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Optimization of Process Parameters of Friction Stirs Processing on Aluminium Alloy 7075

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Abstract: Friction Stir Processing (FSP) is a relatively new entrant in the domain of solid state processing technique mainly applied in the manufacturing of hybrid metal matrix composites. Aluminum and its corresponding alloys have got the excellent combination of properties like high strength to weight ratio, good corrosion resistance, high thermal and electrical conductivity, high reflectivity, low emissivity making it as a ideal choice for the aerospace and automotive industries. Some application in these industries requires high hardness and high strength to weight ratio. Friction Stir Processing realizes achieving this by introduction of reinforcing particles onto the surface of the metal matrix by the rubbing action of the tool. The process is mainly influenced by the process parameters like tool rotational speed, Traverse speed (feed), Geometry of the tool, Tool material, diameter of the hole, spacing of the hole, tool tilt angle, plunge depth etc .In this work, attempts will be conducted to identify the optimum process parametric conditions for Friction Sir Processing by using Taguchi Design of experiments technique to enhance surface properties of Aluminum alloys.

1. INTRODUCTION

Vipin Gopan et al. [1] investigated the effect of various process parameters on Friction Stir Processing of Aluminum alloys. The process parameters selected for this study are speed (rpm), feed (mm/min) and depth of cut (mm). Three levels of speed, feed and depth of cut were selected and experiments were designed on the basis of Taguchi Orthogonal array. NareshNadammal et al. [2] studied the microstructure and texture development during single and multiple pass friction stir processing (FSP) of a strain hard enable wrought Al-Mg alloy (AA5086) was investigated.. S.Chainarong et al. [3]attempted to improve the mechanical properties of SSM 356 aluminum alloys by friction stir processing, a solid-state technique for micro structural modification using the heat from a friction and stirring. The parameters of friction stir processing for SSM 356 aluminum alloys were studied at three different travelling speeds: 80, 120 and 160 mm/min under three different rotation speeds 1320, 1480 and 1750 rpm. The hardness and tensile strength properties were increased by friction stir processing. Vaira Vigneshand Padmanaban [4]applied friction stir processing on AA5083, with an objective to improve its wear resistance. FSP was conducted by varying tool rotation speed, tool traverse speed and tool shoulder diameter as per face centered central composite design. WenjingYanget al. [5] proposed a novel approach named double-sided friction stir processing (DFSP) was proposed to prepare 7050-T7451 aluminum alloy plates, and effects of solution treatment (ST) on microstructures and mechanical properties of DFSP were investigated.

2. EXPERIMENTATION:

Fig.1: FSP

The vertical milling machine model of HMT FM-2V is used during the work process of friction stir processing. The capacity of machine is 10 HP. The range of the speed is 35 RPM minimum and 1800 RPM maximum. The feed capacity is minimum 16mm/min and maximum 800 mm/min and the bed size of 800 mm in "X" direction, 400 mm in "Y" direction and 400 mm in "Z" direction. 6mm thick AA7075-O plates has been cut according to required dimensions as 150mmx100mm with power hacksaw. Tapered cylindrical tool of H13 hardened tool steel with shoulder diameter as 18mm and pin diameter as 6mm at the base and 3mm at the tip has been selected to perform the processing operation. Slots have been made on the AA 7075-O plates with milling machine as per the requirement, three slots have been created on each plate of AA 7075 material and the Silicon Carbide powder with grain size as 150nm has been filled in the slots created. The process parameters such as Tool rotational speed (rpm), Feed (mm/min), Width of slot (mm),Depth of slot (mm)that are considered as per the following table 1. The experiments have been carried out according to L_9 3^4 Orthogonal Array as per the following table 3.

Chemical Composition Of Tool:

Table.1: Chemical composition of H13 Tool Steel

Element	C	Mn	Cr	Mo	V	Si	Fe
Weight (%)	0.40	0.35	5.20	1.30	0.95	1.0	90.8

The process parameters that are considered for the present research work are:

Table.2: Factors and Levels considered of parameters

Levels	Tool rotational speed (rpm)	Feed (mm/min)	Width (mm)	Depth (mm)
1	710	16	1	2
2	900	20	1.5	3
3	1120	25	2	4

The levels of these factors can be depicted in the form of a table as follows:

Table.3: L_9 3^4 Orthogonal Array

	Process Parameters			
Experiment #	Tool Rotational Speed (rpm)	Feed (mm/min)	Width (mm)	Depth (mm)
1	710	16	1	2
2	710	20	1.5	3
3	710	25	2	4
4	900	16	1.5	4
5	900	20	2	2
6	900	25	1	3
7	1120	16	2	3
8	1120	20	1	4
9	1120	25	1.5	2

The surface of the processed plates after the first pass of processing yielded some surface defects like cracking, rough surface and improper mixing of the reinforce material with the Aluminum matrix as shown in figure 2 . Hence a second pass of Friction Stir Processing has been performed with the same set of parameters that are used for the first pass and yielded defect free processed region as shown in figure 3. The quality of the processed regions is evaluated by conducting tests like Tensile test and Rockwell hardness test.

