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A Review on Multi-objective Optimization of Process Parameter of Abrasive Water Jet Machining For Lower Surface Roughness & Higher Removal Rate of Glass Fiber Reinforced Polymer

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Abstract

Glass fiber reinforced polymer (GFRP) composites are increasingly being used in a large number of applications in product manufacturing because of the superior advantages they offer compared to other traditional and non-traditional materials such as high strength to weight ratio, high modulus, high fracture toughness, and corrosion and thermal resistance, low cost of production, light weight, inherent strength, weather-resistant finish and variety of surface textures. However conventional machining of Glass fiber reinforced polymer (GFRP) is not so economical and ease, on the other hand non-conventional processes like laser cutting, abrasive water jet machining (AWJM), and electric discharge machining (EDM) etc., have a very good potential in overcoming these machining difficulties. Among these AWJM is commonly employed for very hard and brittle materials due to its Economical and Technical significance.

Keywords- Abrasive water jet machining, Erosion, Machining, GFRP, Surface roughness, MMR, Kerf geometry

I. INTRODUCTION

Machining of composite materials without causing damage is quite challenging because of properties of composite material like inherent heterogeneity, anisotropy and thermal sensitivity. Some difficulty encountered when machining of composite using conventional technique is the delamination, fibre pulls out from the composite material and rapid wear on the tools used in conventional machining due to hard abrasive fibres in these composite materials. In case of machining of composite using non-conventional techniques like laser machining is the high heat dissipation in to composite work piece material that can create thermal cracks and also create both surface and subsurface defect on composite work piece. In some other cases machining of composite materials using traditional machining techniques and tools such as mills and lathes might also result in Excessive dust and hazardous gases being generated around these machines that can be harmful to machine operators health which leads to air pollution that can causes serious lung cancer [3]. AWJ cutting is a non-traditional machining techniques that overcomes most of the problems associated with traditional machining and some non-traditional machining technique such as laser cutting. Laser cutting involves the dissipation of heat into work piece material that makes the process unsuitable for composites such GFRPs [1]. AWJ cutting technique is well suited for processing composite materials because of reduced interface temperature, low mechanical loading, better surface integrity and ease of operation. It belong to mechanical group of non-conventional processes like Ultrasonic Machining (USM) and it used mechanical energy of water and abrasive phases to achieve material removal or machining.

Dr. Franz in 1950's first studied UHP water cutting for forestry and wood cutting (pure WJ). In1979 Dr. Mohamed Hashish added abrasive particles to increase cutting force and ability to cut hard materials including steel, glass and concrete (abrasive WJ). Waterjet cutting technology is one of the fastest growing major machine tool processes in the world due to its versatility and ease of operation and it can be easily automated for production use.

There are virtually no limits to what waterjets can cut, which is why companies of all kinds and sizes are realizing greater efficiency and productivity by implementing UHP waterjets in their operations. AWJM can cut a variety of applications with ease, whatever the shape, dimensions, or material and it can easy-to-use software makes the job easy. AWJM has Expanded Capabilities like Automotive, aerospace, stone and tile, tool and die, gaskets, fabricator, or job shop and it can cut metal, stone, plastics, composites, glass, ceramics, rubber. Waterjets require minimum fixturing and tooling so we can save valuable time on your shop floor. AWJM uses erosion process with efficiency up to 0.001" can cut any material.

In AWJM cutting head is commonly connected to a high-pressure water pump, where the water is then ejected from the nozzle, cutting through the material by spraying it with the jet of high-speed water as show in figure 1. AWJM uses ultra-high pressure (UHP) pumps that intensify water to pressures of up to 94,000 psi. The waterjet alone can cut up to 2.5" inches , foams and cured composites like Kevlar, fiber-reinforced plastic and graphite in a single pass.

When abrasives such as garnet are entrained in the water stream the abrasive waterjet is powerful enough to cut through 4" inches of either graphite epoxy or magnesium boron carbide without creating heat-affected zones. It is especially useful for cutting tool steel and other metals where excessive heat may change the properties of the material and there is no heat generated. AWJ cutting does not leave a burr or a rough edge, and eliminates other machining operations such as finish sanding and grinding. Typical machine set up of abrasive water jet machining as show in figure 2.

