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# Fabrication and Experimental Analysis of Polymer Matrix Composite by using Abrasive Jet Cutting Process-Technical Paper

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**ABSTRACT**: Composite materials are getting difficult to machine owing to its constituents properties, fiber orientation and relative volume fraction of matrix. Composite materials are being increasingly used in various applications like space, aircraft, marine, architectural and automobile sector because of their superior physical and mechanical properties even though they are a little bit costly. Machining of composite materials is of great interest because of variety of reinforcement from high strength fibers to natural fibers. Due to this, the machine manufacturers do not provide good database for machining the composite materials. Abrasive jet machining provides some advantages over conventional and non- conventional machining process for cutting the composite materials like no thermal effect, high machining versatility and small cutting forces. There are several parameters influencing the performance of abrasive jet machining. In this research three parameters are Abrasive flow rate, traverse speed and standoff distance. Using full factorial method in design of experiment. The objective is to minimize the depth of cut and taper angle. The ANOVA will be performed to investigate the effect of the laser cutting parameters on the kerf taper angle during machining process. The optimization of process parameters will be carried out through regression analysis. The model developed will serve as a base to predict the kerf taper angle by varying process parameters before actual machining is carried out.

KEYWORDS: AJM process, Kerf Taper, Depth of cut, Full factorial method

### I. INTRODUCTION

Composite materials are among the oldest and newest of structural materials. The older concept of composite is simply the mixing of two or more materials to rectify some shortcoming of particular useful component in modern technology. The concept of combining two dissimilar materials has acquired a broader significance: the combination has its own distinctive properties in terms of strength or resistance to heat or some other desirable properties. The principle attraction of modern composite material is that they are lighter, stiffer and stronger than anything made before.

The term composite can simply define as a combination of two or more dissimilar materials having a distinct interface between them such that the properties of the resulting material are superior to the individual constituting components.

Composite materials are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. Composite structures, used to meet the demand for lightweight, high strength/stiffness and corrosion-resistant materials in domestic appliances, aircraft industries and fields of engineering composites, have been one of the materials used for repairing the existing structures owing to its superior mechanical properties. Applications of



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composite materials have been extended to various fields, including aerospace structures, automobiles and robot systems

In abrasive jet machining (AJM) material removal occurs on account of impact of high velocity air/ gas stream of abrasive particles on the work piece. The abrasives are propelled by a high velocity gas to erode material from the work piece. As an outcome of impact of the abrasive particles on the work piece, tiny brittle fractures occur at the surface of the work piece and the carrier gas carries away the fractured fragments. AJM is also called as abrasive blasting process. It is also known by several other names such as abrasive micro-blasting, pencil blasting and micro abrasive blasting. AJM is an effective machining method for hard and brittle materials such as glass, silicon, tungsten and ceramic. Typically the process is used for cutting intricate shapes or forms of specific edges. The process is inherently free from chatter, vibration and heat problems because the tool never touches the substrate. The schematic of AJM process set up is shown in figure 1.



Fig: 1 abrasive jet machining process

In the case of Abrasive jet machining process of polymeric materials, Deepak Doreswamy, et.al.<sup>[1]</sup>Investigate the effect of abrasive jet (AJM) machining parameters such as jet operating pressure, feed rate, stand of distance(SOD), and concentration of abrasive on kerf width produced on graphite filled glass fiber resin forced epoxy composite is investigated. Experiments were conducted based on Taguchi's L27 orthogonal arrays and the process parameters were optimized to obtain small kerf. The main as well as interaction effects of the process parameters were analyzed using the analysis of variance (ANOVA) and regression models were developed to predict kerf width. Vishal Gupta et.al.<sup>[2]</sup>Attempts to investigate kerf characteristics in abrasive jet machining of marble which is having wide applications in domestic, commercial and industrial construction work. Three different process parameters were undertaken for this study; water pressure, nozzle transverse speed and abrasive flow rate. Experiments were conducted according to Taguchi's design of experiments. Analysis of variance (ANOVA) was used to evaluate the data obtained to determine the major significant processfactors statistically affecting the kerf characteristics. The results revealed that the nozzle transverse speed was the most significant factor affecting the top kerf width, the kerf taper angle. P. Shanmughasundaram et.al.<sup>[3]</sup> Investigate the influence of abrasive water jet machining (AWJM) parameters such as water pressure, standoff distance, and traverse speed each at three different levels were analyzed on the surface roughness of the Al- graphite composites which are fabricated through the squeeze casting method. The experiments were conducted using L<sub>9</sub> Taguchi technique. The percentage contribution of each process parameter on surface roughness was analyzed by means of analysis of variance. The contribution of water pressure on surface roughness was found to be more significant than traverse speed and standoff distance. P. P. Badgujar et.al.<sup>[4]</sup> Optimize the input parameter of abrasive jet machining such as water pressure abrasive material grain size standoff distance, nozzle



