Investigations of delamination in GFRP material cutting using Abrasive Waterjet Machining

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***Abstract-* The fiber-reinforced composite materials supersede the metals in innumerable domestic and commercial applications like automotive and aerospace industries because of its advantages like high strength to weight ratio, better mechanical properties, durability, impact resistance and most important the corrosion resistance properties. But the machining of these heterogeneous type of materials is serious apprehensions because most of the FRP manufacturers do not provide standard procedure to machine these type of materials. Delamination is considered the major defect in machining of the FRP materials. Glass fibre-reinforced polymer (GFRP) composite materials are one of the important materials and are economic alternative to engineering and other FRP materials. In this study the abrasive waterjet machining of GFRP material is studied. The abrasive waterjet machining (AWJM) is one of the advance machining process of material removal in which high velocity abrasive particles are used to remove the material. The various process parameters like jet pressure, standoff distance and the feed rate were considered to study the effect on delamination of the material and the kerf width of the cut. It is found that the delamination of the material cannot be eliminated but it reduces in AWJM. It is observed that delamination is more on top side as compare to bottom side. The jet 1pressure, standoff distance and feed rate plays important role in deciding the delamination of the material.**

***Keywords-* abrasive waterjet machining, delamination, kerf taper.**

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I. Introduction

Glass fiber materials now a days become common materials in many applications like aerospace, automotive industry and sports industry due to its properties like reduced weight of structural components which results in better fuel economy. Inopportunely these materials are difficult to machine because of properties like non-homogeneous, anisotropy and hard reinforced fibers [1], [2]. While machining these materials damages like delamination and fiber pull-out takes place which may reduce strength against fatigue, thus degrading the long-term performance of composite laminates [3]. Delamination is very much perilous defect as it reduces the load-carrying capacity of the composite part but also upset the structural reliability in the service life. [4], [5]. It was reported that, in aircraft industry, the rejection of parts due to delamination damages were as high as 60% [3]. Most of the study is carried out related to the delamination occurs due to drilling of the laminate. Therefore delamination in profile cutting of GFRP material is considered in this study. Almost all the machining shows delamination of the GFRP material. Only thing is that it is more or less. Reference [5] and [6] reported that AWJM is a better option than the other machining processes. A high velocity jet of abrasive slurry is allowed to impact on work surface and it removes the material by the process of erosion of the material. AWJM possess some advantages like high machining versatility, small cutting forces, high flexibility and no thermal distortion [7]. Based on above literature the present study is focused on machining of GFRP laminate using AWJM.

II. Materials and Methods

The experimentation is carried out by using CNC abrasive waterjet machine with working bed size is 3500 x 1500 mm. The X, Y and Z axis travel is 3000 mm, 1200 mm and 200 mm respectively. The maximum working pressure is 400 MPa. The accuracy and repeatability of the machine is ±0.05 mm and ±0.03 mm. The workpiece used is a bidirectional GFRP laminate with size 100x100x10 mm and the fiber orientation is 90°.

Considering the literature review the process parameters considered for this experimentation is jet pressure, feed rate, and standoff distance. The jet pressure in AWJM decides the kinetic energy of the abrasive particles. More the jet pressure, more is the kinetic energy [6]. For any machining process the efficiency of the process is affected by the feed rate. Reference [9] reported that with increase in standoff distance the kerf width increases. The method used for the experimentation is based on the method used for CFRP material by the same first author.[10]. The parameter level decided is as follows

TABLE I. Parameter Level

Sr. No.	Parameter	Unit	Level				
1	Jet Pressure	MPa	50	60	70	80	100
2	Feed Rate	mm/min	2	4	6	8	10
3	Standoff Distance	mm	10	15	20	25	30

III. Results and discussion

A. Delamination Factor

It is considered that the delamination is the major defect observed in machining of the GFRP materials. It is observed on both side of the laminate i.e. top and bottom side. Reference [5] reported that the delamination is started by the shock wave generated by the jet in AWJM and it is the reason why the delamination is more on top side as compare to the bottom side. Figure 1. and figure 2. shows that the delamination on top side and bottom side increases with increase in jet pressure. This might be due to the increase in kinetic energy of the abrasive particles with increase in jet pressure. More the jet pressure more is shock wave generated which causes the delamination of the material. Abrasive particles possess more kinetic energy when they reach to the top surface.

The delamination factor is calculated as

$$\text{Delamination Factor} = \frac{\text{Wd}}{\text{Wo}} \qquad \text{.........[1]}$$

Wd- maximum damaged width

Wo – Original width of cut.

