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A REVIEW- ABRASIVE WATER JET MACHINING OF COMPOSITE MATERIALS

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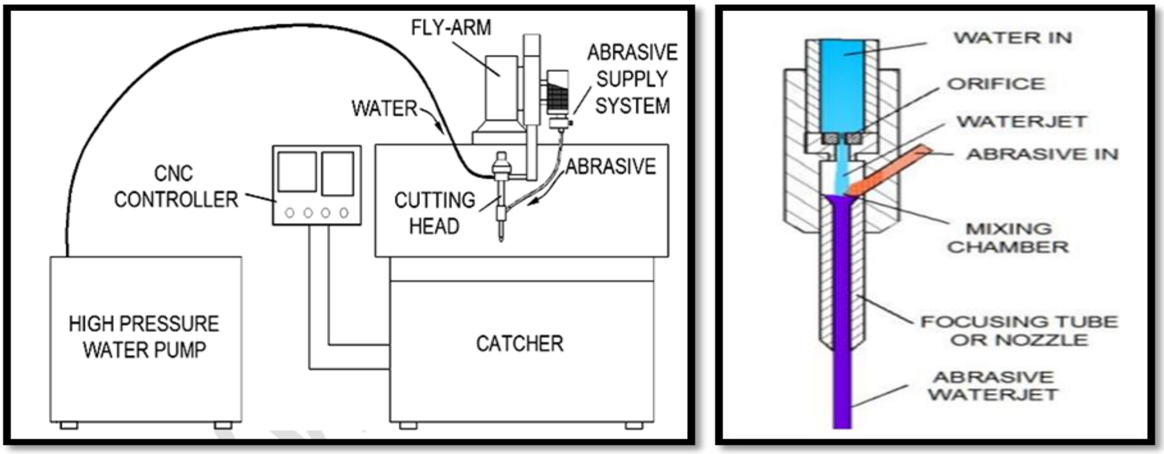
Abstract : Composites materials are getting difficult to machine owing to its constituents properties, fiber orientation and relative volume fraction of matrix. Composite materials are being increasingly used in various applications like space, aircraft, marine, architectural and automobile sector because 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 water 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 water jet machining. Important process parameters which mainly affect the quality of cutting are traverse speed, hydraulic pressure, abrasive flow rate, standoff distance, and abrasive type, work material. Material removal rate (MRR) and surface roughness (Ra), taper of cut, width of cut are important quality parameters of AWJM. This paper reviews the various experimentations carried out by number of authors in this field.

***Keywords*: Abrasive water jet machining, Process parameter, composite**

I. INTRODUCTION

Abrasive water jet cutting is one of the non-traditional cutting processes capable of cutting wide range of hard-to-cut materials. Abrasive water jet machining is a process applicable to all the types of the materials[1] . The idea of machining with Water jet (WJ) is adopted from nature that has been showing phenomena of erosion of hardest of the rock by a stream of water. The rate of erosion is observed to be faster when the water stream is mixed with sand particles and that has lead to the development of AWJ technology. High velocity water jet is created by passing high pressure water through a very small orifice while the abrasive is added to it in a so called mixing chamber to generate AWJ. These added cutting edges provided by abrasive particles increase the rate of erosion, enhancing the cutting capability of AWJ many folds than pure WJ. The removal of material from the work piece involves one or more of the following mechanisms: micro cutting, ploughing deformation, and micro-fracture. The dominant mechanism of material removal is determined by the properties of impacting abrasive

particles in terms of shape, size and hardness, the jet impact angle, abrasive feed rate, and the properties of the work piece material. Micro cutting and ploughing deformation are associated with ductile materials and shallow impact angles; where micro cutting occurs for sharp particles while ploughing deformation is associated with spherical particles. Micro cracking occurs when the particles impact about normal to the work piece. Micro cutting is believed to be the dominant material removal mechanism in AWJ machining of FRPs.[2]



(a) (b)

