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# Parametric Analysis of AWJM Process Parameters on Wood Filler Based Reinforced Polymer Composites using Taguchi Approach

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**ABSTRACT:** The aim of this paper is to study the effect of AWJM process parameters on machining of wood filler based reinforced polymer (WFRP) composites using Taguchi method. The machining parameters considered are standoff (SoD), Water Pressure (WP), Nozzle Speed (NS), and Abrasive Grain Size (AGS) while Material Removal Rate (MRR) is considered as a response parameter. The development of experimental design with L9 (orthogonal array) and parametric analysis is performed by Taguchi approach. The optimal parameter setting is determined by using parametric analysis to get the maximum MRR in AWJM process, during the machining of natural filler polymer composites. At last, a confirmatory test is performed using parametric setting obtained from parametric analysis to verify with experimental results.

**KEYWORDS:** Abrasive Water jet Machining (AWJM), Natural filler reinforcement polymer (NFRP) composite, parametric analysis, Taguchi Method.

## I. INTRODUCTION

At present, natural filler reinforcement polymer (NFRP) composite are employed in many of the industrial applications such as automotive, aerospace, tool and die making, house hold applications etc.[1], due to their superior properties like eco-friendly nature and sustainability. Moreover, conventional machining creates long lasting problems while machining of NFRP composite. Among the various natural fillers, wood filler based reinforced polymer (WFRP) composites have also find the application in various areas due to their distinct properties such as low cost, renewable in nature, less abrasive, lower specific weight, environmental friendly, and non-toxicity etc. over the other NFRP composites[2]. In spite of applications, the machining of WFRP composites is found to be difficult and costly attempt using conventional machining. This is because, due to their intermolecular structure, fibres pull-out during drilling, poor surface roughness, improper cutting, low productivity, etc. Hence, non- conventional machining processes are essential [3].

Today, various non-conventional machining processes are available such as electrical discharge machining (EDM), wire electrical discharge machining (WEDM), ultrasonic machining (USM), laser machining (LM), and abrasive water jet machining (AWJM) etc. for machining of various engineering materials[4]. Due to the poor conductivity of the WFRP composites material, the EDM and WEDM process are not applicable[5]. Further, due to more ductility and low hardness of the wood dust base composite, machining in USM is also not applicable[6]. In case of LM on WFRP composites, temperature of beam badly effects material surface and this process burn edge of cutting hole[7]. Besides, other process for machining of WFRP composite, it has been found that AWJM is more preferable method for machining of WFRP composite material because the process offers many advantages such as no thermal effect, impose low stress on work piece, higher versatility and higher flexibility[8].

In spite of application of AWJM in machining of WFRP composite, the determination of its performance during the machining is also essential. The performance of AWJM process is mainly depends on their process and response parameters [8]. Improper selection of these parameters and response parameters results in error in machining quality, machining time, and machining performance. Therefore, the study of each parameter effect on the AWJM responses during the machining of WFRP composite is essential [9].

The objective of the paper is to study the effect of AWJM process parameters on machining of WFRP composites using Taguchi method. The experimentation is carried out using L9 orthogonal array and effect of each process parameters on AWJM responses using Taguchi methodology. Finally, a confirmatory test is also carried out to verify the optimal setting result with experimental results.

## II. MATERIAL AND METHOD

For preparation of specimen, Sundi wood dust (SWD) gained through the cutting of Sundi tree wood and epoxy resin (Araldite LY 556) with density 1.26 gm/cc and corresponding hardener (HY 951) both mixed in the ratio of 10:8 by weight. At the time of material fabrication 6% of SWD is mixed in the 94% of matrix material and stirred until it attains homogeneous condition. After proper mixing the dough (known as epoxy filled with SWD) is gradually poured into the vacuum glass chamber [10]. At last the poured mixture is placed up to 12 hours for nature drying and dried specimen is used for experimentation as shown in Fig. 1.

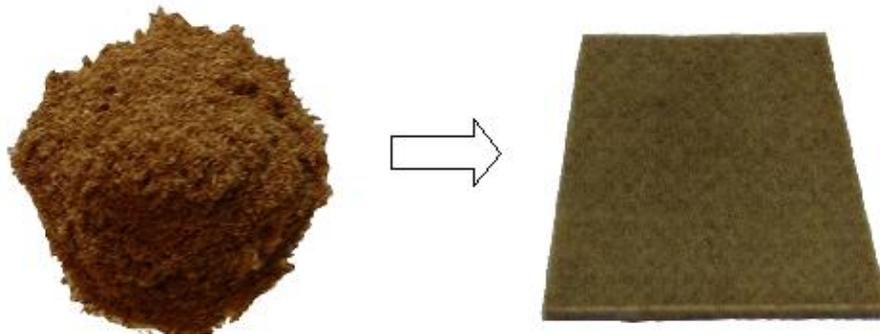


Fig. 1(a) Sundi wood dust (b) Prepared specimen (6% SWD + 94% Matrix material)

The machining of specimen was carried out on CNC water jet machine make by DARDI International Corporation, China. Four input parameters such as such as standoff distance (SoD), water pressure (WP), nozzle speed (NS), and abrasive grain size (AGS) were considered for perform this experiment, The input parameters and their levels are shown in Table. 1.