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speed and abrasive mass flow rate for machining SS304. Taguchi design of experiment, the signal to noise ratio, and analysis of variance are employed to analyze the effect of input parameter in order to achieve minimum surface roughness. It was found that surface roughness decrease with increase of abrasive material grain size, water pressure and abrasive mass flow rate. Surface roughness increase with increase of standoff distance and nozzle speed. M. ChithiraiPon Selvan et.al<sup>[5]</sup>Assesses the influence of process parameters on depth of cut which is an important cutting performance measure in abrasive jet cutting of ceramics. Experiments were conducted in varying water pressure, nozzle traverse speed, abrasive mass flow rate and standoff distance for cutting ceramics using abrasive waterjet cutting process.Depth of cut is considered as the performance measure as in many industrial application it is the main constraint on the process applicability.Taguchi's experimental design was used to construct the design of experiments (DOE). Jignesh k patel et. al<sup>[6]</sup>. Investigate the effect of important process parameter water pressure, traverse speed and standoff distance on surface roughness and kerf taper ratio on abrasive water jet machining. Banana fiber reinforced composite using general purpose polyester resin was used to carrying abrasive water jet machining. It was observed that surface roughness and kerf taper ratio was reduced by increasing water pressure. It is also observed that surface roughness and kerf taper ratio was increase in traverse speed due to less overlapping of abrasive and water particle on work material. Surface roughness and taper ratio increases with increase in standoff distance.

### **II. EXPERIMENTATION AND MEASUREMENTS**

I.	Mechanical	and properties	of the polymer.
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Polymer	Yield Strength (MPa)	Ultimate Tensile Strength	Density (g/cm <sup>3</sup> )	Elongation
BANANA	56	3097	1.44	2.8

Natural fibers present important advantages such as low density, appropriate stiffness and mechanical properties and high disposability and renewability. Moreover, they are recyclable and biodegradable. There has been lot of research on use of natural fibers in reinforcements. Banana fiber, a ligno-cellulosic fiber, obtained from the pseudo-stem of banana plant is a bast fiber with relatively good mechanical properties.

Banana fibers obtained from the stem of banana plant have been characterized for their diameter variability and their mechanical properties, with a stress on fracture morphology. The nature of representative stress strain curves and fracture at different strain rates have been analyzed through SEM. It has good tensile and flexural strengths.

Table 1



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II. Material (BANANA FIBER)



Figure 2 Banana fiber

### III. Input processing variables

### Table 2

Levels of independent input machining parameters.

FACTORS DESIGNATION	FACTORS	LEVEL 1	LEVEL 2	LEVEL 3
Α	Abrasive flow rate (g/min)	200	300	400
В	Traverse Speed(mm/min)	120	220	320
С	Standoff Distance(mm)	2	3	4



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IV. Experimental Setup



**Figure 3 Abrasive jet machines** 

## **III. RESULT AND DISCUSSION**

To investigate the effect of Abrasive flow rate, traverse speed and standoff distance on depth of cut and kerf taper, experiments were conducted using three level full factorial design. The aim of the study is to investigate the effect of three AJM process parameters on depth of cut and kerf taper. The analysis of variance was carried out to identify the significant variables and to quantify their effects on the response characteristics. Main effect plots and their interaction plot were plotted using ANOVA for each parameter at all levels. The main effect plots were used to examine the parametric effects on the responses characteristics. All the results were analyzed using "Minitab 16"- statistical software.

