Development of Alloys on FSP for Industrial Applications

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Abstract— **FSP complex process that involves many numbers of input process parameters to be controlled to get the best quality weld joints. Selecting the appropriate and optimal combination of input process parameters is the key to the success in the process. However it is very difficult to identify and set the right combination manually by the process engineer either by using trial and error method or from the past references. Hence there is a need to develop a methodology that helps the manufacturing engineer or process engineer for proper setting of the input process parameter. This research mainly was carried out to develop the method which helps to run the process in an efficient manner and also the process can be automated.**

Keywords-Metals; Alloys; Paradigm; Environment Friendlyness; Parameters; Automation;

I. INTRODUCTION

The joining of 2024 aluminum alloy with novel method for the keyhole of welds on friction stir spot welding of protrusion of anvil height [1] of tool rotational speed with variables are affected and increasing of nugget zone and joint length rotational speed 1600 rpm and protrusion height 0.4 mm and fine grains average size of 5 µm at nugget zone with high plastic deformation and dynamic recrystallization.[2] The process parameters of rotational speed, welding speed, penetration shoulder, pin profile, profile shoulder is optimized and maximize tensile strength with rotational speed 1100 rpm and hexagonal pin profile welding speed 3.2 mm/s 0.15 mm shoulder penetration good and shoulder taper 10º and metallographic investigated of weld nugget zone fine stirred with magnesium silicide particles.[3] Mainly focuses on applications different parameters of tool rotational speed, weld speed, tilt angle and tool geometry with plunge speed on joining of softer structural alloys and aluminum alloys emerging technologies of lesser emphasis of different materials plasticization and generation of heat and quality of product on metals of lightweight fabrication. Studied of dissimilar joining of titanium or aluminum with concave end face tool and head enlarged are [4] designed to width of lap at flow of material and load of tensile is 12.2 KN with 85.3 % on aluminum alloy of heat affected zone effect due to ductile fracture with aluminum base metal. Investigated of brass plates 6 mm thickness of process parameters rotational speed 450 and 710 rpm. The rotational speed has higher and cracks taken place with a [5] smooth weld zone of free defect and size of grain at parent metal stirring zone are thermo mechanical effect zone and heat affect zone taken place in microstructural analysis and weld zone has higher hardness with recrystallized fine zones. Studied AZ31B Mg and AA6061 has advantages in [6] fuel consumption and transportation sectors, weight, and emission reduction. The stir zone has poor corrosion resistance and analyzed surfaces and microstructural techniques. The aluminum alloys and magnesium surfaces of PH are equal to 7 of $Mg(OH)_2$ alloy on corroding with an increase of concentration chloride enhances of corrosion decreases with the increase of exposure time.[7] Studied simulations numerical on the reduction of time by using thermal analysis on rotational speed 2000 rpm and weld speed is 10 mm/min with a tensile test of joints weld on stress fracture validation is done. The joining of AA6061T4alloy and AZ31B increase in process temperature is 145º C of TMAZ and nugget zone of weld boundary decreased by [8] ultrasonic vibrations and tensile strength is improved low rotational speed but less noticeable higher rotational speeds. The welding of two similar polymer composites at configuration compares with two dissimilar thermoplastic materials that have similar viscosity [9] good chances. The input parameters of tool pin, tool shoulder, rotational speed, welding speed, tilt angle with a plunge have optimum heat generation of material flow time and resource energy have a minimum loss. Studied of FSW of Incoloy 800H on tensile strength, burn of length, micro-hardness, optimizing by using artificial neural network and algorithms for good predicted of parameters[10] with friction stir welding. Joining of A7N01-T4 alloy of methods on different joints shows free defect and comparisons of mechanical properties and microstructure on stir zone of grains.

II. EXPERIMENTAL WORK

The experiments were carried out Dissimilar Alloys with artificially aged due to stretching of stress relieved and heat treated solution aluminum alloys having 6mm thickness of each on a computer numerically controlled Friction Stir Welding it's a special purpose machine done with three different tools used after studies of literature survey as depth on investigations used tools are square tool, taper threaded tool, straight cylindrical threaded tool using M2 grade super high-speed steel tool of shoulder dia 18 mm and probe length 6 mm.. The plates are finished with a dimension of 100 mm × 50 mm×6 mm plates on individually flattering the surfaces of effect for adjusting a mechanism of two pairing edges. The specimens are prepared for the tests on the basis of American society of testing materials standards.