Table 1 Input parameters and their levels for AWJM process

Parameters	Symbol	Units	Level 1	Level 2	Level 3
Stand of Distance	SoD	mm	1	2	3
Work Pressure	WP	MPa	100	125	150
Nozzle Speed	NS	mm/min	100	200	300
Abrasive Grain Size	AGS	mesh	70	80	90

However, Taguchi L9 orthogonal array is used as design of experiment for performing the experiments as depicted in Table. 2. Each experiments are carried out minimum three times and average values are taken for further analysis. Accordingly, the MRR is calculated for understanding and improving machining performance of AWJM on prepared WFRP composite using following expression:

$$MRR = \frac{Iwt - Fwt}{C_{tm}} \tag{1}$$

Where Iwt and Fwt is initial weight and final weight in gram (g) respectively; C<sub>tm</sub> is the cutting time in sec (s); MRR is the material removal rate.

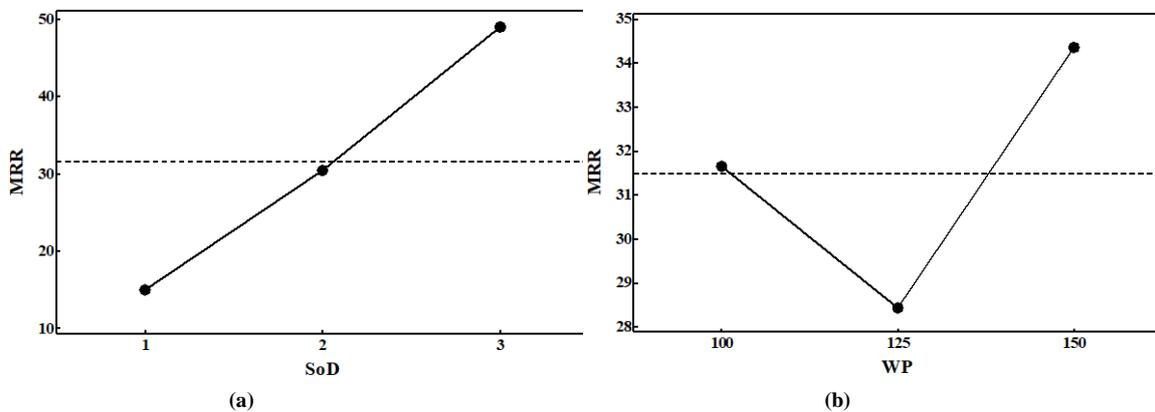


Table 2 Experimental design matrix and result.

Exp. no.	Input parameters				Output parameters
	SoD (mm)	WP (MPa)	NS (mm/min)	AGS (mesh)	MRR (g/s)
1	1	100	100	70	03.251
2	1	125	200	80	12.652
3	1	150	300	90	28.927
4	2	100	200	90	24.956
5	2	125	300	70	47.853
6	2	150	100	80	18.6251
7	3	100	300	80	66.771
8	3	125	100	90	24.784
9	3	150	200	70	55.551

