio of Grey relational grade (GRG) (B) Main effects of Grey relational grade (GRG)

Tensile Strength:

Tensile strength is one of the responses that was measured for similar FS welds of Al-alloy (6065) and Al 6065 composite. The result shows that tensile strength is directly proportional to the rotational speed and inversely proportional to the traverse speed of the tool for this reason: that the lower traverse speed and higher rotational speed produce adequate heat for joining the base metal.

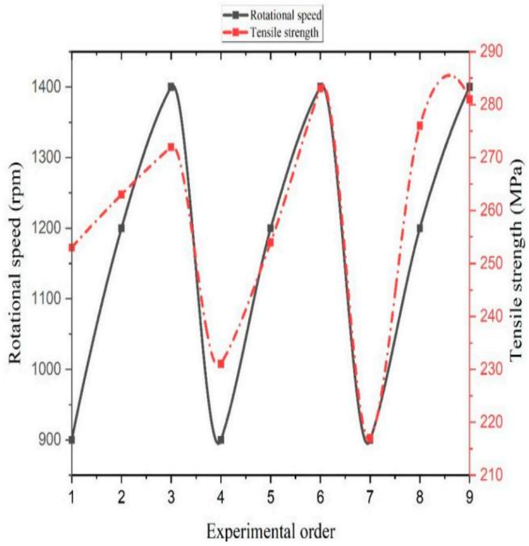


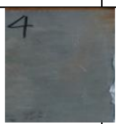
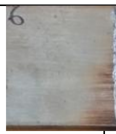
Figure 2: Effects of rotational speed on the tensile strength property of AA 6065

Welding Parameter Effects on the Joint Quality:

In the friction stir welding process, a variety of process parameters affects the weld joint quality. FSW welding process parameters mainly include rotational speed of a tool, welding traverse speed and tool profile.

Table 4: **Rotational speed and traverse speed effect on the response study.**

S.NO	RPM	Tensile strength (Mpa)	Welding Joint	Observations

1	900	30.5		Name of the defect: Flash Location of the defect: A.S Lower welding speed
2	900	42.5		Name of the defect: Defect free Location of the defect: Nil Reason for the defect: Adequate heat input
3	900	45.2		Name of the defect: Defect free Location of the defect: Nil Reason for the defect: Adequate heat input
4	1000	30.5		Name of the defect: Tunnel Location of the defect: Stir zone Reason for the defect: Too low RPM
5	1000	42.5		Name of the defect: Defect free Location of the defect: Nil Reason for the defect: Adequate heat input
6	1000	45.2		Name of the defect: Tunnel Location of the defect: Stir zone, at the beginning Reason for the defect: Inappropriate pin offset
7	1200	30.5		Name of the defect: Flash Location of the defect: Advancing side Reason for the defect: Very high RPM and lower welding speed
8	1200	42.5		Name of the defect: Tunnel Location of the defect: Stir zone Reason for the defect: Inappropriate pin offset

9	1200	45.2		Name of the defect: defect: Location of the defect: Advancing side

Taguchi Prediction

S.NO	S/N	MEAN	St.Dev	Ln. St.Dev	Rank
1	39.5242	143.294	103.607	4.64793	1
2	40.4977	161.844	117.443	4.76322	2
3	41.0587	173.661	127.130	4.84197	6
4	40.6990	168.461	124.584	4.82175	4
5	41.0782	175.194	129.204	4.86621	7
6	40.4705	166.544	124.938	4.82578	5
7	40.8951	175.994	132.787	4.88734	8
8	40.1056	162.261	123.453	4.81262	3
9	41.2609	185.894	142.356	4.96221	9

Conclusions:

In this study, a combination of Taguchi based grey relational analysis method was implemented to come up with the optimal process parameters for FSW. Analysing the effect of combined factors on the mechanical strengths, the following conclusions are drawn. It was observed that the temperatures on the advancing side of the weld are bit higher than that of the retreating side of the weld. From the study it can be concluded that the appropriate temperature for a defect free friction stir weld of Al 6065 and Al 6065 composite can be within the range of 350 - 450^0 C. The joints fabricated with 20mm shoulder diameter yields maximum joint efficiency. The experimental results obtained can be helpful to control various process parameters during FSW of Al 6065 to achieve defect free, sound and good quality welds.

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