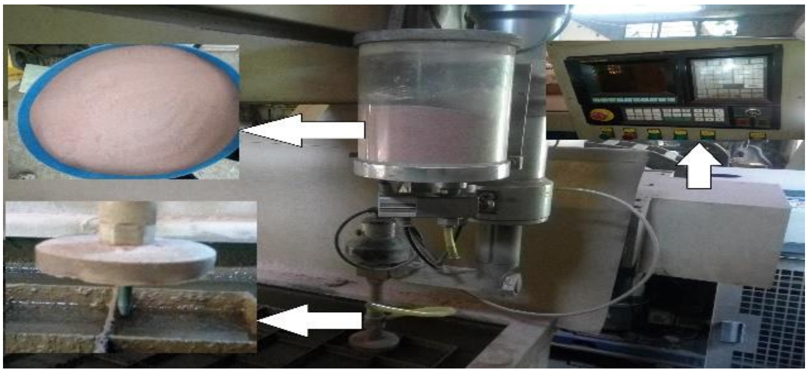

Figure 1

Figure 2

Fiber reinforced polymer composite is used in product manufacturing due to its distinct advantages. In recent days, Nano fillers such as graphite particles are impregnated with glass fiber reinforced polymer (GFRP) to enhance specific properties [2]. AWJ machining is a relatively new manufacturing tool which has been realized to overcome limitations mentioned earlier

II. LITERATURE REVIEW

1) E. Lemma and L. Chen show that the improvements in surface quality are much higher with increase in the angle of oscillation than with increase in the frequency of oscillation and the lowest improvement in surface quality was obtained when high value of frequency and a low value of the angle of oscillation was used [1].

2) M. Dittrich and M. Dixa shown that a statistical approach on structuring surfaces of aluminium oxide by using abrasive waterjet is a good way to examine the influences of the different adjustable working parameters on the response variables [3].

3) D.S. Srinivasu and D.A. Axinte show that Maximum erosion depth was observed at jet impingement angle in the range of 70 ˚ to 80˚ as the effective average impact angle of abrasive particles approaches 90˚ at a < 90˚ and also this shift can be attributed to the material hardness and amplitudes of kerf geometries are very much dependent on the jet feed rate due to increase in erosion along jet axis and erosion capability of abrasive particles at shallower impact angle [4].

4) G. Fowler and I.R. Pashby show that for the particle types examined, high traverse speeds result in lower material removal rates as material is removed primarily by high angle impingement. The surface roughness is higher at the high traverse speeds, but there is a significant reduction in the surface waviness and material removal rate and surface roughness increase if particle hardness is increased [6].

5) M.A. Azmir and A.K. Ahsan show that Hydraulic pressure (MPa) and type of abrasive materials (i.e. garnet and aluminium oxide) were considered as the most significant control factor in influencing Ra and TR, respectively and decreasing the standoff distance and traverse rate may improve both criteria of machining performance [7].

6) A. Alberdia and A. Suareza show that the machinability index of different composite materials is very different, so they have to be studied. This index may be related to the tensile modulus and/or to the fibre content of the composite materials, but further research is required in order to relate the machinability index with the material properties [8].

7) G. Fowler and P.H. Shipway show that the traverse speed, grit size and number of passes of the jet all influence changes in the way that the material is removed in the AJW milling of titanium and traverse speeds result in lower material removal rates as material is removed primarily by high angle impingement[6].

8) E. Lemma and L. Chen show that for relatively thin materials a consistently improved surface quality can be achieved using head oscillation technique, for relatively thick materials better consistency across the cut-wall thickness and overall improvements in surface qualities can be achieved when head oscillation is superimposed at higher traverse speed and for cutting aluminium samples, higher oscillation angles still need to be used to achieve a better surface quality [5].

