Abrasive Water Jet Machining of Polymer Matrix Composite - A Review

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***Abstract*-Composite material is difficult to machine with the use of conventional machining process, so non-conventional machining processes are widely used for the cutting and machining of composites. Abrasive water jet machining is one of the important machining processes used for cutting of composite because of its distinct advantages like no thermal distortion, high machining versatility & small cutting force.**

The present research is to study the influence of Abrasive water jet machining parameters as input parameter like Pressure, Traverse speed, Stand-off distance, abrasive flow rate etc., on output response like surface roughness & kerf taper during Abrasive water jet machining of polymer matrix composite.

***Index Terms*— Abrasive water jet machining, Kerf taper, Polymer matrix composite, Surface roughness**

I. INTRODUCTION

Abrasive water jet machining (AWJM) is an advanced machining process, which are widely used in industry for machining of difficult-to-cut materials such as composites, Ti alloys, silica Kevlar, rocks and ceramics. The main advantages of this process are no thermal distortion, minimal residual stresses on the work piece, no burr formation, no delamination and flexible to cut any material. In AWJM, material removal occurs due to erosion caused by the impact of abrasive particles on the work surface. A jet of water at high pressure and velocity mixed with a stream of fine grained abrasive particle like silicon carbide, aluminium oxide in suitable ratio such that the water jets momentum is partly transferred to the abrasive particles. Water is used as a carrier fluid to accelerate the abrasive particles to produce a highly coherent AWJ, which is focused on the work piece surface through a nozzle. [3] A schematic of the AWJC process is shown in Fig. 1.

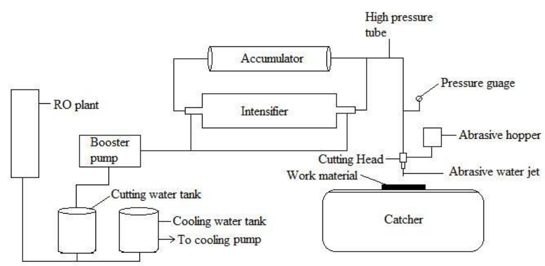

Fig. 1 Schematic diagram of water jet machining

II. LITERATURE REVIEW

Jignesh k Patel et al [1], has investigate output response such as kerf taper ratio(T_R) and surface roughness(R_a) during abrasive water jet machining of Banana fiber reinforced composite, which are fabricated using compression molding process with use of polyester resin as matrix. The machining parameters selected for study are hydraulic pressure (P), Traverse speed (S) and Standoff distance (D). They used full factorial design of experiment to determine the influence of machining parameter on output response. They observed that traverse speed and standoff distance are significant parameter for output response. It leads to increase in both surface roughness and kerf taper ratio.

Kalirasu.S et al [2], has studied on the optimization of machining parameters of abrasive water jet such as feed rate, pressure, standoff distance and abrasive method with 3 levels for minimizing the output response such as kerf width & kerf taper for banana/polyester composites, which are fabricated using hand layup method followed by compression moulding technique. They selected l_9 orthogonal array to conduct the experiment & with the help of ANOVA they analyzed significant of cutting parameter and the optimum process parameters were identified with the help of signal to noise ratio (S/N). From the experiment, the optimum process parameter such as abrasive method; feed rate and standoff distance on kerf taper angle were identified. They also found that abrasive method (Granet 120), feed rate (20 mm/sec), standoff distance (2 mm) & pressure (250 Mpa) were found to be better in order to improve kerf quality.

Dr. Tauseef U.Siddiqui et al [3], has prepared mathematical model and investigated on optimize the parameter design in Abrasive Water Jet machining of Kevlar-epoxy composite fabricated by standard autoclave vacuum bagging process. They studied influence of process parameters such as water jet pressure, abrasive flow rate, quality level and standoff distance etc., on surface roughness & top kerf width during Abrasive Water Jet Cutting using l_9 orthogonal array design of experiment. They observed that the quality level and water jet pressure has more significant effect on surface roughness and top kerf width than abrasive flow rate & standoff distance. They also found that the developed regression model successfully predicted the surface roughness & kerf width within the range of cutting parameter and it can be used for the determination of optimal cutting parameter for producing a better cut surface quality.

Jun wang [4], studied kerf characteristics & machiniability of polymer matrix composite during abrasive water jet cutting. The PMC were 3mm polymer based matrix compound reinforced with Teflon fabric using phenolic resin. He selected various machining parameters as water pressure, nozzle diameter, traverse speed and standoff distance. Top & bottom kerf width with a 'Carl zeiss' universal measuring microscope is measured. He found that cut surface may be defined by roughness ,when high water pressure and low traverse speed are used & conversely at low water pressure and high traverse speed, striation become the main feature of the cut surface. WJP, SOD has more significant effect on top & bottom kerf width. Traverse speed and standoff distance has not significant effect on kerf taper & roughness/striation respectively.

D.K.Shanmugam et al [5], has investigated kerf characteristics in abrasive water jet cutting of two different layered composite. Epoxy pre-impregnated graphite woven fabric and glass-epoxy are selected. Comprehensive factorial design of experiment was carried out in varying the process parameter such as traverse speed, abrasive flow rate, standoff distance & water pressure. They used dimensional techniques & adopt energy conversion approach; the kerf taper angle has been related to the machining parameter in a form of a predictive model. They developed a semi analytical model to comprehend the jet characteristics, material properties & machining parameters. . Model was verified with the experimental work. They found the kerf taper is a phenomenon that can be minimized if a controlled combination of machining parameter is used. Based on test condition, a combination of high water pressure, low traverse speed, low standoff distance is recommended to minimize the kerf taper angle. They also found that when water pressure and abrasive flow rate are increased than decrease in kerf taper angle are observed & when Traverse speed and standoff distance are increased than increase in kerf taper angle are found .