Figure 1 (a) Schematic diagram of AWJM, (b) Inside AWJ generator

A generic AWJ machine tool is shown schematically with major components in Fig. 1(a). The high pressure pump may comprise of an intensifier, prime mover, controller, and an accumulator. Pure water is pressurized to about 200-400 Mpa (2000-4000 bar) and fed to the module called cutting head through high pressure tube. As depicted in Fig. 1 (b) schematically, the high pressure water is then passed through a small orifice (of 0.2 - 0.3 mm diameter), to form a very high velocity (200 - 300 m/s) WJ. This WJ then enters in to the mixing chamber to get mixed with abrasives supplied though abrasive supplying system making it which comes out of outlet nozzle of relatively large diameter (0.7 - 0.8 mm). The position and motion of the cutting head is controlled by computer numerical control (CNC) system[2].

Abrasive water jet (AWJ), due to its various distinct advantages over the other cutting technologies such as no thermal distortion, high machining versatility, high flexibility and small cutting forces, is being increasingly used in various industries to cut wide range of material, in particular the difficult-to-cut materials such as advanced composites and ceramics.[3]

Composite material

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 composite materials have been extended to various fields, including aerospace structures, automobiles and robot systems.[4]

Fiber-reinforced composites, specifically those based on fiber reinforced materials, combine the best of both materials inheriting the high stiffness and strength from the fibers. In addition, the fiber-reinforced material tends to be more resistant to damage and defects than the homogeneous material. Cracks in the matrix are either shortened by an encounter with a fiber or occur parallel to the fiber, which, presumably is in the loading direction, causing little effect on the tensile/flexural strength. The matrix keeps the fibers together and oriented, protects the fibers from the environment (e.g. moisture, surface abrasion) and each other (fibers rubbing against each other), and acts as a load-transfer medium between fibers.[5]

Fabrication methods of composite material

There are various methods to make composite material as per application of the component which are : Hand lay up , automated tape placement, filament winding, pultrusion, resin inject process , autoclave curing etc.

