Joining Efficiency and Optimization of Nylon 6 Plate by Friction Stir Welding Process Using Threaded Pin Profile

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ABSTRACT

The use of polymeric materials has grown widely in various sectors such as packaging, building, electronic, automotive, and aerospace industries. Particularly, Nylon 6 has wide engineering applications and is used in large quantities in automotive oil pans, gears, slides, cams, bearings, fluid reservoirs, and the sports industry. Friction Stir Welding (FSW) is a solid-state process in joining thermoplastic materials. In this investigation, FSW process has to be applied to join a Nylon 6 plate of 8mm thickness with specially designed threaded tool pin profile. The research will be applied Taguchi Method on nylon-6 specimen of dimensions 100 × 100 × 8 mm, which have following parameters: various RPM, Feed and Axial Load. The experiments will be done in following aspects: Ultimate tensile strength and other mechanical properties. The main objective of the experimental of factors affecting to mechanical property of nylon-6 with FSW at different welding parameters and it has to be followed by L4 arrays. In this research work threaded tool profile was used. Highest tensile strength obtained with maximum speed and tool traverse with low axial force parameter. 1200 rpm, 20 mm/min and 8KN of axial force has the highest tensile strength which is 9.59 N/mm2. During the investigation found hardness strength low value obtained with parameter 1200 rpm, 15 mm/min and 10KN of axial force has the lowest Hardness strength which is 27 HRL. No Angle distortion found at second and third test plate.

Keyword: - *FSW, NYlON-6, Mechanical properties.*

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1. INTRODUCTION

Friction Stir Welding (FSW) is considered to be the most significant development in metal joining in a decade and is a "green" technology due to its energy efficiency, environment friendliness and versatility (Mishra and Ma, 2005). As compared to the conventional welding methods, FSW consumes considerably less energy. No cover gas or flux is used, thereby making the process environmentally friendly. The joining, does not involve any use of filler metal and therefore any aluminum alloy can be joined without concern for the compatibility of composition, which is an issue in fusion welding. When desirable, dissimilar aluminum alloys and composites can be joined with equal ease.

In contrast to the traditional friction welding, which is usually performed on small ax symmetric parts that can be rotated and pushed against each other to form a joint, FSW can be applied to various types of joints like butt joints, lap joints, T butt joints and fillet joints.

2. EXPERIMENTAL DETAILS

Friction stir welding operation is done using the KODI-40 vertical milling machine shown in Fig 4. The quality of the welded joint is ascertained by visual inspection of weld bead and defect free joints along the weld region.

Fig -1: Vertical Milling Machine

Nylon-6 known for its light weight, superior strength and corrosion resistance is used for experimentation. In this study, the effect of the presence of various parameters with threaded profile tool welded with friction stir processing Nylon-6 plates is documented. Friction stir welded Nylon-6 plates have to be evaluated by using through macro test. The tests were conducted as per the statistical procedure and the results were correlated of the tested weld samples with threaded tool.

2.1 TAGUCHI METHOD

Basically, experimental design methods were developed original fisher. However experimental design methods are too complex and not easy to use. Furthermore, a large number of experiments have to be carried out when the number of the process parameters increases, to solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. The experimental results are then transformed into a signal– to – noise (S/N) ratio to measure the quality characteristics deviating from the desired values Usually, there are three categories of quality characteristics in the analysis of the S/N ratio, i.e., the–lower–better, the–higher–better, and the–nominal–better.

Table -1: LEVELS AND RANGES OF FSW PROCESS PARAMETERS TAGUCHI METHOD L4 FACTOR

S.NO	**SPEED RPM**	**TOOL-TR Mm/min**	**AXFC KN**
1	1100	15	8
2	1200	20	10

Table -2: AN ORTHOGONAL ARRAY L_4 FORMATION

SL.NO	**SPEED RPM**	**TOOL-TR Mm/min**	**AXFC KN**
1	1100	15	8
2	1100	20	10
3	1200	15	10
4	1200	20	8

2.2 Weld Appearance

The FSW weld appearance of polymer NYLON-6 welded with square pin tool shown in Fig 5. The each sample shows a closer view of the weld photography. All of the plates that show on that figures are defect-free samples. Particularly sample 3 has good weld appearance.