9) A.A. Khan and M.M. Hague analyses the performance of different abrasive particles in abrasive water jet machining of glass. They compare the effect of different abrasives on taper of cut by varying the stand-off distance, work feed rate, pressure. Garnet abrasive produce the largest taper of cut, followed by aluminium oxide, and silicon carbide. The study also describe that the taper of cut increases with increase in the standoff distances because water jet get widen with increase in standoff distance. The taper of cut decreases with increase in jet pressure, with increase in pressure the cutting energy of jet increases. The depth of penetration of jet increases with increases in hardness of abrasives [10].

10) Mohemed Hashish observed that as the pressure increases the power required for cutting get reduced drastically. This suggests that cutting at higher pressure is more efficient than at low pressure for the same power consumption. Plain waterjets are capable of cutting the sheet metals at pressure of 600 MPa. Elevated pressure promise cost reduction due to reduction in abrasive usage or increased cutting speed. The study shows that the depth of cut increases with increases in water pressure [11].

11) J. Wang, W.C.K. Wong conducted a statistically designed experiment to study the effect of abrasive water jet cutting of metallic coated sheet steels. The relationship between kerf characteristics and process parameters are also investigated in this experiment. An empirical model was developed for kerf geometry and quality of cut for the prediction and optimization of AWJ cutting performance. A three-level four-factor full factorial designed experiment performed for analysing the AWJM process. The various process parameters used are water jet pressure, traverse speed, abrasive flow rate and standoff distance (SOD). The study found that the top and bottom kerf widths increase with increase in hydraulic pressure, standoff distance but the rate of increase for the bottom kerf width is smaller. The traverse speed produces an inverse effect on the top kerf width and bottom kerf widths but at same time the kerf taper increase as the traverse speed increase. The surface roughness of the cut surface decreases with an increase in the abrasive flow rate [12].

12) P K Ray and Dr A K Paul had investigated the effect of air pressure, grain size and nozzle diameter on material removal rate. MRR is found to increases with increase in standoff distance (SOD) at a particular pressure. Their investigation found that the MRR increases and then it is almost constant for small range and after that MRR decreased as SOD increases. They also introduced a material removal factor (MRF), MRF is a non-dimensional parameter and it gives the weight of material removed per gram of abrasive particles. MRF is found to decrease with increase in pressure that means the quantity of material removed per gram of abrasives at a lower pressure is higher than the quantity of material removed per gram of abrasives at a higher pressure. This is happened because at higher air pressure more number of abrasive particles are carried through the nozzle so more numbers of inter particle collisions and hence more loss of energy [13].

13) H. Hocheng and K.R. Chang conducted experimental evaluation on the kerf formation over ceramic plate cut with an abrasive water jet. It found that a critical combination of hydraulic pressure, abrasive flow rate and traverse speed are required for through- out cut of ceramics, below which it cannot be achieved for certain thickness. A sufficient supply of hydraulic energy, fine mesh abrasives at moderate speed gives smooth kerf surface. By experiment investigation they found that the kerf width increases with increasing these factors such as pressure, traverse speed, abrasive flow rate and abrasive size. They also found that the taper ratio increases with increase in traverse speed and decreases with increase pressure and abrasive size. Abrasive flow rate has no influence over taper ratio [14].

14) M. Chithirai Pon Selvan, Dr. N. Mohana Sundara Raju, Dr. R. Rajavel had investigated the effects of process parameters on the depth of cut in abrasive waterjet machining of cast iron. They investigated that the depth of cut increases with increases in water pressure, when mass flow rate, standoff distance, traverse speed were kept constant. Increases in abrasive flow rate also increase the depth of cut keeping other parameters constant. The depth of cut is found to decrease with increase in traverse speed because the contact of abrasive particle over the work piece is for shorter duration. It is also found that the depth of cut decreases with increase in the standoff distance between nozzle and work piece keeping other operational parameters constant [15].

III. CONCLUDING REMARK

Based on literature review it has been clear that effective process parameters on glass fiber reinforced epoxy composites such as Type of abrasive, work piece hardness, operating pressure, standoff distance and jet traverse rate were significant control factors which affect surface roughness (Ra) and material removal rate (MRR).

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