Factor affecting AWJ machining

Input Parameters-

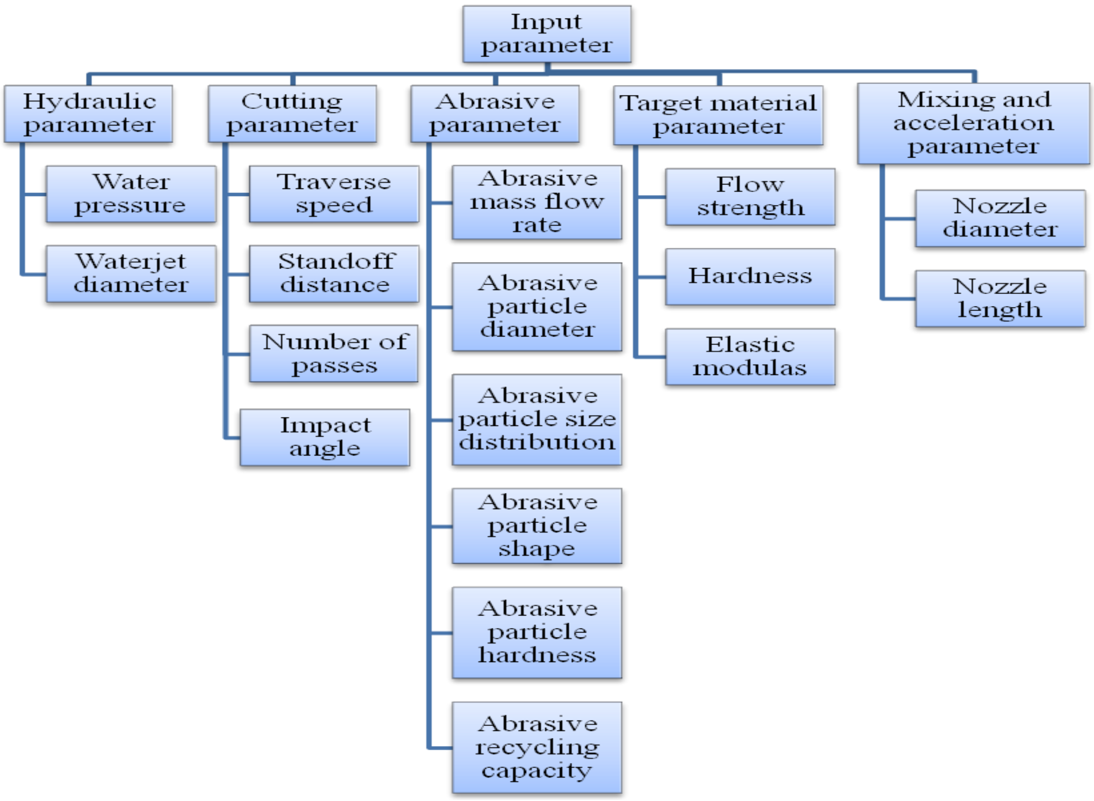


Figure 2 Input parameters of AWJM

Output parameters

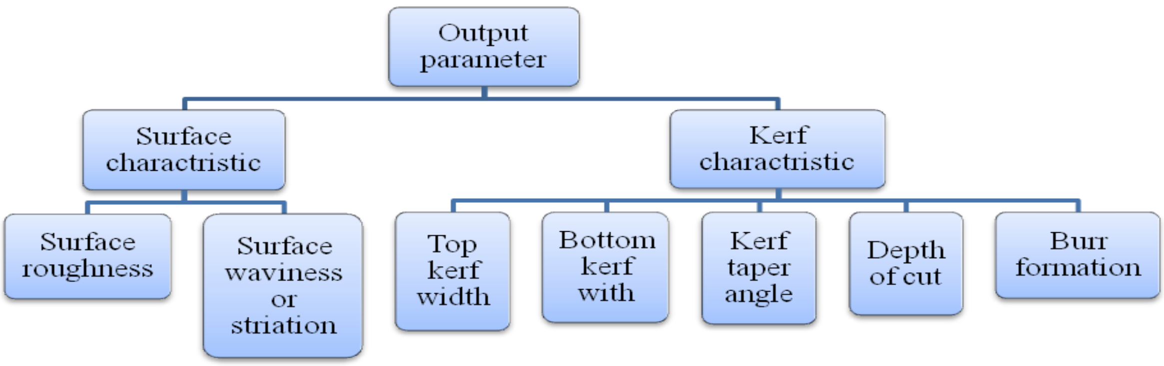


Figure 3 Output parameters of AWJM

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II. LITERATURE REVIEW

M. Chithirai Pon Selvan et.al[1] assesses the influence of process parameters on depth of cut which is an important cutting performance measure in abrasive water 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 water jet 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.

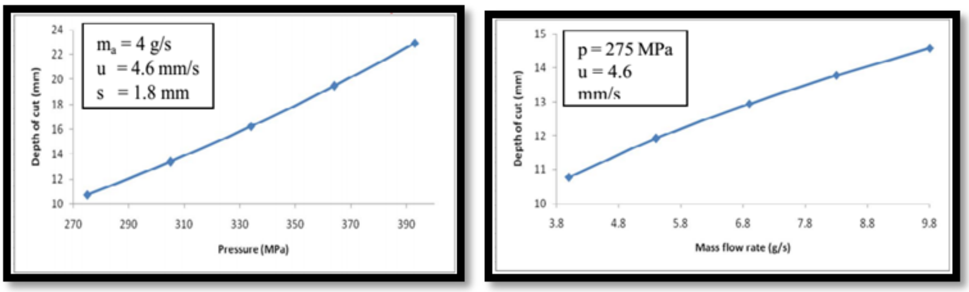

Figure 4 (a)Water pressure versus depth of cut, (b) Abrasive mass flow rate versus depth of cut