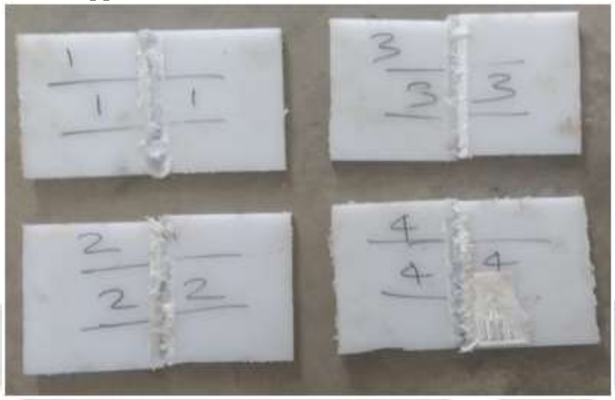

Fig -2: Weld Appearance of FSW

3. RESULT

Table -3: TENSILE STRENGTH VALUE

TEST PLATES	THICK mm	WIDTH mm	CSA mm^2	TL KN	TS N/mm^2	IGL mm	FGL mm	%E
T_1	8.04	19.87	159.75	1.29	8.07	50.00	50.12	0.24
T_2	8.06	20.06	161.68	1.49	9.22	50.00	50.17	0.34
T_3	8.14	19.95	162.39	1.37	8.44	50.00	50.29	0.58
T_4	7.98	19.87	158.56	1.52	9.59	50.00	50.09	0.18

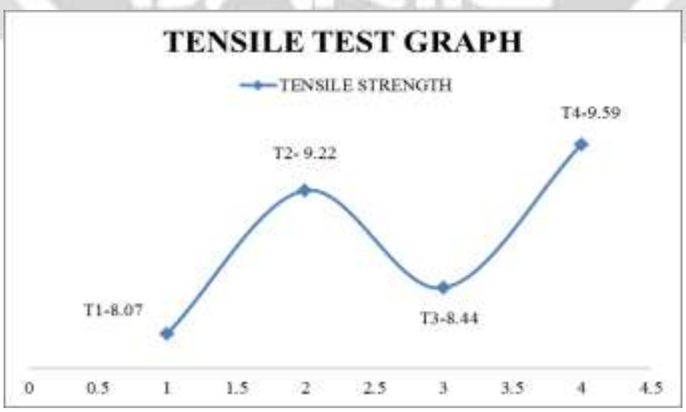

Fig -3: Tensile Strength Graph

Table 3 illustrates the tensile test data in table. The graph shows the sample number 4 for using threaded shape with parameter 1200 rpm, 20 mm/min and 8KN of axial force has the highest tensile strength which is 9.59 N/mm2. The sample number 2 has the second height tensile strength of 9.22 N/mm2.

Table -4: S-N RATIO TABLE FOR TENSILE STRENGTH

SL.NO	SPEED RPM	TOOL-TR Mm/min	AXFC KN	TENSILE LOAD	TENSILE STRENGTH N/mm^2	SNRA1
T_1	1100	15	8	1.29	8.07	18.1375
T_2	1100	20	10	1.49	9.22	19.2946
T_3	1200	15	10	1.37	8.44	18.5268
T_4	1200	20	8	1.52	9.59	19.6364

Table -5: RESPONSE TABLE FOR SIGNAL TO NOISE RATIOS- LARGER IS BETTER

LEVEL	SPEED RPM	TOOL-TR Mm/min	AXFC KN
1	18.72	18.33	18.89
2	19.08	19.47	18.91
Delta	0.37	1.13	0.02
Rank	2	1	3

Table -6: ANALYSIS OF VARIANCE TENSILE

SOURCE	DF	SEQ SS	ADJ MS	F	P	% OF CONTRIBUTION
SPEED	1	0.13690	0.13690	-	-	10
TOOL TRAVERSE	1	1.32250	1.32250	-	-	90
AX FC	1	0.00000	0.00000	-	-	0
Error	0	-	-	-		0
Total	3	1.45940				100