Tauseef uddin siddiqui et al [6], has Investigated influence of process parameter on two kerf quality characteristics namely surface roughness (R_a) & kerf taper(K_t) for three different grade (Aramid, glass & carbon) of bi-directional epoxy composite laminate. The process parameters used in experiment are abrasive flow rate water jet pressure & quality level each at 3 levels. They found their optimum selection from the use of L_{27} (3^3) Taguchi orthogonal array. They found that higher level of water jet pressure & quality level and lower level of abrasive flow rate is desirable for producing maximum surface finish & minimum kerf taper. They also found that Water jet pressure and quality level are the most significant factors that affect the surface roughness and kerf taper & Abrasive flow rate has the least effect on R_a and K_t among the three process parameters.

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D.V.Srikanth et al [8], has investigated on the influence of different process parameters on the material removal rate and kerf width of FRP (Fiber Reinforced Polymer) composite by abrasive water jet machining. They used 3 process parameters for their experiments are pressure, standoff distance, nozzle diameter each at 3 levels. The results of the experiments conducted were analyzed and optimized with TAGUCHI method of optimization and ANOVA for optimal value. They found the optimal levels of performance 'larger is better' MRR was identified as pressure (7 Kg/cm²), standoff distance (9 mm), nozzle diameter (2 mm); and the optimal levels of performance found at 'smaller is better' kerf was identified as pressure (7 Kg/cm²), standoff distance (7 mm), nozzle diameter (3 mm).

Hussein Mohammed Ali et al [9], has compare experimentally the influence of cutting parameter on dimensional accuracy & strength of hole making in GFRP(Glass Fiber Reinforced polymer) by using laser beam & abrasive water jet cutting technologies. They used five factors, each at 2 level (2^5=32 test) full factorial design as a statistical method to study the effect of predictor variable on the response variable. For AWJC machining parameters are nominal hole diameter, material thickness, cutting feed, jet pressure, standoff distance and for LBM machining parameters are nominal hole diameter, material thickness, cutting feed, laser power, standoff distance. From the experiment they found that the AWJC gives a less out of roundness in cutting hole diameter, less reduction in strength & large difference between upper and lower diameter compared to laser cutting technology of hole making in the type of glass fiber reinforced composite used.

M.A.Azmir et al [10], has investigated on the influence of process parameter of Abrasive Water Jet such as abrasive material, Hydraulic pressure, Standoff distance, Traverse rate, cutting orientation on surface roughness of glass fiber reinforced epoxy composite. The experiments were conducted using taguchi method & also optimize the process parameter for effective machining on abrasive water jet using ANOVA. They were found that the Type of Abrasive material, Hydraulic pressure, Standoff distance & Traverse rate are most significant control factor and the cutting orientation is insignificant control factor to control R_a. For noise factor effect, the form of glass fiber & thickness of composite laminated showed the greatest influence on R_a. They were developed a mathematical model from use of piecewise linear analysis to predict the performance of R_a in terms of cutting parameter of AWJM. The model was successfully predicted the R_a of glass/epoxy laminate within the limit of their study. Verification of the improvement in the quality characteristic has been made through confirmation test with respect to their choose reference parameter setting. It was confirmed that their determined optimum combination of AWJM parameter satisfied the real need for machining of glass fiber reinforced epoxy composite in practice.

M.A.Azmir et al [11], has studied the surface roughness & kerf taper characteristics of Abrasive Water Jet machining of Glass/epoxy laminate composite. They were used Taguchi`s design of experiments & ANOVA to determine the effect of machining parameter such as Abrasive type, Hydraulic pressure, Standoff distance, Traverse rate, Cutting orientation on surface roughness & kerf taper. They found that the Hydraulic pressure & Type of abrasive material are the most significant control factor in influence of surface roughness & kerf taper, respectively. Due to hardness of aluminium oxide used as a type of abrasive material; it performs better than garnet in terms of both characteristics. They were found, while increase the hydraulic pressure & Abrasive mass flow rate it may result in better performance for both response variable. Meanwhile, decrease the standoff distance & traverse rate may improve both criteria of machining performance in both cases.

Deepak Doreswamy et al [12], has investigated the effect of abrasive water jet (AWJ) 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 reinforced epoxy composite. Experiments were conducted based on Taguchi's L_{27} 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. The results show that the operating pressure, the SOD, and the feed rate are found to be significantly affecting the top kerf width and their contribution to kerf width is 24.72%, 12.38%, and 52.16%, respectively.

Vishal Guptaa et al [13], has attempted to investigate the kerf characteristics in abrasive water 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 process factors 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. Shanmugha sundaram et al [14], investigated the influence of abrasive water jet machining (AWJM) parameters such as water pressure, standoff distance, and traverse speed at three different levels on the surface roughness of the graphite composites which are fabricated through the squeeze casting method. The experiments were conducted using L_9 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.

III.CONCLUSION

The above literatures represent an overview of work on Abrasive Water Jet Machining of different Polymer Matrix Composite. From literature it can be conclude that: Abrasive water jet machining is viable & effective method for processing of polymer matrix composite. Traverse speed and water pressure have more significant effect on surface roughness and kerf width rather than abrasive flow rate and standoff distance and also higher level of water jet pressure and lower level of abrasive flow rate are desirable for producing better surface finish. Lower water jet pressure and standoff distance was desirable for minimum top kerf width.

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