Fig.2: Process of FSP

Fig.3: FS Processed plates with single pass

3. RESULTS AND DISCUSSION:

a) Tensile test: Tensile test has been performed on the FS processed plates to determine yield strength, ultimate tensile strength, % elongation of the weldment. One tensile specimen from each of the processed region has been cut with wire cut EDM according to ASTM E8/E8-M-16a standard

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Fig.4: Tensile specimens of FSP Plates

Results of Tensile Test

Tensile tests have been performed on the FSP plates with Nano UTM. The results of the tensile test are tabulated as follows:

Table 4. Results of Tensile test

Experiment No.	Ultimate Tensile Strength (MPa)	Peak Load (kN)	% Elongation
1	326.14	11.741	11.192
2	294.866	10.615	7.376
3	241.207	8.638	4.616
4	342.028	12.313	9.226
5	299.124	10.768	15.514
6	170.093	6.123	10.340
7	176.078	6.339	8.633
8	235.05	8.462	9.338
9	235.23	8.468	9.385
Base Material	280	9.025	11.940

A graph has been plotted by taking experiment number on the X-Axis and the Ultimate tensile strength on the Y-axis to determine the impact of process parameters on the processed region and it can be depicted as shown figure 5

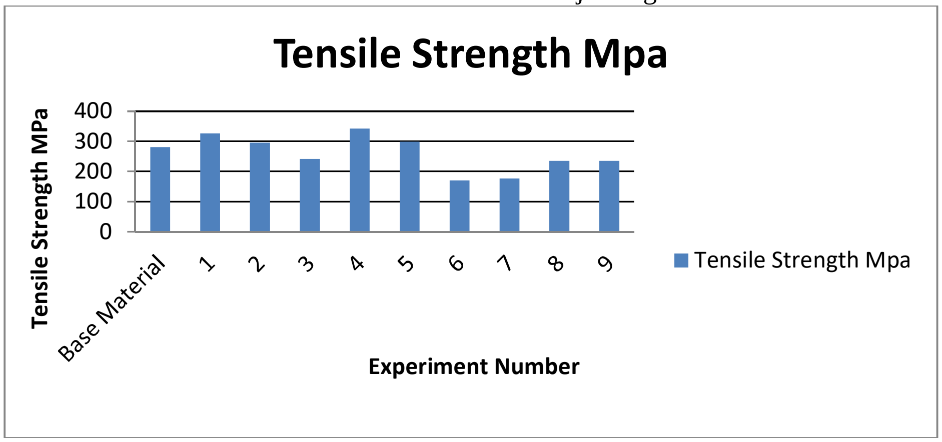

Figure 5: Comparison of Tensile strength

The region processed by tool rotational speed as 910rpm, feed as 16mm/min, width as 1.5mm, depth of slot as 4mm yielded better results when compared with its counterparts and is about 62.5% of the base material ultimate tensile strength. This might be due to proper heat generation in the processed zone and proper plasticizing the base material resulting in the effective mixing of the reinforcement material with the matrix material.

Results Of Hardness Test

Rockwell B scale hardness test has been performed on the cross section of the processed region to determine the impact of the process parameters and the abrasive material used in the research work in determining hardness of the Aluminium matrix.

Table 5 Results of Hardness test

Experiment No.	Distance from Centre of Processed zone (mm)				
	-10	-05	00	05	10
1	72	98	91	70	66.5
2	76	70	65	60	74
3	75	52	80	56	65.5
4	55	62	92	74	70
5	24	61	56	56	61
6	54	28	75	75	76
7	55	31	63	8	71
8	62	62	85	61.5	77
9	76.5	30	71	76	63

A graph has been plotted by considering distance from the weld centre on the X-Axis and Rockwell hardness value on the Y-Axis to investigate the impact of process parameters and abrasive material in altering the hardness of aluminium matrix.

