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AN OPTIMIZATION OF ABRASIVE WATER JET MACHINING ON COCOS NUCIFERA POLYMER COMPOSITE

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ABSTRACT
Composite materials have assumed a crucial role in the material system due to their distinctive performance in many specialized applications. The incorporation of fibre and the diverse characteristics of composites complicate the process of machine using the traditional machining method. Nonetheless, other unconventional techniques have been used for machining composites, with abrasive water jet machining (AWJM) demonstrating superior efficacy and being the preferred approach for machining fiber-reinforced composite materials. This article aims to elucidate and classify the machining performance of fiber-reinforced composites in the context of the Abrasive Water Jet Machining (AWJM) process.

Keywords:
Abrasive water jet machining, composites, kerf, surface roughness.

INTRODUCTION

The unique characteristics of composite materials render them advantageous in several applications. The majority of applications use composite materials with continuous fibers, complicating the formation of holes and holes without compromising the fiber reinforcement during construction. In such case, machining is the only preferable solution to generate holes and for other requirements. Composite materials with natural phases /a filler have been developed in a present in the material engineering. The natural filler is used in a form of microparticle filler or plant fibers. A substitution of synthetic fillers/reinforcements with natural ones is important in the material research. Bio composites are also made with the use of various other ingredients, e.g. egg shell [1], seeds of Phoenix [4], Ensete ventricosum [5], oil palm fibers [6, 7], sisal fibers [8, 9], flax [10, 11] and other natural fibers (cellulose fibers, rice – husk, jute etc.) [12,13, 14]. Many research studies deal with mechanical properties of composite materials. However, focus should also extend to other necessary operations in an engineering production, i.e. material dividing and subsequent machining [15]. The material dividing is a common attribute of production companies [16]. Traditional machining methods are not always applicable technically and economically the most suitable for machining of new materials [17]. Various variants of cutting One of the possible techniques for separating composite materials is using water jet technology. It does not come to a heat affecting of machined materials, to an evaporation and to a degradation of the material. A temperature is a problematic factor mainly at machining of polymers and polymeric composites. The liquid-jet is the working tool for the manufacturing. With an element of abrasive materials, it is finished at the abrasive water jet technology [16]. Thwater jet and water jet at its impact on a surface of the machined polymeric composite material with the coconuts approach is based on a mechanism for producing strong water pressure. which goes through a nozzle of a small diameter so the water gains very high kinetic energy similarly as at the water jet [17-19]. Abrasive particles several fold increasing its effect are added into the high-speed water stream [16]. An interaction between a matrix and a reinforcement can be failed at acting of high-speed liquid with abrasive grains with the surface of the work piece at the composite materials cutting [19-20]. The AWJ technology proved to cut in the effective way also the reinforcing glass fabric, corundum and glass-bead

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particles without their delamination from the matrix. The delamination and significant removal of the material show themselves in the first stage of the cutting. Subsequent cut is regular [21]. However, the results proved the delamination of layers at various traverse speeds. The aim of the research is to study an influence of the abrasive with the coconut; the water jet strikes the surface of the processed polymeric composite material. Shell micro particle filler.

MATERIAL AND METHODS

Composite materials have gained significant usage in several industrial and consumer sectors because of their unique characteristics. “Fiber-reinforced polymer (FRP)” composites have emerged as a viable alternative to metallic counterparts, effectively replacing them in several applications. In recent years, “cocos nucifera polymer composite (CFRP)” laminates have gained significant popularity and are widely utilized in diverse engineering and residential applications. For the present work the CFRP of size 200 mm × 12 mm × 20 mm has been selected.

EXPERIMENTAL PLAN

The machining tests were carried out on the three-axis G1010 Aqua jet (CNC) AWJM machine. The AWJM machine setup was displayed in Figure 1. The thickness of the manufactured composites was cut via a traverse cut of constant length. Based on prior trial experiments and process variable values disclosed in the literature cutting experiments and process parameter selection were developed. The focusing tube was 70 mm long, and the nozzle's diameter was 1.02 mm. Table 1 lists the machining settings and cutting circumstances for AWJM. Table 2 displays the outcomes of the experiments.