III. RESULTS AND DISCUSSIONS

The experimental planning of input process parameters rotational speed (rpm), welding speed (mm/min), tilt angle (degree), axial force (KN) and output parameters are tensile strength (Mpa), Impact strength (J), Elongation (%) with three different tools of the square tool, taper threaded tool, straight cylindrical threaded tool of coded values of input process parameters and Taguchi design models. The grey Taguchi analysis of friction stir welding by using taper threaded tool model design for input and output responses, S/N ratios and Means, Different Responses on Average values of Responses and Signal-to-noise-ratios, Sequences of responses after data processing and deviation of sequence.

IV. OPTIMUM LEVEL OF FACTORS FOR TAPER THREADED TOOLS

The average grey relation grade for each level of the factor in the case of the Taper threaded tool was computed. The Higher grey relation grade implies better quality characteristics. Based on the higher grey relation grade optimum level of each controllable factor was determined. The average grey relation grade and the optimum levels of factors were listed in Table 1. shown below. The optimum levels of factor base on grey relation grade were found A1-B2-C1-D2.

TABLE 1. Optimal Level of Factors for Taper Threaded Tool

Input Variables	**Level 1**	**Level 2**	**Level 3**
Rotational Speed	0.2742	0.173	0.167
Welding Speed	0.1389	0.2415	0.1359
Tilt Angle	0.2062	0.1846	0.2054
Axial Force	0.168	0.2177	0.1099

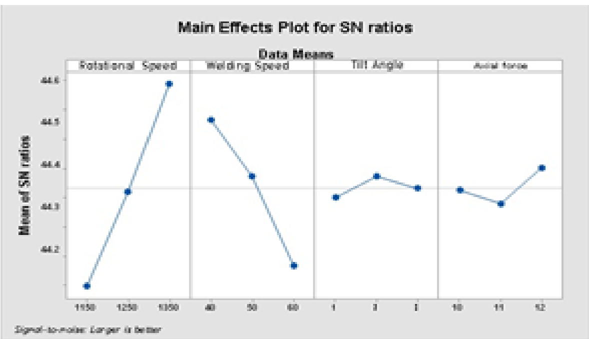

Figure 1. Effect of tensile strength for Signal-to-Noise Ratio of taper threaded tool.

The Effect of tensile strength for Signal-to-Noise Ratio of taper threaded tool is shown in Figure 1. It is clear that a larger Signal to Noise ratio corresponds to better quality characteristics. Therefore, the highest Signal to Noise ratio corresponds to the optimum setting of the process parameters. Signal to Noise ratio for tensile strength was calculated by statistical software indicating that the tensile strength was at a maximum at level 3,3,3, i.e. Rotational speed at 1350 rpm, welding speed at 40 mm/min, tilt angle 3^0 and axial force at 11kN. The comparison of mean effect and S/N ratio are presented. The Response tables for S/N ratios of tensile strength for taper threaded tool, the mean response corresponds to the average value of quality characteristics for every parameter at different levels is given below Table 2.

TABLE 2. Response Table of S/N Ratios of Tensile Strength for Taper Threaded Tool

Level	**Rotational Speed**	**Welding Speed**	**Tilt Angle**	**Axial Force**
1	43.90	44.47	44.20	44.22
2	44.22	44.27	44.27	44.18
3	44.59	43.97	44.23	44.30
Delta	0.69	0.50	0.07	0.12
Rank	1	2	4	3

Figure 2. Effect of tensile strength for means of taper threaded tool

The effect of tensile strength for means of taper threaded tool is shown in Figure 2. The analysis of mean for each of the experiments will give the better combination of parameters levels rotational speed 1250rpm, welding speed 50 mm/min, tilt angle 2^0, axial force 11 KN that ensures a high level of response according to the experimental set of data. The Response table for means of tensile strength for the taper threaded tool, the mean response of raw data of tensile strength for each parameter at each level were calculated and are given in below Table 3. The mean response corresponds to the average valueof quality characteristics for every parameter at different levels.