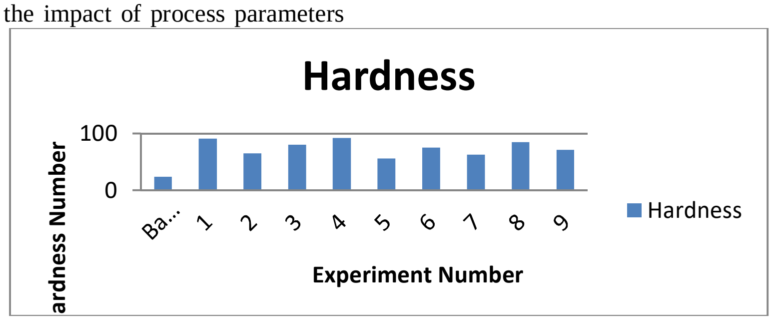

Fig.6: Comparison of Hardness

From the Figure 6 it can be seen that, for most of the processed zones there is great increase in the hardness value in the processed regions and is eventually high for the joint processed by tool rotational speed as 910rpm, feed as 16mm/min, width as 1.5mm, depth of slot as 4mm yielded better results when compared with its counterparts and is about 62.5% of the base material ultimate tensile strength. This might be due to proper heat generation in the processed zone and proper Plasticizing the base material resulting in the effective mixing of the reinforcement material with the matrix material.

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Optimal combination of factor levels for Tensile strength:

Table 6. Optimal combination of factor levels for tensile strength

Parameters	Optimal levels	Optimal value
Speed	1	710
Feed	2	20
Width of groove	2	1.5
Depth of groove	1	2

Regression Equation of Tensile Strength:

TENSILE STRENGTH = 1559 - 1.492 SPEED - 96.0 FEED + 623 WIDTH OF GROOVE + 15.5 DEPTH OF GROOVE + 0.0995 (N X F) - 0.488 (N X W) - 4.83 (F X W)

Main Effect Plots for Tensile Strength

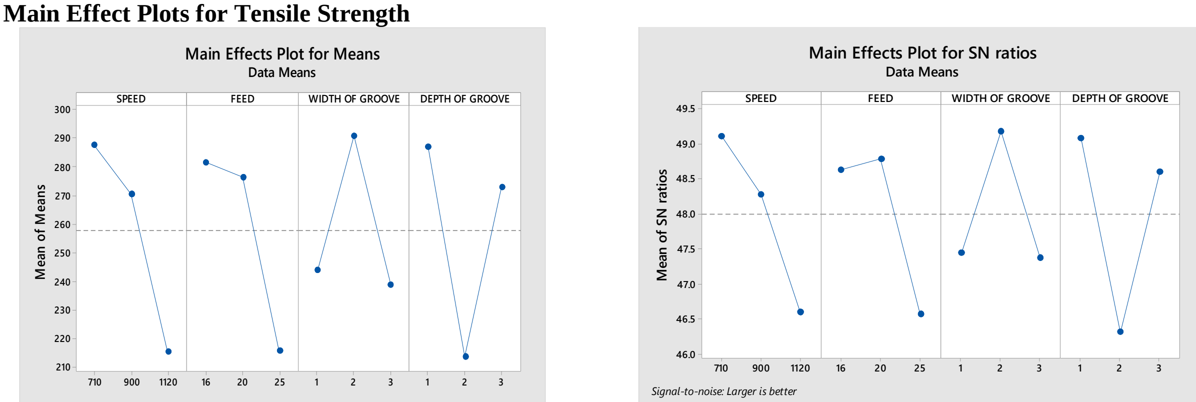

Fig.7: Main effect plots for Tensile strength

The above graph indicates that which level of process parameter is mostly affected on the tensile strength of fsp plates. According to above graph fist level of rotational speed is best to get optimum tensile strength i.e 710 RPM.

Interaction Plots for Tensile Strength:

Second level of feed is best is best to get optimum tensile strength i.e 20mm/min. Third level of width of groove is best to get optimum tensile strength i.e 2mm.

