PARAMETRIC OPTIMIZATION OF FRICTION STIR LAP WELDING OF AA2024-AA7075 USING TAGUCHI METHOD

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Abstract: The basic principle of friction stir welding is to enable joining of metals by heating the base metal to temperature below the recrystallization temperature. This reduces welding defects like porosity, cracks, and property deteriorations due to melting, solidification, dissolution, and softening of heat affected zones common during fusion welding. The friction stir weld joint exhibits better quality and properties compared to other fusion welding techniques. AA2024 and AA7075 aluminium alloys are known for its higher strength to weight ratio which makes them suitable for marine, aerospace and chemical industry applications. Dissimilar joining process is considered as a challenge when compared to welding of similar material due to the variation in the chemical composition and mechanical properties of the joining metals. Optimization of FSW process parameters plays a key role in meeting the demands for more efficient FSW joint. It becomes necessary to optimize the parameters of FSW process to get optimum weld joint properties. This research attempts to study the effect of process parameter on mechanical properties of friction stir welded lap joint of dissimilar aluminium alloys AA2024-AA7075 and of different thickness and to optimize experimental results using Taguchi method. The results are then analysed by using ANOVA statistical tools. ANOVA table clearly shows the percentage of contribution of each factors can be determined.
Keywords: friction stir welding, AA2024, AA7075, Lap joint

I. INTRODUCTION

Friction stir welding (FSW) was invented as solid state joining technique at The Welding Institute (TWI), Cambridge in 1991 and it was initially applied to aluminum alloys. FSW is solid state metal joining process hence, it minimizes the defects and property deteriorations due to melting, solidification, dissolution, and softening of heat affected zones[1]. The process uses a third body non consumable tool to join two sheets. A high speed rotating tool inserted between two butting surfaces generates heat due to friction and plastic deformation thereby plasticizing base material nearer to tool surface. Rotary motion of the tool leads to intermixing of both plates and the plates are joined by applying mechanical pressure. This process is continued by traversing tool along the path of joint. [1]

The tool serves three primary functions:
(a) Heat generation at butting of work-piece,
(b) Stirring of material to produce the joint.
(c) Applying mechanical pressure to confine the flow of material below the shoulder of tool.

The heat is generated by the friction between the wear resistant tool and work-piece and plastic deformation of work-piece. The localized heating softens the material around the pin and the work-piece material. The combined motion of tool rotation and translation leads to movement of material from the leading edge to trailing edge of the pin. The viscoplastic flow of the material around the tool pin is quite complex because of various geometrical features of the tool and tool pin. The advancing side corresponds to the side at which the directions of tool surface and the tool translation direction are the same. The other side is called the retreating side [2]. Probe or pin is the part of the tool plunged into the work piece during welding process. Shoulder is the part of the tool, which is pressed on to the surface of the work piece to confine the viscoplastic flow during welding. The front edge of the shoulder in a cylindrical tool is called leading edge of the tool. The rear edge of the shoulder in a cylindrical tool is called trailing edge [1].

II. FRICTION STIR WELDING PROCESS

In friction stir welding process can be divided in to basically four phase:

Step 1. Plunging: The FSW tool rotates at constant speed about its own axis and then the tool-pin is slowly plunged into the abutting edges of work pieces rigidly clamped to a backing plate. The tool is plunged until the shoulder of the tool touches the upper surface of the work pieces.

Step 2. Dwelling: The tool rotating at constant speed is to dwell for few seconds to generate sufficient heat to soften the localized material before the tool is moved along the line of joint.

Step 3. Traversing: The tool is then translated at constant traverse speed along the length of the joint with an axial force applied. Frictional heat generated due to the relative motion between tool and the top surface of the work piece under the action of an axial force softens the material of the base metal plate. The translation of the tool results in severe deformation and viscoplastic flow of the material from the leading edge of the tool to the trailing edge and forms a joint in the solid state. During traversing process the material in weld region undergoes combined action of extrusion and forging and creates sound weld joint.

Step 4: Pull out.: The tool is then taken out of the joint after completion of weld. In FSW process, at the end of weld joint, the tool leaves a hole which is called the exit hole. The exit hole is considered as limitation of the process. There are many repairing techniques available for filling up of this hole at the end of the weld joint.

III. METHODOLOGY

1. Design of experiment:

The parameters identified for investigation are tool rotation speed, welding speed, Tilt angle. The selected Process parameter and their levels are shown in table 1.This is the design of experiment by which the works are done.

Table 1 Process parameter and their levels.

Process parameters	Spindle speed(RPM)	Traverse speed(mm/min)	Tool tilt angle(°)
Level 1	765	20	2
Level 2	1070	31.5	3
Level 3	1500	50	4

2. Taguchi's method

Taguchi's method is a tool for design of a high quality system. This method is a systematic Approach for performance and quality optimization. By this method the number of experiment is reduced to 9. The total degree of freedom must be calculated to choose the correct orthogonal array. The degree of freedom For the orthogonal array should be greater than or at least equal to those for the process parameters. So, L9 Orthogonal array was selected which has a degree of freedom of 8. Nine experimental runs were conducted as per Taguchi L9 orthogonal array.

3. ANOVA analysis

Analysis of Variance (ANOVA) is a statistical method which is used to discuss the relative importance of the entire control factor. They are also used to find the contribution of each parameter. F-test proposed by Fisher is used as an auxiliary tool of inspection. Thus, the larger the value of f-test the more dominant the parameters are.