Regression Equation

```
        TS = 8.830 - 0.1850 SPEED_1100 + 0.1850 SPEED_1200 - 0.5750 TOOL_15
   + 0.5750 TOOL_20 + 0.000000 AXFC_8 - 0.000000 AXFC_10
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Table -7: HARDNESS STRENGTH VALUE-HRL

SAMPLES	**T_1**	**T_2**	**T_3**	**T_4**
NYLON-6	35	27	47	45

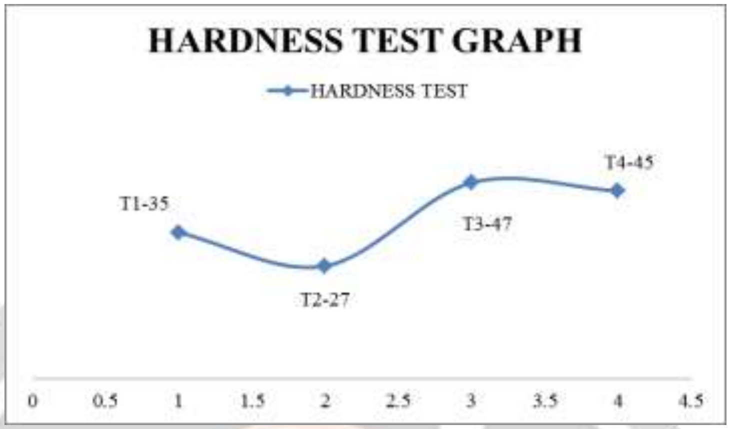


Fig -4: Hardness Test Graph

Table 7 Illustrates the Hardness strength test data in table. The value shows minimum hardness value in second test plate with the RPM 1100 rpm, Tool Traverse 20 mm/min and Axial force 10KN of axial force has the lowest Hardness strength which is 27 HRL. The first test plate has the second lowest Hardness strength of 35 HRL.

Table -8: S-N RATIO TABLE FOR TENSILE STRENGTH

SL.NO	**SPEED RPM**	**TOOL-TR Mm/min**	**AXFC KN**	**HARDNESS HRL**	**SNRA1**
T_1	1100	15	8	35	-30.8814
T_2	1100	20	10	27	-28.6273
T_3	1200	15	10	47	-33.4420
T_4	1200	20	8	45	-33.0643

Table -9: RESPONSE TABLE FOR SIGNAL TO NOISE RATIOS- LARGER IS BETTER

LEVEL	**SPEED RPM**	**TOOL-TR Mm/min**	**AXFC KN**
1	-29.75	-32.16	-31.97
2	-33.25	-30.85	-31.03
Delta	3.50	1.32	0.94
Rank	1	2	3

Table -10: ANALYSIS OF VARIANCE TENSILE

SOURCE	DF	SEQ SS	ADJ MS	F	P	% OF CONTRIBUTION
SPEED	1	225.000	225.000	-	-	87
TOOL TRAVERSE	1	25.000	25.000	-	-	10
AX FC	1	9.000	9.000	-	-	3
Error	0	-	-			0
Total	3	259.000				100

Regression Equation

HARDNESS = 38.50 - 7.500 SPEED_1100 + 7.500 SPEED_1200 + 2.500 TOOL_15 - 2.500 TOOL_20 + 1.500 AXFC_8 - 1.500 AXFC_10

Table -11: DEPTH OF PENETRATION

SAMPLES	AREA	MEAN	MIN	MAX	ANGLE	LENGTH
S1	3.156	205.782	180	232.333	0	16.571
	0.98	217.802	188.667	234.667	90	5.143
S2	2.176	212.106	182	226.667	0	13.6
	0.768	202.544	162.667	228.333	90	4.8
S3	1.964	198.55	167	221	0	12.769
	0.592	197.32	141	227.333	90	3.846
S4	1.988	216.087	147.333	235.333	0	12.923
	0.734	218.301	185	237.333	90	4.769