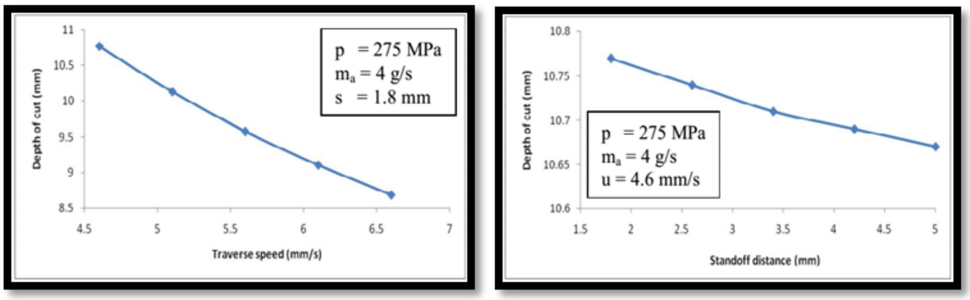

Figure 5 (c) Traverse speed versus depth of cut , (d) Standoff distance versus depth of cut

Within the operating range selected, increase of water pressure results in increase of depth of cut when mass flow rate, traverse speed and standoff distance were kept constant as shown in fig 4 (a).Increase in abrasive mass flow rate also increases the depth of cut as shown in fig.4 (b). This is found while keeping the pressure, traverse speed and standoff distance as constant. Increase of traverse speed decreases the depth of cut within the operating range selected, by keeping the other parameters constant. If other operational parameters constant, when standoff distance increases, depth of cut decreases as shown in fig. 5.(d). However standoff distance on depth of cut is not much influential when compared to the other parameters.

D.K. Shanmugam et al[3]. investigate action on the kerf taper angle, an important cutting performance measure, generated by abrasive water jet (AWJ) technique to machine two types of composites: epoxy pre-impregnated graphite woven fabric and glass epoxy. Laminate composites of bidirectional, thermoset-moulded, 6-mm thick consisting of graphite (GY70-carbon fibers) and epoxy (type 934) resin and 6-mm thick glass epoxy (781/5245C) are used as the specimens. Comprehensive factorial design of experiments is carried out in varying the traverse speed, abrasive flow rate, standoff distance and water pressure. influence of water pressure on the Kerf taper angles Results indicate that, within the operating range selected, increase of water pressure results in decrease of Kerf taper angles. Increase of traverse speed increases Kerf taper angle . The increase in Kerf taper angle. With increase in standoff distance, the Kerf taper increases within the range 2–5 mm.

With an increase in the abrasive mass flow rate the Kerf taper angle seems to decrease insignificantly.

Dr. Tauseef U. Siddiqui et.al.[6] investigate four important process parameters namely water jet pressure, abrasive flow rate, quality level and standoff distance to study their influence on kerf quality characteristics, namely, surface roughness and top kerf width during AWJ cutting of Kevlar-epoxy composites. The optimal setting of cutting parameters determined using Taguchi's robust design method. It was observed that the quality level and water jet pressure have more significant effect on surface roughness and top Kerf width rather than abrasive flow rate and standoff distance.

Tauseef Uddin Siddiqui et.al.[7] presents a comparative study of the effect of three major process parameters namely water jet pressure (WJP), abrasive flow rate (AFR) and quality level (QL), on two Kerf quality characteristics (KQCs) namely surface roughness (Ra) and Kerf taper (Kt) in AWJ cutting of three different grades (aramid, glass and carbon) of bi-directional epoxy composite laminates fabricated from prepregs. Three levels of process parameters were used to study their influence on Ra and Kt and find their optimum selection using a $L27(3^3)$ Taguchi orthogonal array. It was found that higher level of WJP and QL and lower level of AFR are desirable for producing maximum surface finish and minimum Kerf taper.