4. S/N ratio

Taguchi also recommended analysing the valued using S/N ratio. It involves conceptual approach which graphs the effect and identifies the significant values.

5. Experimental setup

4.5mm thick AA2024 plates welded to 6mm thick AA7075 plates using FSW process with set of process parameters provided by L9 orthogonal array process parameters are shown in table 2

Figure 1 Schematic diagram of material arrangement

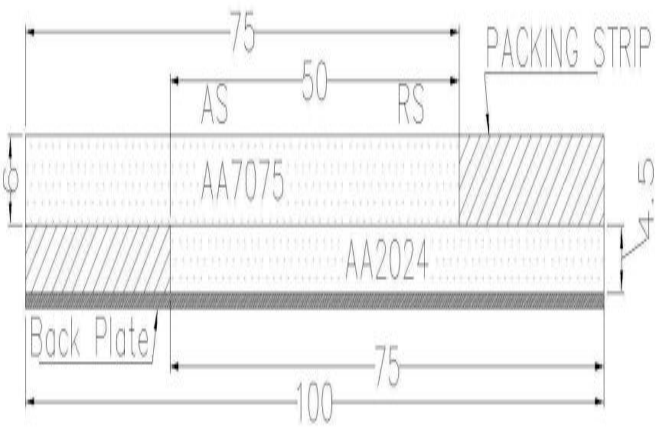


Table 2 Orthogonal array with Ultimate Shear Tensile Load (USTL) and S/N ratio

	TRS(RPM)	TS(mm/min)	Tilt angle	shear tensile strength (N)	S/N Ratio
L1	765	31.5	2	3735	71.43
L2	765	50	3	11553	81.12
L3	765	20	4	2940	68.65
L4	1070	31.5	3	4026	71.95
L5	1070	50	4	7787	77.74
L6	1070	20	2	2279	66.98
L7	1500	31.5	4	5462	74.65
L8	1500	50	2	6705	75.89
L9	1500	20	3	4401	72.87

IV. RESULT AND DISCUSSION

1. Shear tensile load:

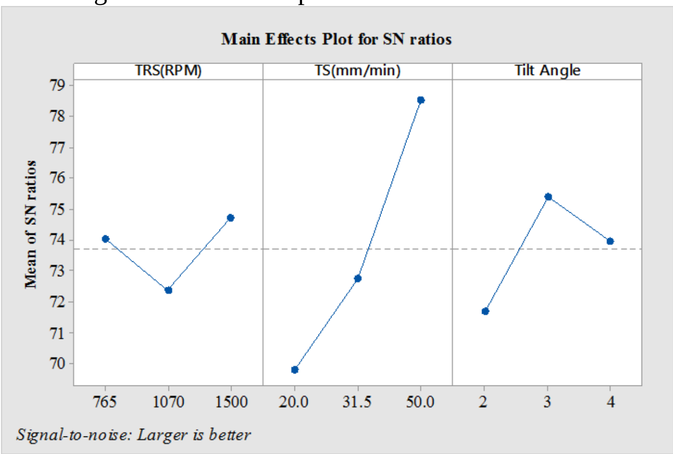
shear tensile strength or ultimate shear tensile strength is the maximum stress that a material can withstand while being stretched or pulled before failing or breaking. The value of the test specimen does not depend on thesize of the work piece but it spends on factors like surface finish, the temperature of the test environmentetc. Tensile testing of material was carried out at ASTM D3164M.Thus we need larger shear tensile strength to make the material withstand while stretched or pulled. Thus we use Larger the better to calculate S/N ratio. Table 3 shows the ANOVA table for shear tensile strength. Shear tensile specimens were subjected to shear tensile load up to failure.

Table 3 Analysis of variance (ANOVA) table for USTL

Source	DOF	SS	MS	F-Value	P-Value	% Contribution
TRS (RPM)	1	272648	272648	0.08	0.784	0.41
TS (mm/min)	1	48101924	48101924	14.73	0.012	72.11
Tilt angle	1	2006817	2006817	0.61	0.469	3.01
Error	5	16323785	3264757			24.47
Total	8	66705174				100.00

From the table 3 we can clearly see that the combine contribution of tool rotation speed and tool tilt angle with compared to welding speed is much lesser than the contribution of welding speed. Traverse speed has a major contribution of 72.11%. The optimum machining parameter can be found by response table which is shown in table 6.

Figure 2 Main effect plot of S/N ratio for USTL



V. CONCLUSION

In this study, the Taguchi method was used to obtain optimal condition for Friction Stir Welding Of AA7075-2024 aluminium alloy. Experimental results were evaluated using ANOVA. The results can be drawn as follows:

- Maximum shear tensile load strength of 11553 N was exhibited by the FSW lap joints fabricated with the optimized
- Parameters of 765 r/min rotational speed, 50mm/min welding speed, 3 tilt angles, shoulder diameter of 20mm, pin diameter of 6mm.
- Tool traverse speed was the major factor affecting the ultimate shear tensile strength.
- Tool rotational speed of 765 rpm welding speed of 50 mm/min and 3 degree tilt angle is the optimum machining condition to get a good shear tensile strength.
- Tool rotational speed has the lowest negligible influence on shear Tensile strength

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