### Analysis of depth of cut

The work piece was cleaned and dried properly before measuring the depth of cut. Table 6.1 shows the design matrix which is different combination of process parameters and response. The photographs of cut surface of work piece are as shown in figure 6.1



(a)

**(b)** 

(c)

Figure 4 experimentally cut of Polymer composite



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The normal probability plot of the residuals and the plots of residuals versus standard run order for depth of cut are shown in Figures 5.2 and 5.3 respectively. Normal probability plot (Figure 5.2) revealed that the many residual points fall on a straight line implying that the errors are distributed normally.





Figure 5 Residuals versus normal probability



From the results, it is reviled pressure (A) has maximum influence on the depth of cut than traverse speed (B) and stand-off distance (C). An ANOVA table is commonly used to summarize the tests performed. Table 5.3 shows the ANOVA Table for response surface designed model for depth of cut. The analysis was carried out for the confidence level of 95%.

Source	DOF	Sum of square (SS)	Mean of square (MS)	F	Р
Abrasive flow rate	1	7.47	7.47	30.37	0.0001
Traverse speed	1	7.34	7.34	29.82	0.0001
SOD	1	1.07	1.07	4.35	0.572
Error	4	1.58	0.40		
Total	7	17.46			
S = 0.502		R-Sq = 77.62%		<b>R-Sq</b> $(adj) = 79.37\%$	

### Table 3: ANOVA for Depth of cut

As show in table 5.3 the Model F-value of 29.82 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case **main effect Abrasive flow rate, traverse speed are significant model terms**. Values greater than 0.0500 indicate the model terms are not significant.

#### 6.2 Analysis of kerf taper

Taper of the cutting kerf is one of the most important accuracy problems at abrasive jet cutting operations. Taper can be different at different materials and depends on the applied process parameters (flow rate, traverse speed, standoff distance etc.). Experiments were conducted as per standard run order as shown in table 5.6. Figure 5.12 shows cutting test for the investigation of kerf taper for banana composite. Calculation for the kerf taper ratio is made using equation.



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$$\theta = \tan^{-1}(\frac{Wt - Wb}{2t})$$

Where W<sub>t</sub> and W<sub>b</sub> are top kerf width and bottom kerf width respectively. t is a thickness of the material.



Kerf taper Figure 7 Experimentally through cut of banana composite

<b>Fable 4:</b>	ANOVA	for	kerf	taper
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Source	DOF	Sum of square (SS)	Mean of square (MS)	F	Р
Abrasive flow	1	0.84	0.84	77.52	< 0.0001
rate	1				
Traverse speed	1	0.23	0.23	21.58	0.0024
SOD	1	0.13	0.13	12.16	0.0102
Error	4	0.10	0.10		
Total	7	1.30			
S = 0.10		R-Sq = 95.70%		<b>R-Sq (adj) = 90.17%</b>	

The influence of traverse speed on kerf taper is as shown in figure 5.16. The value of kerf taper found minimum when traverse speed is at lower level. As traverse speed increases kerf taper increases. Figure 5.16 show the relationship between SOD and kerf taper and it is observed that the kerf taper decreases as SOD decreases. This is due to fact that the material surface is exposed to the downstream of the jet by increasing the standoff distance. At downstream, the jet starts to diverge losing its coherence thereby reducing the effective cutting area that directly affects the kerf taper .



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#### Figure 7 Main effect plots for kerf taper

#### **IV. CONCLUSION**

- 1. Abrasive flow rate has a significant effect on the kerf taper angle. An increase in the Abrasive flow rate results in a significant reduction in kerf taper angle.
- 2. Traverse speed also plays a major role in kerf taper angle. A decrease in the value of cutting speed results in minimization of kerf taper.
- 3. SOD has a significant influence on the kerf taper. With an increase in the number of passes, the kerf taper is found to be decreasing for constant SOD and speed setting.
- 4. By increasing the standoff distance depth of cut is decreasing.

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