TABLE 3. Response Table of Means of Tensile Strength for Taper Threaded Tool

Level	Rotational Speed	Welding Speed	Tilt Angle	Axial Force
1	18.79	20.56	19.65	19.80
2	19.63	20.18	20.01	19.60
3	20.99	18.67	19.75	20.01
Delta	2.21	1.89	0.36	0.42
Rank	1	2	4	3

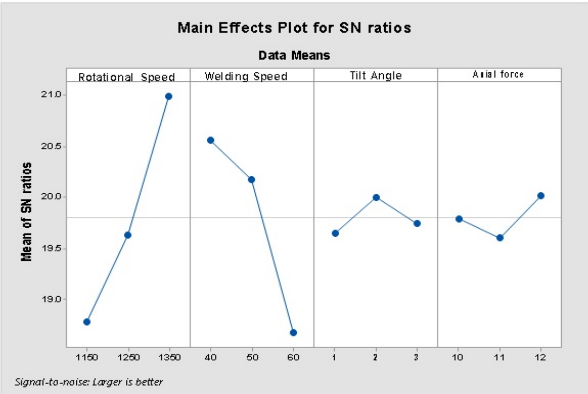

Figure 3. Effect of impact strength for a signal-to-noise ratio of taper threaded tool

The effect of impact strength for a signal-to-noise ratio of the taper threaded tool is shown in Figure 3. The process parameters of each level for the calculation of GRG average value is considered rotational speed RS 1350 rpm, welding speed WS 40 mm/min and tilt angle TA 2^0, axial force 12 KN are better characteristics performance of S/N ratios and mean. The influence of rotational speed, the impact strength is almost the same for all the specimens and it is low for the joint prepared by taper threaded tool. The Response table for S/N ratios of impact strength for taper threaded, the mean response of raw data and Signal to Noise ratio of impact strength for each parameter at each level were calculated and are given in below Table 4.

TABLE 4. Response Table of S/N Ratios of Impact Strength for Taper Threaded Tool

Level	Rotational Speed	Welding Speed	Tilt Angle	Axial Force
1	156.7	167.3	162.3	162.7
2	162.7	163.7	163.7	162.0
3	169.7	158.0	163.0	164.3
Delta	13.0	9.3	1.3	2.3
Rank	1	2	4	3

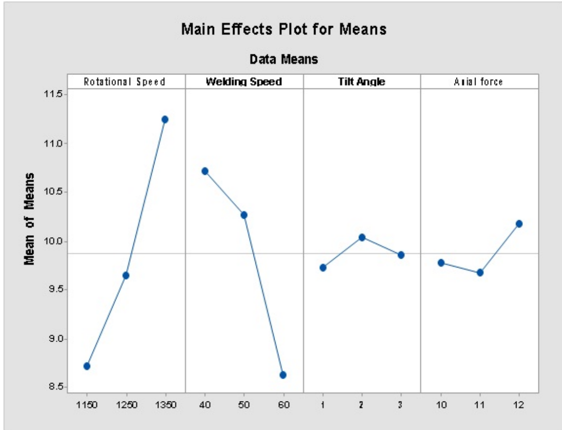

Figure 4. Effect of impact strength for means of taper threaded tool

The Effect of impact strength for means of taper threaded tool is shown in Figure 4. The analysis of mean for each of the experiments will give a better combination of parameter levels that ensures a high level of response according to the experimental set of data. The mean response corresponds to the average value of quality characteristics for every parameter at different levels. The Response table for means of impact strength for taper threaded tool tables is shown below Table 5. The mean response of raw data impact strength for each parameter at each level was calculated maximum rotational speed 1350 rpm, welding speed 40 mm/min, tilt angle 2^0, axial force 12 KN.