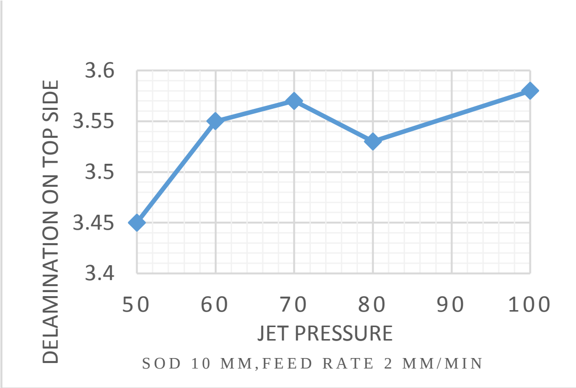

Figure 1. Jet pressure vs delamination on top side

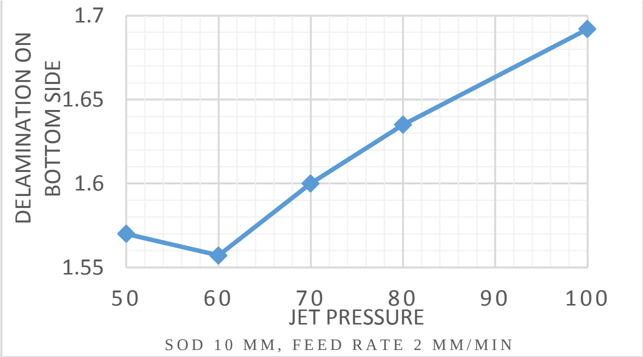

Figure 2. Jet pressure vs delamination on bottom side.

The standoff distance also shows the same results like that of jet pressure. Figure 3. and figure 4. shows that the delamination increases with increase in standoff distance though the cutting ability of the abrasive particles reduces with increase in standoff distance. The jet diameter increases with increase in standoff distance so that it will cover more area on work piece therefore the material damage will be more.

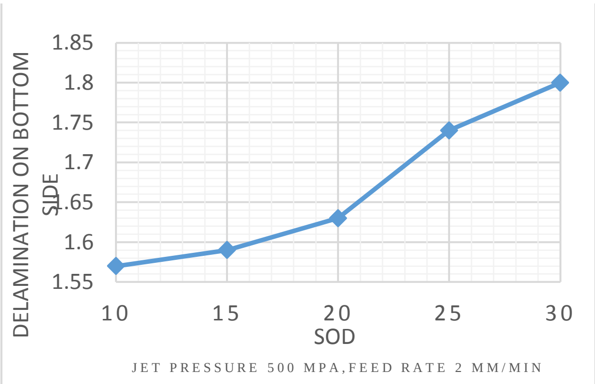

Figure 3. SoD vs delamination on bottom side

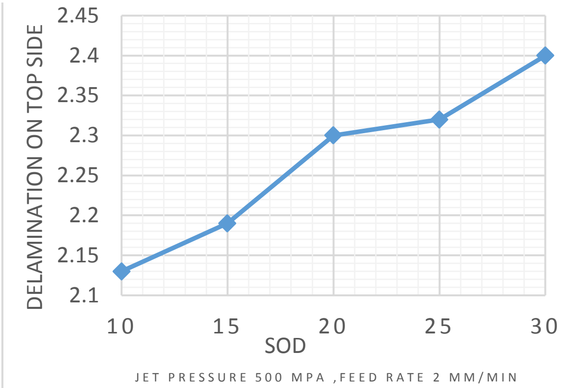

Figure 4. SoD vs delamination on top side

The feed rate which decides the efficiency of the process is less significant parameter in deciding the delamination of the material. It shows that the delamination on top or bottom side is less as compare to the previous parameters i.e. jet pressure and standoff distance. Only thing is that it also shows increase in delamination with increase in feed rate which might be attributed to the clean cuts are difficult to achieve with increased cutting speed. (Figure 5. and figure 6.).

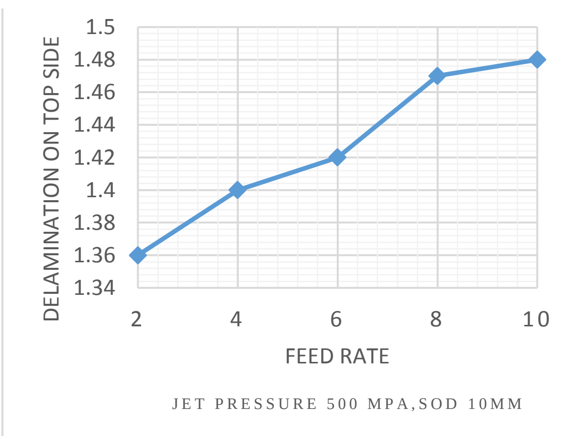

Figure.5 Feed rate vs delamination on top side

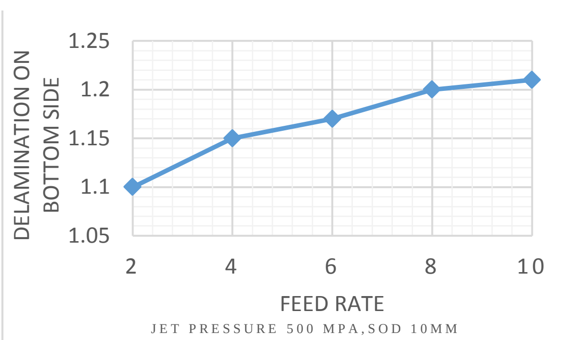

Figure 6. Feed rate vs delamination on bottom side

B. Kerf Taper:

The kerf Taper is calculated as:

Kerf Taper = Lt – Lb ……….. [2]

Lt- Kerf width at top side

Lb - Kerf width at bottom side

Kerf taper is also the objectionable consequence of any machining process. It is consider that the process with minimum possible kerf taper is good for machining the particular material. Figure 7. shows that the kerf taper decreases with increase in jet pressure which might be due to increase in cutting ability of the abrasive particles which is the result of increase in kinetic energy of the particles with increased jet pressure.

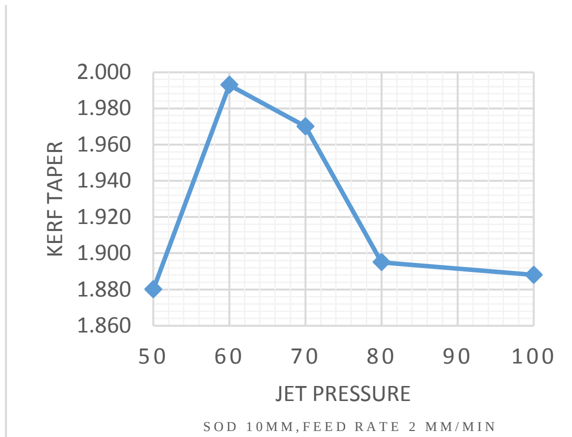

Figure.7 Jet pressure vs kerf taper

The kerf taper shows tangled results regarding the effect of standoff distance. In figure 8. it shows increase in kerf taper upto certain SoD value then it decreases and again increases. This may due to effect of other process parameters like jet pressure and feed rate which contribute in deciding the kerf taper.

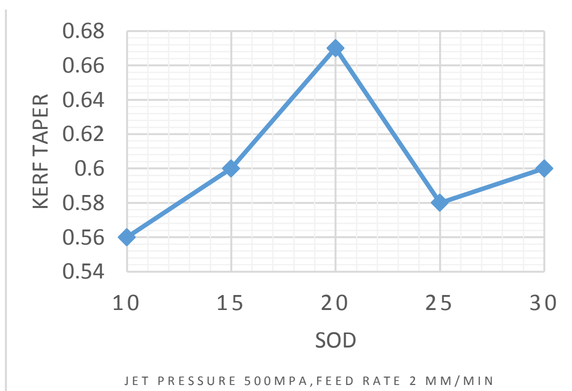

Figure 8. SoD vs kerf taper

Figure 9. shows the effect of feed rate on kerf taper. The trend line shows that the kerf taper increases with increase in feed rate. This might be attributed to the time period available to cut the material. As the feed rate increases the abrasive particles get less time to cut the material therefore the clean cuts are difficult to achieve with less time.

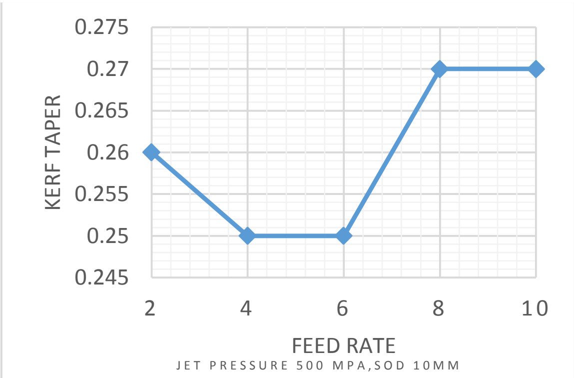

Figure 9. Feed rate vs kerf taper

IV. Conclusions

The machining of GFRP laminate using AWJM shows that different process parameters affect the cutting quality of the machining. The most influencing process parameter is jet pressure. It decides the delamination on top and bottom side of the material. The jet pressure decides the cutting ability of the abrasive particles. Therefore it influence the AWJM process more as compare to other process parameters. The standoff distance also leave it impression in AWJM process. The delamination on both the side increases with increase in standoff distance. The third parameter studied in this work has less significance in deciding delamination and kerf taper. Feed rate shows less effect on the quality of the cut as compare to other studied parameters. It is recommended that in AWJM, higher jet pressure, less standoff distance and moderate feed rate will give desirable results.

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