S.No	Input Process Parameters	Level 1	Level 2	Level 3	Level 4	Level 5
1	Abrasive flow rate (AFR), g/min	250	300	350	400	450
2	Traverse Speed (TS), mm/min	70	85	100	115	130
3	Stand of Distance (mm)	3	3.5	4	4.5	5
4	Pressure (MPa)	100	150	200	250	300

Table 1 Machining parameters with levels

Figure 1 AWJM machining of Polymer composite

Std	Run	Factor 1	Factor 2	Factor 3	Factor 4	Response 1	Response 2
		A PRESSURE	B Standoff distance	C Traverse speed	D Abrasive Flow rate	Surface Roughness	Kerf Taper
	Unit	MPa	mm	mm/min	g/min	Ra µm	Degree
15	1	300	3	130	450	3.689	0.337
16	2	300	5	130	250	4.192	0.606
8	3	200	4.5	100	350	4.815	0.78

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5	4	200	4	100	300	4.934	0.821
13	5	150	4	100	350	5.195	0.924
1	6	200	4	115	350	4.825	0.804
14	7	100	3	130	250	5.805	1.27
2	8	300	3	70	450	3.492	0.182
6	9	200	4	100	350	4.755	0.761
7	10	250	4	100	350	4.284	0.58
4	11	200	4	100	400	4.545	0.698
11	12	200	4	85	350	4.683	0.711
3	13	200	4	100	350	4.785	0.765
12	14	200	3.5	100	350	4.705	0.745
17	15	100	3	70	250	5.646	1.12
9	16	300	5	70	250	4.025	0.404
10	17	100	5	130	450	5.475	1.09
18	18	100	5	70	450	5.302	0.915

Table 2 Design of Experiments order with response results

RESULTS AND DISCUSSION

Optimization of Surface Roughness

Table 3 shows the ANOVA results Surface Roughness, the Predicted R^2 of 0.7589 is not as close to the Adjusted R^2 of 0.9980 as one might normally expect; i.e. the difference is more than 0.2.

The response surface graphs that are drawn to obtain the lowest surface roughness with various combinations of AWJM process parameter during the machining of composite are shown in the regression model for surface roughness in figure 2

In spite of the condition of the material, more uniform degradation occurs throughout the composite thickness direction with fewer hitches due to the higher energy abrasive particles flowing in the machining zone. This causes an adequate decrease in Ra (3.492 µm) as the water jet pressure increases. with operating conditions of at operating conditions of pressure, standoff distance, traverse speed, abrasive flow rate as (300, 3, 70 and 450 respectively).

As a result, the target material is impinged with more abrasive flow rate. The target material had a homogeneous cutting action with fewer surface imperfections, which increased the surface roughness to 5.805 µm at operating conditions of pressure, standoff distance, traverse speed, abrasive flow rate as (100, 3, 130 and 250 respectively). A rise in water jet pressure may enhance the kinetic energy of the water jet, pushing the abrasive particles to a high energy state. Furthermore, Inconsistent abrasive particle distribution in the water jet during AWJM and the presence of entrained air in the water jet's tangential region both contribute to the increase in surface roughness.

The increase in surface roughness is as effect of inappropriate coordination impact with traverse speed at lower pressure, the cutting ability was compromised, resulting in micro cutting and rough patches.

A uniform amount of abrasive cutting energy was generated by abrasive particles when they reached their threshold energy during cutting operations at a higher abrasive flow rate. Through the micro erosion process, this outcome gave the machined surface a superior surface polish. The machining nonuniformity and composite surface roughness both rise with an increase in traverse speed.

Source	**Sum of Squares**	**DF**	**Mean Square**	**F-value**	**p-value**	
Model	6.79	14	0.4851	601.21	< 0.0001	
A-Pressure	0.4150	1	0.4150	514.31	0.0002	
B-Standoff distance	0.0061	1	0.0061	7.50	0.0714	
C-Traverse Speed	0.0692	1	0.0692	85.78	0.0027	
D-Abrasive Flow Rate	0.0757	1	0.0757	93.78	0.0023	
AB	0.0145	1	0.0145	17.91	0.0241	

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AC	0.0001	1	0.0001	0.1586	0.7171	
AD	0.0020	1	0.0020	2.45	0.2158	
BC	0.0000	1	0.0000	0.0397	0.8549	
BD	0.0015	1	0.0015	1.91	0.2607	
CD	0.0002	1	0.0002	0.2999	0.6220	
A^2	0.0004	1	0.0004	0.4767	0.5395	
B^2	0.0002	1	0.0002	0.2368	0.6599	
C^2	0.0000	1	0.0000	0.0202	0.8960	
D^2	0.0004	1	0.0004	0.4767	0.5395	
Residual	0.0024	3	0.0008			
Lack of Fit	0.0020	2	0.0010	2.19	0.4312	
Pure Error	0.0005	1	0.0005		**R^2**	0.9996
Cor Total	6.79	17			**Adjusted R^2**	0.9980
					Predicted R^2	0.7589
					Adeq Precision	89.425

