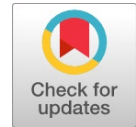# Influence of AWJM Parameter on GFRP Reinforced Nylon-6 Composite

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Abstract: This research article is aiming to comprehend the cause of Abrasive Water Jet Machining (AWJM) parameter on kerf angle of the polymer based composites. Direct extrusion method is adopted to fabricate the Nylon 6 – GFRP composites. L_{27} OA design is followed to carry out to study the behaviour of AWJM parameter Kerf Angle (K_a). Three parameters with three levels are formulated; the selected parameters are pressure of the jet, standoff distance and feed rate and output is K_a. Taguchi optimization tool is used to locate the optimal combination of the AWJM parameter. The maximum pressure, low feed rate and standoff distance are the beneficial for reducing the kerf angle. ANOVA is also employed to determine the contribution of each process parameter on kerf angle and it is found that pressure combined with standoff distance plays important role in reducing the K_a followed by standoff distance and feed rate.

Keywords : Nylon 6, GFRP, AWJM, Kerf angle, Taguchi.

I. INTRODUCTION

Glass Fibre Reinforced Plastic (GFRP) materials are extensively used in numerous uses owing to their elevated strength and modulus and added with low specific weight [1]. This property attracts the requirement of aerospace and ship constructional materials. On other side Nylon 6 composites are used extensively in bearings and gear wheels, because of their high temperature stability [2]. Nylon 6 is used as reinforcement and polycaprolactone is used as matrix materials. Compression molding technique is used for the fabrication of Nylon 6 reinforced composites [3]. Nylon 6 is used as reinforced with kenaf fiber and their properties of the composites are studied, it noted that tensile strength of the composites improved marginally [4]. The problem persists with the novel and a new material is forming into the desired shape and size. Parida et al revealed that Abrasive Water Jet Cutting (AWJM) of composite have a number of defy. So, it is essential to build up a method to acclimatize the process parameters for every GFRP material. The reason is machine manufacturers may not have the complete data base for the new/novel materials. The outcome of the study narrated that machinability index of different composite materials is vary and different and it is noted that feed rate important factor which affects the kerf angle of the composites [5]. Palleda conducted the experimentation to learn influence AWJM parameter on two different materials and it is compared with GFRP, based on its kerf angle and material removal rate. Pressure and Standoff Distance are the key factors in affecting the kerf angle and material removal rate [6]. Palanikumar et al studied the influence of AWJM machining parameters on Ra and MRR of GFRP composites using full factorial design. Coated carbide tool is used to perform the experimentation and the most influencing cutting speed, work piece fiber orientation angle, depth of cut and feed rate are selected as control factors. Fiber orientation angle and cutting speed highly influences the Ra and MRR [7]. Libor conducted an experimental study on AWJM by oscillating the nozzle to cut the GFRP composites and a performance is compared with the standard AWJM process. It is noted that oscillating nozzle is capable of producing good surface quality and texture [8]. It is understood from the literature survey there are studies which dealt with GFRP composites, there no or less systematic studies in Nylon 6 reinforced GFRP composites. In this work, an effort is made to studies the machining behaviour of Nylon 6 reinforced composites.

II. EXPERIMENTAL DETAILS

A. Materials and Methods

Nylon 6 and GFRP materials are purchased from Aaravi marketing limited, India. Nylon 6 is purchased in the form of plastic granules and GFRP sheet. GFRP sheet is cut into small pieces equal to the size of Nylon 6 granules. Extrusion process is used to fabricate the required number of composites. APPL plastic extrusion machine with 100 kW power supply is used to melt and to extrude the specimen with the size of 30X200 mm.

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B. Abrasive water jet machining of Nylon 6 reinforced with 15% GFRP

To cram the influence of the abrasive water jet machining parameters, the required numbers of nylon 6 reinforced with 15% GFRP is fabricated through extrusion process. The dimension of the specimen is diameter 30 mm and 200 mm in length. The abrasive water jet machining process is conceded through Dardi International. The garnet abrasive particle with 80 micron is used for the cutting the composites. The flow rate of the garnet abrasive particle is maintained constant throughout the cutting process. The cutting length is fixed as 20mm for each cut, and the experiments are repeated twice. Fig. 1. shows the experimental setup used for abrasive water jet cutting operation.