Inadequate weld bead dimensions such as shallow depth of penetration may contribute to failure of a welded structure since penetration determines the stress carrying capacity of a welded joint. To avoid such occurrences the input or welding process variables which influence the weld bead penetration must therefore be properly selected and optimized to obtain an acceptable weld bead penetration and hence a high-quality joint. To predict the effect of welding process variables on weld bead geometry and hence quality researchers have employed different techniques.

TP-1 SPEED-1100, TOOL-15, AXFC-8

TP-2 SPEED-1100, TOOL-20, AXFC-10

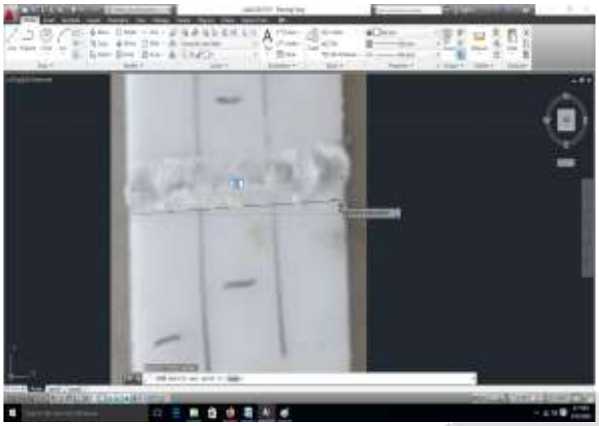
TP-3 SPEED-1200, TOOL-15, AXFC-10

TP-4 SPEED-1200, TOOL-20, AXFC-8

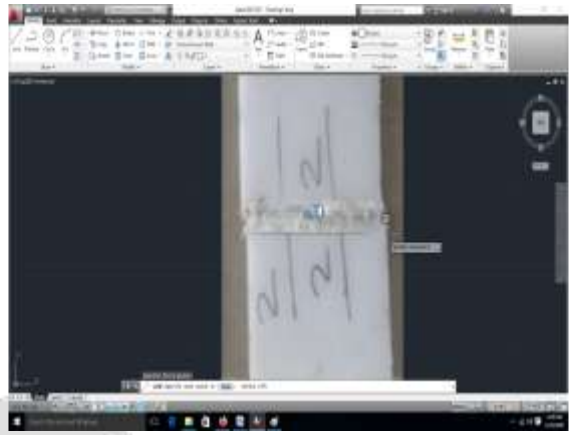
With the help of analyzed through image j software the maximum penetration and minimum bead width obtained at 4th welded samples (SPEED-1200, TOOL-20, AXFC-8)

Table -12: ANGLE DISTORTION

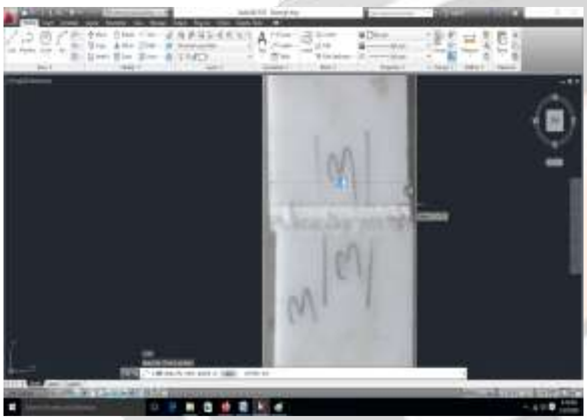
NO OF PLATES	ANGLE DISTROTION
plate-1	3º
plate-2	0 º
plate-3	0 º
plate-4	4 º



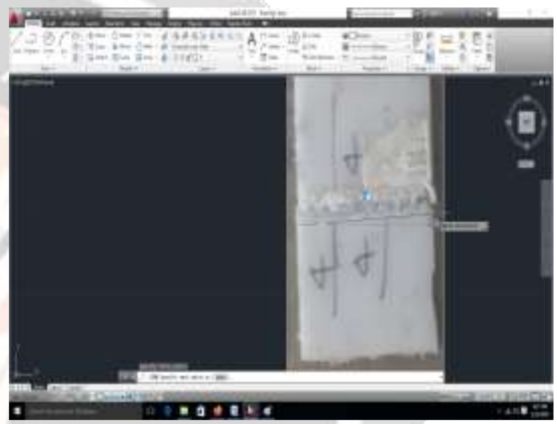
ANGLE DISTORTION PLATE-1



ANGLE DISTORTION PLATE-2



ANGLE DISTORTION PLATE-3



ANGLE DISTORTION PLATE-4

4. CONCLUSIONS

The work pieces were welded with various parameters like speed, tool traverse and axial force of machine. In order to achieve to good welding strength as well as minimum metallurgical deviation. Friction sir welded polymer plates visually inspected sample 3 has good weld appearance. The sample number 4 for using threaded tool shape with parameter 1200 rpm, 20 mm/min and 8KN of axial force has the highest tensile strength which is 9.59 N/mm2. The bead geometry was analyzed through Image J software and found good the 4th testing sample (Speed -1200.Tool traverse 20 mm/min & axial force-8 KN) is obtained maximum depth of penetration and minimum bead width (Depth 4.8mm & Width12.9mm). During the investigation found hardness strength low value shows the sample number 2 for using Threaded tool shape with parameter 1200 rpm, 15 mm/min and 10KN of axial force has the lowest Hardness strength which is 27 HRL. No Angle distortion found at second and third test plate.

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