Table 3 Analysis of Variance for Surface Roughness

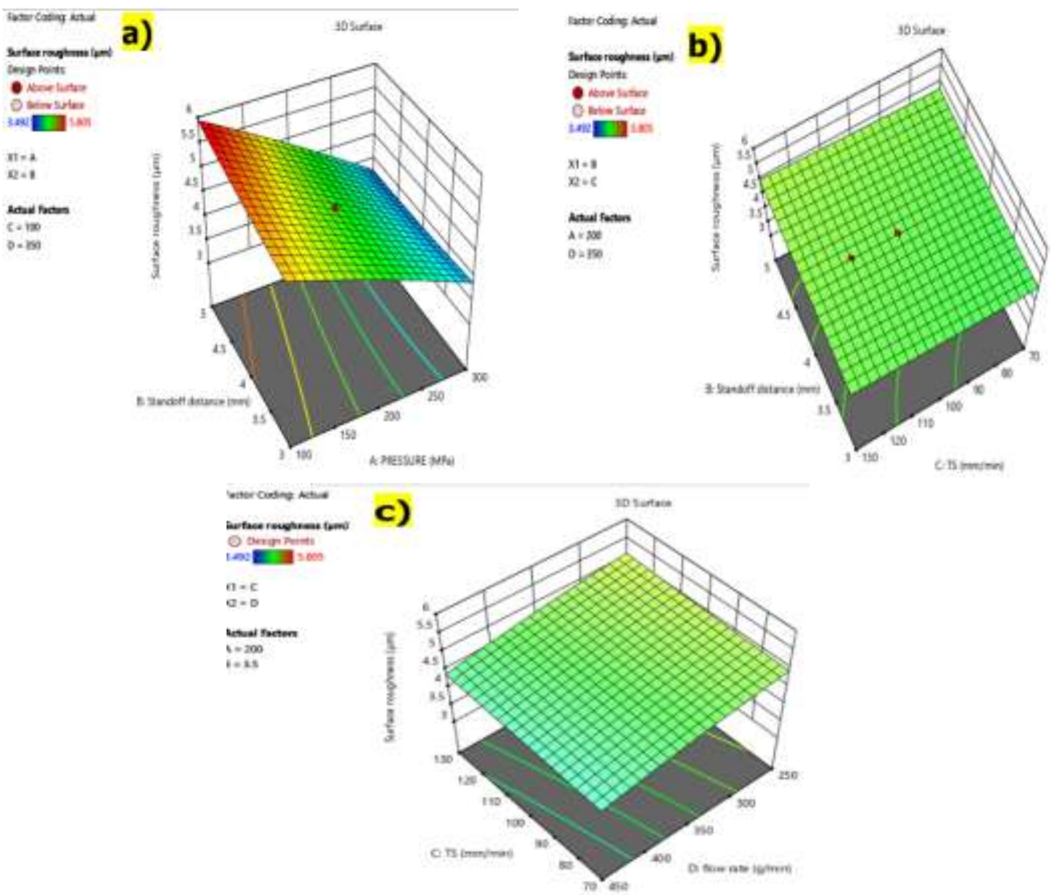

figure 2 (a-c) Influence of interaction between Standoff distance, Pressure, Traverse speed, abrasive flow rate with respect to 2D surface roughness

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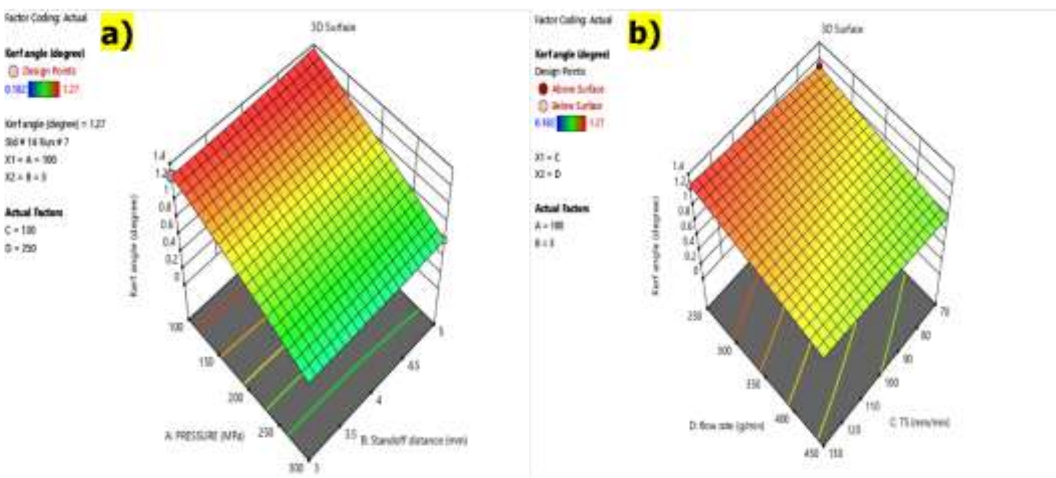
Source	Sum of Squares	DF	Mean Square	F-value	p-value	
Model	1.26	14	0.0897	4431.97	< 0.0001	significant
A-Pressure	0.0592	1	0.0592	2922.19	< 0.0001	
B-Standoff Distance	0.0006	1	0.0006	30.25	0.0118	
C-Traverse Speed (TS)	0.0624	1	0.0624	3083.62	< 0.0001	
D-Abrasive flow Rate	0.0076	1	0.0076	373.60	0.0003	
AB	0.0001	1	0.0001	4.24	0.1317	
AC	0.0001	1	0.0001	6.32	0.0866	
AD	0.0002	1	0.0002	10.99	0.0452	
BC	0.0006	1	0.0006	32.00	0.0109	
BD	0.0001	1	0.0001	4.72	0.1182	
CD	0.0001	1	0.0001	2.99	0.1823	
A^2	0.0001	1	0.0001	6.61	0.0825	
B^2	0.0000	1	0.0000	1.53	0.3046	
C^2	6.738E-06	1	6.738E-06	0.3328	0.6045	
D^2	4.436E-07	1	4.436E-07	0.0219	0.8917	
Residual	0.0001	3	0.0000			
Lack of Fit	0.0001	2	0.0000	3.30	0.3629	R^2 = 1.000
Pure Error	8.000E-06	1	8.000E-06			Adjusted R^2 = 0.99
Cor Total	1.26	17				Predicted R^2 = 0.971
						Adeq Precision = 265.09