Fig. 1. Abrasive water jet machining of nylon reinforced composites

Kerf angle (K_a) is carefully measured with non contacting type optical measurements system. The top and bottom dimension of the cut surface is taken at three positions in entry and exit of the abrasive water jet machined area. The procedure is repeated two times at both position of the machined surface, and the mean values are listed. In this learn, three levels are considered for every process parameter, as given in Table I.

Table- I: Abrasive water parameters and its array

Parameters	Unit	Level 1	Level 2	Level 3
Pressure (P)	MPa	144	192	240
Standoff Distance (SoD)	mm	1	2	3
Feed Rate (FR)	mm/min	20	30	40

The parameter levels are selected inside the intervals, based on the specification given by the machine supplier. Three process parameters at three levels directed to a total of 27 examinations. L_{27} orthogonal array is selected; table has 27 rows equivalent to the number of parameter combinations, with 26 degrees of freedom and 13 columns. The first, second, and eighth columns of the orthogonal array are allocated to the pressure, standoff distance and feed rate.

III. RESULT AND DISCUSSION

This section presents the experimental examination of the effect of significant process parameters, such as pressure, standoff distance and feed rate on kerf angle characteristics. The production performance characteristics are kerf angle. Assortment of an appropriate orthogonal array is plays vital responsibility in conducting the trial. Only the main factors are taken into consideration and its interactions. Degree of Freedom (DoF) for each control parameter is two (total number of level – one = two degree of freedom), interaction between the parameter is four and consequently, the total DoF is twenty six. DoF should be more than one or at least equal to the number of experiments. In this case, L_{27} is selected, therefore DoF is 26. Taguchi technique is utilized to examine the result of the three water jet cutting parameters by reducing the discrepancy on the response, and optimizing the response by computing S/N ratio. Abrasive water jet machining parameters such as pressure, standoff distance and feed rate has important role in influencing the K_a. K_a values for different pressure, feed rate and standoff distance are given in Table II.

Table- II: Abrasive water jet experimental results

Ex. No	P	SoD	FR	K_a
1	144	1	20	0.9034
2	144	1	30	0.5689
3	144	1	40	0.5692
4	144	2	20	0.3348
5	144	2	30	0.7362
6	144	2	40	0.5689
7	144	3	20	0.3348
8	144	3	30	0.5357
9	144	3	40	1.0707
10	192	1	20	0.1673
11	192	1	30	0.1337
12	192	1	40	0.5016
13	192	2	20	0.7697
14	192	2	30	1.0372
15	192	2	40	0.4683
16	192	3	20	0.9034
17	192	3	30	1.4054
18	192	3	40	0.8032
19	240	1	20	0.7697
20	240	1	30	0.2678

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21	240	1	40	0.6021
22	240	2	20	0.2675
23	240	2	30	0.1673
24	240	2	40	0.5018
25	240	3	20	0.2962
26	240	3	30	0.4686
27	240	3	40	0.9003

240	1	30	3.433	11.4438
240	1	40	3.371	4.4066
240	2	20	3.523	11.4535
240	2	30	2.859	15.5301
240	2	40	3.718	5.9894
240	3	20	3.317	10.5683
240	3	30	3.966	6.5840
240	3	40	4.689	0.9123