### III. RESULT AND DISCUSSION

The effect of input parameters such as SoD, WP, NS, and AGS on MRR is shown in Fig. 2(a). As per graphical representation SoD and NS is positive effect on MRR. Besides, AGS is negative effect on MRR. While, WP is minimal effect on MRR. As per Fig.2 (a) MRR is significantly increased from 14.94 gm/s to 49.04 gm/s when SoD is increased from 1mm to 3mm. This is because at higher SoD, water spread diameter on the specimen surface is more and larger material is removed. Similarly, MRR increases from 15.55 g/s to 47.85 g/s significantly when NS is increased from 100 mm/min to 300 mm/min because NS increases the kinetic energy of the abrasive particles inside the nozzle, which results in higher material removal rate similar trend, can be seen in Fig. 2(c). However, MRR decreases from 31.65 g/s to 28.42 g/s when WP increases from 100 MPa to 125 MPa and afterward MRR increases from 28.42 g/s to 34.36 g/s at the time when WP increases from 125 MPa to 150 MPa. This is because; in case of WP high pressure of water directed at the specimen surface removes the material. But at low pressure, wood particle present in the WFRP composite, absorb the impact of water and material removal rate decreases can be seen Fig. 2(b). In case of AGS, MRR decreases from 35.55 g/s to 26.22 g/s when AGS increases from 70 mesh to 90 mesh, because, in general smaller abrasive cover lesser area to impact and remove lesser material i.e. lesser MRR while bigger size of abrasive cover larger area to impact and remove the higher material i.e. higher MRR. But, in the case of WFRP composite, due to the presence of wood fillers in cutting zone, the MRR is obtained to opposite i.e. larger in case of lesser AGS i.e. 70 mesh and smaller MRR in case of larger AGS i.e. 90 mesh. This is due to the fact that, smaller AGS particles covers lesser area i.e. area includes less number of wood fillers results in more penetration which subsequently increases the MRR. On the other hand, larger AGS particles cover larger area i.e. area contains more number of wood fillers which disturb the penetration of abrasive particles in to the WFRP composite and obtain lesser MRR as seen in Fig. 2(d).



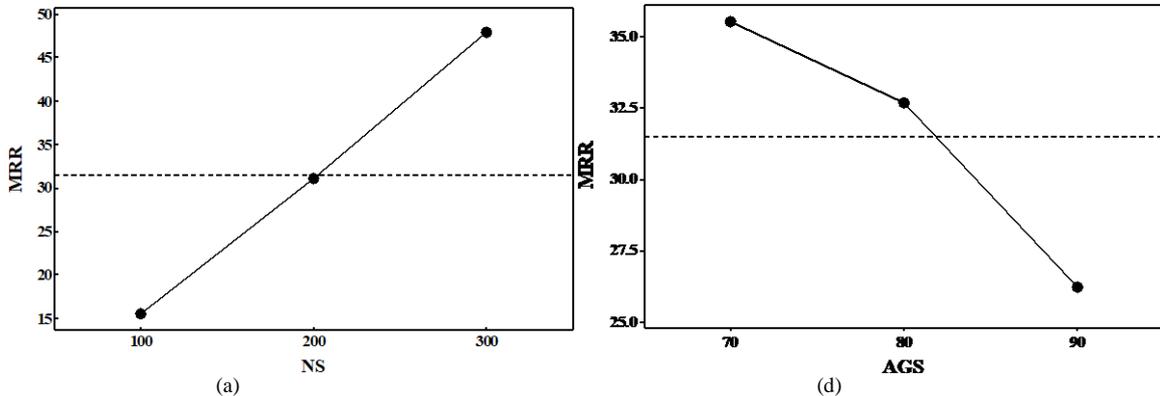


Fig. 2 Main effect plots (a) SoD vs. MRR, (b) WP vs. MRR, (c) NS vs. MRR, (d) AGS vs. MRR

At last, from the parametric analysis it is observed that initial parametric setting found from L<sub>9</sub> orthogonal array is not significant for obtained higher MRR. Based on the results seen in Figs. 2 (a-d), input parametric settings required to get higher MRR are SoD 3mm (level 3), WP 150 MPa (level 3), NS 300 mm/min (level 3), and AGS 70 mesh (level 1).

#### IV. CONFIRMATION TEST

The parametric setting obtained from parametric analysis is verified through confirmatory test. Obtained Parametric setting is used for Taguchi prediction. The experimental and predicted result is depicted in Table. 3. Confirmatory result shows that predicted MRR and experimental MRR are comparable. The % improvement of MRR is calculated between initial setting and optimal setting via. Initial experimental results (Table 2) and Taguchi prediction and confirmatory test. The % improvement of MRR is obtained to be 8.352 %, this shows the drastic improvement of MRR in case of WFRP composites machining in AWJM process.

Table 3 Confirmation experiments at optimum settings

Input Parameter	Initial Setting	Experimental MRR (g/s)	Optimal setting	Predicted MRR (g/s)	Confirmatory MRR (g/s)
SoD	3		3		
WP	100		150		
NS	300	66.771	300	72.348	71.890
AGS	80		70		

#### V. CONCLUSION

The parametric analysis of AWJM on WFRP composite has been carried out successfully through experimentation. The study of each parameter effect on the response MRR is explored using main effect plots and optimal setting for higher MRR is established. The parametric setting obtained are SoD 3mm (level 3), WP 150 MPa (level 3), NS 300 mm/min (level 3), and AGS 70 mesh (level 1). Further, confirmatory test is performed to verify the obtained results from the parametric analysis with experimental and prediction results. The results show that, the confirmatory test results and prediction results are comparable and 8.352 % improvement in MRR is obtained.

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