TABLE 5 Response Table of Means of Impact Strength for Taper Threaded Tool

Level	Rotational Speed	WeldingSpeed	Tilt Angle	Axial Force
1	8.723	10.720	9.727	9.773
2	9.657	10.267	10.040	9.673
3	11.243	8.637	9.857	10.177
Delta	2.520	2.083	0.313	0.503
Rank	1	2	4	3

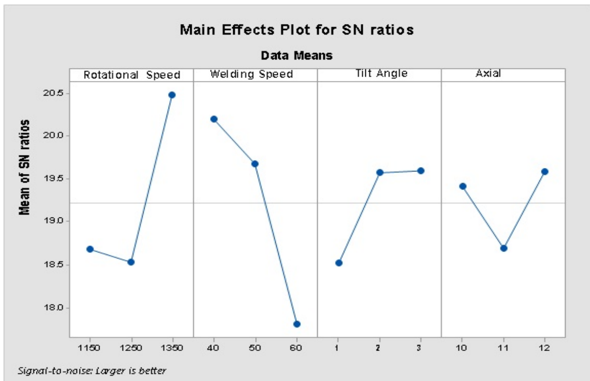

Figure 5. Effect of elongation for a signal-to-noise ratio of taper threaded tool

The Effect of elongation for a signal-to-noise ratio of taper threaded tool is shown in Figure 6 . The process parameters of each level for the calculation of GRG average value is considered rotational speed RS 1350 rpm, welding speed WS 60 mm/min and tilt angle TA 3^0, axial force 11 KN are better characteristics performance of S/N ratiosand mean. The Response table for S/N ratios of elongation for taper threaded tool Table 6. is shown below.

TABLE 6. Response Table of S/N Ratios of Elongation for Taper Threaded Tool

Level	Rotational Speed	Welding Speed	Tilt Angle	Axial Force
1	8.600	10.280	8.640	9.347
2	8.640	9.667	9.533	8.877
3	10.597	7.890	9.663	9.613
Delta	1.997	2.390	1.023	0.737
Rank	2	1	3	4

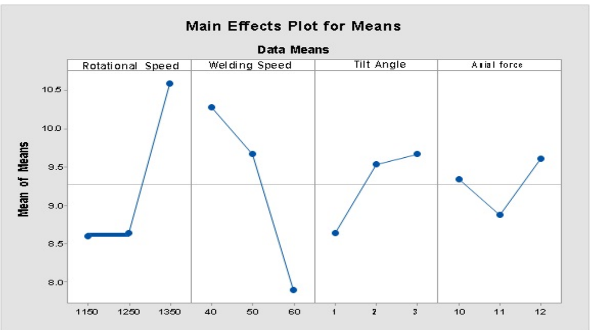

Figure 6. Effect of elongation for means of taper threaded tool

The effect of elongation for means of taper threaded tool is shown in Figure 6. The analysis of mean for each of the experiments will give a better combination of parameter levels that ensures a high level of response according to the experimental set of data. The mean response corresponds to the average value of quality characteristics for every parameter at different levels. The mean response of raw data and Signal to Noise ratio of elongation for each parameter at each level were calculated rotational speed 1350 rpm, welding speed 60 mm/min, tilt angle 3^0, axial force 11 KN. The Response table for means of elongation for taper threaded tool Table 7. is shown below.

TABLE 7. Response Table of Means of Elongation for Taper Threaded Tool

Level	Rotational Speed	WeldingSpeed	Tilt Angle	Axial Force
1	18.68	20.20	18.52	19.41
2	18.53	19.68	19.57	18.69
3	20.48	17.81	19.60	19.58
Delta	1.94	2.39	1.08	0.90
Rank	2	1	3	4

V. Conclusion

This paper concludes Based on the pilot experiments and literature survey, the most significant variables (Rotational speed, Welding speed, Tilt angle, and Axial force) were found and used them as input process parameters. Taguchi L9 Orthogonal Array was used to carry out the experiments. Because three different tool profiles i.e. Taper threaded tools used for research. Application of Taguchi Design of Experiments helped us in conducting the experiments in an effective manner without losing accuracy. Two-dimensional plots are plotted between the input process parameter and the output responses using Design-Expert software. It was observed that the tensile strength is increasing with the increase in rotational speed and the axial force values and the tensile strength is decreasing with the increase in the weld speeds. The Impact strength increases, when there is an increase in the values of Rotational Speed and the Axial force. Whereas the impact strength tends to decrease with the increase in the weld speeds. The elongation also increases with the increase in rotational speed and axial force. The models can be further used for optimizing the process.

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