Fig. 2. **Kerf angle of the machined surface**

Table- III: S/N Ratio

AP	SoD	T_s	R_a	S/N Ratio
144	1	20	3.664	0.8824
144	1	30	3.352	4.8993
144	1	40	3.481	4.8947
144	2	20	3.881	9.5043
144	2	30	3.506	2.6601
144	2	40	3.624	4.8993
144	3	20	3.209	9.5043
144	3	30	4.572	5.4216
144	3	40	4.122	-0.5934
192	1	20	3.273	15.5301
192	1	30	3.642	17.4774
192	1	40	3.631	5.9928
192	2	20	3.352	2.2736
192	2	30	4.01	-0.3173
192	2	40	3.757	6.5895
192	3	20	3.872	0.8824
192	3	30	3.809	-2.9560
192	3	40	3.935	1.9035
240	1	20	3.555	2.2736

In this effort, it is intended to reduce the K_a of the machined surface; if the expectation is the lower the better, therefore the following Eqn.1 is employed to compute the S/N ratio for entire experimentation results.

$$\eta_{ij} = -10 \log \left(\frac{1}{n} \sum_{j=1}^{n} y_{ij}^2 \right) \qquad (1)$$

The mean S/N ratio is computed for entire tests by taking the average of S/N ratios for the first level of each parameter. For instance, the mean S/N ratio for the first level of pressure is 0.8824. The mean S/N ratio for entire experiments is listed in Table III. The computed S/N ratio is shown as a diagram in Fig. 3.
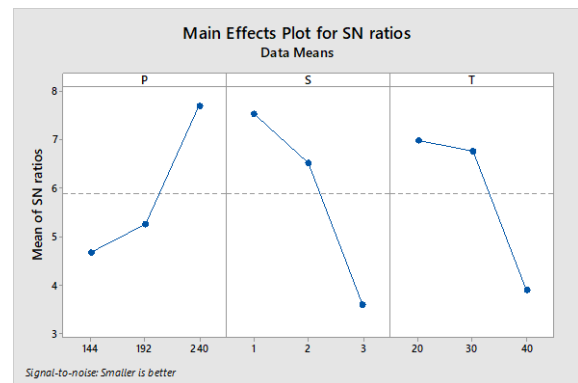

Fig. 3. **Means of S/N Ratio**

As per the S/N ratio values and diagram of the mean S/N ratio, the maximum value gives the enhanced performance (minimum kerf angle). Fig. 2 shows the kerf angle of the machined surface at optimal condition. The optimal ideals to minimize the K_a are established as A_3 B_1 and C_1 i.e. pressure (240 MPa), standoff distance (1 mm), and feed rate (20 mm/sec).

Eqns. 2 and 3 are utilized to figure out the Sum of Squares (SS), Variance (V) and contribution of every control parameter. Table IV demonstrate the SS, V and contribution of every control parameter. F test is carried out to study the significance of the process parameter.

$$ss_j = \sum_{i=1}^{j}(\eta_{ji} - \bar{\eta})^2 \qquad (2)$$

where SS_j is the sum of square deviation of the jth factor, i is the level of the jth vector.

$$V_j = \frac{ss_j}{f_j} \qquad (3)$$

V_j and f_j is the variance and degree of freedom respectively of the jth factor.

Table- IV: ANOVA for K_a

Parameter	SS	DoF	V	F value	Contribution
P	0.2232	2	0.1116	1.815	16.56
SoD	0.3190	2	0.1595	2.594	23.67
FR	0.0855	2	0.0427	0.695	6.34
PXSoD	0.7354	4	0.1839	2.991	27.29
PXFR	0.3199	4	0.0800	1.301	11.87
SoDXFR	0.3842	4	0.0961	1.562	14.26
Error	0.4918	8	0.0615		

The final column of Table IV shows the % of contribution every of parameter, and its point out the degree of influence on the cutting performance. In this examination, the pressure of the cutting process is extremely important factor, and plays a most important responsibility in affecting the Ka of the machined surface.

IV. CONCLUSION

Nylon 6 and GFRP composite successfully fabricated through direct extrusion process. The effect of three process parameter on kerf angle of the composites is studied with L_{27} orthogonal array. It is found that A_3, B_1 and C_1 are the best optimal combination to minimize the kerf angle. ANOVA is also employed, it is found that standoff distance contribute with 23.67 % in affecting the kerf angle followed by feed rate and pressure.

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