Deepak Doreswamy, et.al.[8] investigate the effect of abrasive water jet (AWJ) machining parameters such as jet operating pressure, feed rate, standoff 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. 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. Further, morphological study is made using scanning electron microscope (SEM) on the samples that were machined at optimized process parameters. It was observed that AWJ machined surfaces were free from delamination at optimized process parameters.

Vishal Gupta et.al.[9] attempts to investigate 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[10]**.** 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_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.

P. P. Badgujar et.al.[11] optimize the input parameter of abrasive water jet machining such as water pressure ,abrasive material grain size ,standoff distance , nozzle 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.A.Azmir et.al[12]. optimize the abrasive water jet machining parameter using orthogonal array with grey relation analysis. in that study Kevlar 129 woven fabric is used and hand laminated with in prepreg form of modified phinolic resin having real weight of 410 g/m^2. The orientation of fiber within the fabric was kept constant all the time during lay-up process hence they are considered as bidirectional laminates [0°/90°]. Four machining parameters, namely hydraulic pressure, abrasive mass flow rate, standoff distance and traverse rate are optimized with consideration of multiple performance characteristics. The measurement of surface waviness of each machined specimen was obtained at four measurement depths cut viz. 1.0 mm, 2.0 mm, 4.6mm and 7.2 mm. The mean GRG for each level of the machining parameters can be calculated by averaging the GRG based on OA as shown Figure 6.

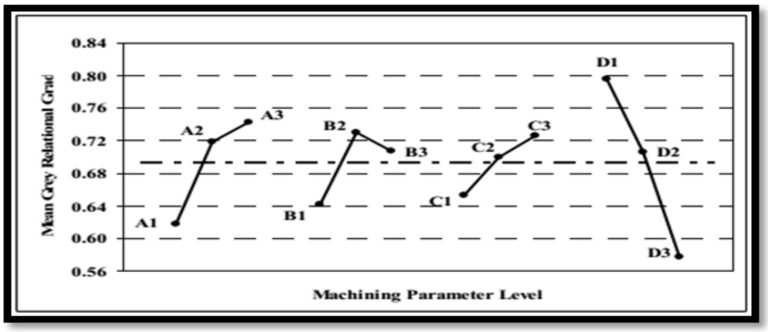

Figure 6 grey relation grade plot

The optimal process parameter level yields the highest particular GRG in Figure 6. The optimal machining parameter maintaining pressure at level 3 (310 Mpa), level 2 for abrasive mass flow rate (7.5 g/s), level 3 for standoff distance (2 mm) and level 1 traverse rate (0.5 mm/s).

III. SUMMARY

The investigation of various process parameter of AWJM shows that depth of cut increases with increase in water pressure but surface roughness also increase with increase in water pressure. Traverse speed , standoff distance and abrasive flow rate also effect various quality parameter. Comparative analysis and summary of results are as shown in table.

TABLE 1. EFFECT OF PROCESSING PARAMETERS ON PROCESS OUTPUTS IN AWJM

Quality parameters (→) Process parameters(↓)		Surface roughness	MRR	Kerf width	Top width of cut	Bottom width of cut	Kerf taper	Width of cut
Pressure	Increases	↑	↑	↑	↑	↑ (to a small	↑	↑

						extent)		
	Decreases							
Traverse speed	Increases	↑					↑	
	Decreases							
Standoff distance	Increases		↑ (to some extent)		↑	↑(to a small extent)	↑	↑
	Decreases							
Abrasive flow rate	Increases	↓						
	Decreases							

IV CONCLUSION

Quality of cutting surface in AWJM is depending on so many process parameters. 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. Increase of water pressure, abrasive mass flow rate, results in increase of depth of cut when mass flow rate, traverse speed and standoff distance kept constant. Increase of traverse speed and standoff distance decreases the depth of cut within the operating range selected, by keeping the other parameters constant. Kerf taper decrease with increase of water pressure and abrasive mass flow rate. Kerf taper increase with increase of standoff distance and traverse speed.

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