Table 4 ANOVA of Kerf Angle



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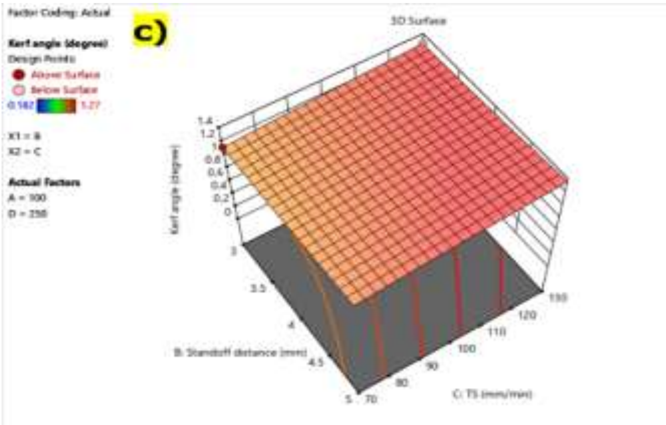

Figure 3 (a-c) Influence of interaction factors with Pressure, standoff distance, Traverse speed, mass flow rate

The analysis of the experimental results on obtained taper angle is also obtained through ANOVA as respected in table 4. It is noted that the standoff distance, or Factor B's p-value, is merely less than 0.05. Therefore, at the 95% confidence level, these factors have a statistically significant impact on the taper angle. The Predicted R^2 of 0.9716 is in reasonable agreement with the Adjusted R^2 of 0.9997; i.e. the difference is less than 0.2. Adeq. Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 265.090 indicates an adequate signal. This model can be used to navigate the design space. The Model F-value of 4431.97 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.
P-values less than 0.0500 indicate model terms are significant. In this case A, B, C, D, AD, BC are significant model terms. Figure 3 (a-c) shows the various interaction set on machining parameters of composite. There is a 36.29% chance that a Lack of Fit F-value this large could occur due to noise. The most significant influence of increased taper angle is 1.27º and the minimum level of kerf taper angle is 0.182 º at level (100, 3, 130, 250) and (300, 3 ,70, 450) operating conditions of pressure, standoff distance, traverse speed, abrasive flow rate respectively.
The kerf taper will be reduced when the jet energy is increased, and will be increased if the cutting speed is increased. Uneven kerf profiles are prevented in the machined composite due to the greater abrasive flow rate's uniform penetration impact at the bottom cut surface. This result lead to a less narrow or larger kerf taper profile, and it turned out that the kerf taper angle was lower. It also managed to retain a jet profile with constant kinetic energy despite mixing with a lot of air. This shows that the tougher abrasives' contact with the air phase during cutting has been minimised, ultimately leading to a thin kerf profile

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CONCLUSION

The experimental analysis on abrasive water jet machining of natural fibre composite was carried out and major conclusions are given below.
1. Polymer composite is successfully fabricated through hand lay off technique, without casting defects.
2. Better surface finish is obtained with minimum Ra (3.42 µm). Increase in pressure level is most important factor as increase the surface roughness and smaller bottom kerf.
3. The development of regression model yields an R2 value is 99.9 % was most satisfactory to evaluate the surface roughness and taper angle.
4. The residuals between the expected and experimental values are validated by a confirmation experiment to be a lesser than 5%.
5. These developed composite and machining study is mainly used for automotive industries to obtain a smooth machining process.

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