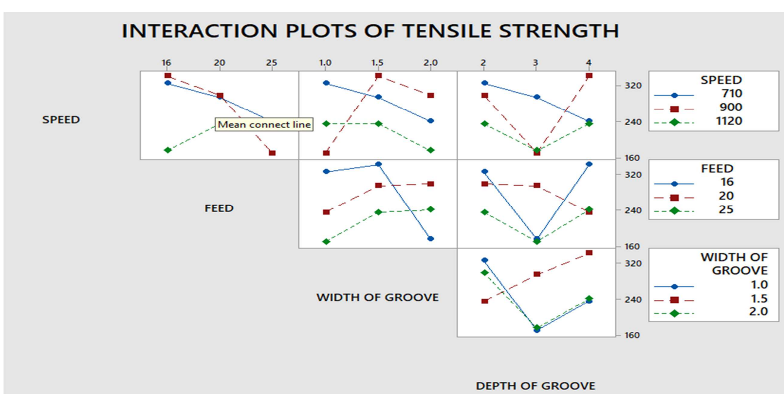

Fig.8: Interaction plots for Tensile strength

Figure 8 explains the interaction of process parameters. It means that, all the parameters which were considered for friction stir processing are affecting the tensile strength. The above graph indicating that the tensile strength of FSP plates is depended on all the process parameters

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Taguchi Analysis of Hardness Test:

Table 7: Optimal combination of factor levels for hardness

Parameters	Optimal levels	Optimal value
Speed	1	710
Feed	1	16
Width of groove	2	1.5
Depth of groove	3	4

Main effects plot for Hardness

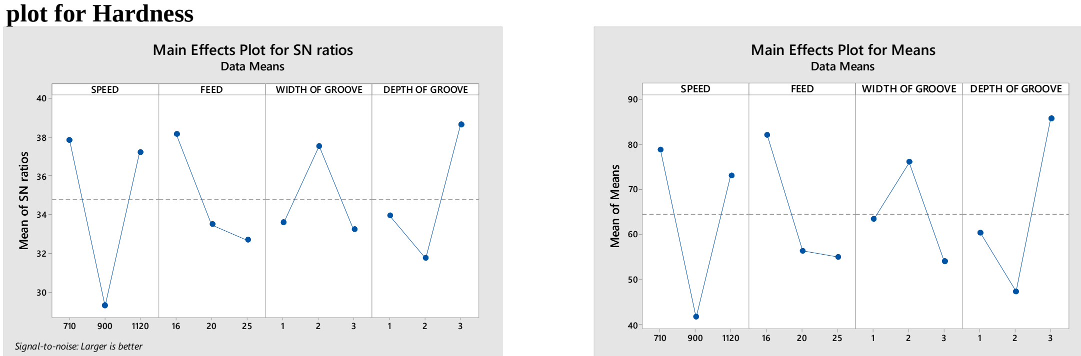

Figure 9: Main effect plots for Hardness

The above graph indicates that which level of process parameter is mostly affected on the hardness strength of fsp plates. According to above graph fist level of rotational speed is best to get optimum hardness i.e 710 RPM. Second level of feed is best is best to get optimum hardness i.e 16mm/min. Third level of width of groove is best to get optimum hardness i.e 2mm.

Regression Equation

HARDNESS = 1243 - 0.854 SPEED - 46.3 FEED - 643 WIDTH OF GROOVE + 37.7 DEPTH OF GROOVE + 0.0222 (N X F) + 0.322 (N X W) + 17.71 (F X W)

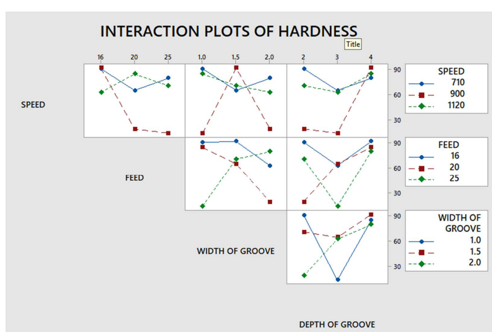

Figure 10: Interaction plots for Hardness

Figure 10 explains the interaction of process parameters. It means that, all the parameters which were considered for friction stir processing are affecting the Hardness strength. The above graph indicating that the tensile strength of FSP plates is depended on all the process parameters.

4. CONCLUSIONS:

1.The results of the tensile tests revealed that the joint fabricated with by tool rotational speed as 900rpm, feed as 16mm/min, width as 1.5mm, depth of slot as 4mm yielded better results when compared with its counterparts and is about 62.5% of the base material ultimate tensile strength. This might be due to proper heat generation in the processed zone and proper Plasticizing the base material resulting in the effective mixing of the reinforcement material with the matrix material.

The results of Rockwell B-Scale hardness test revealed that the joint processed with by tool rotational speed as 900rpm, feed as 16mm/min, width as 1.5mm, depth of slot as 4mm yielded better results when compared with its counterparts

This might be due to proper heat generation in the processed zone and proper plasticizing the base material resulting in the effective mixing of the reinforcement material with the matrix material.

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