A REVIEW ON ABRASIVE WATER JET CUTTING

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ABSTRACT

The development of high performance material such as composites and advanced ceramics has a variety of manufacturing challenges. It is known that many of these materials cannot be effectively machined by conventional machining methods. Apart from economics, the process selection is based on the machined surface integrity. The high pressure waterjet with abrasive additives known as abrasive water jet (AWJ) is one viable alternative to conventional processing and has been suggested for use in post mold shaping of composites and other hard to cut material. The research works on water jet cutting is discussed in this paper. Omni directional cutting potential as well as minimal thermal and mechanical loading are few advantages. 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.

KEYWORDS:

Composites, Water jet, Omni-directional, Abrasives, Mechanical loading & Parameter

1. INTRODUCTION

Abrasive waterjet machining is a mechanical, non-conventional machining method in which abrasive particles such as Silica sand, Garnet, Aluminum oxide, Silicon carbide etc are entrained in high speed waterjet to erode materials from the surface of material. About 90% of machining is done by using garnet as abrasive particle. In AWJM material removal take place by erosion induced by the impact of solid particles. Material removal occurs by cutting wear and deformation wear, cutting wear defines erosion at smaller impact angle. Deformation wear occur by repeated bombardment of abrasive at larger impact angle. Abrasive waterjet machined surface are grouped into three sections they are a) Initial damage region (IDR), b) Smooth cutting region (SCR) and c) Rough cutting region (RCR). [1]

During 60s the study of application of pure water for cutting was conducted by O. Imanaka, University of Tokyo, and by late 60's R. Franz of University of Michigan, analyze the cutting of wood using high velocity water jets. Main applications of pure waterjet machining include cutting paper products, wood, cloths, plastics etc. By the end of 1970's composites materials was introduced and its advantages such as high strength, low weight, resistant to heat, hard etc increase its use and applications, but there was no suitable method to machine such materials economically. Thus abrasive waterjet machine was made available at industries by 1980's to

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machine hard to machine materials. The abrasive water jet machine became commercially available by the end of 1983 and the various types of abrasives are garnet, silicon carbide, aluminum oxide, glass pieces etc. The added abrasives in the water jet increase the range of cutting materials, which can be cut with a Water jet drastically. [2]

Abrasive water jet machining is very much suitable for cutting soft, brittle and fibrous materials. AWJM is a unconventional machining process without much heat generation and the machined surface is virtually without any heat affected zone. The other advantages of abrasive waterjet machining over other unconventional machining are:

i) Rapid setup of the abrasive water jet cutting, ii) High accuracy of the components and features generated, extreme versatility of the system, iii) No heat generated during the process and above all, minimal kerf is obtained. Therefore, in this paper, a review of the contributions by important researchers on water jet machining using abrasives (AWJM) is presented. The idea of development of a abrasive water jet machining system is followed by identification of relevant processing parameters. The processing parameters, their importance and influence on the abrasive water jet machining system are finally compared and critically summarized to understand the process outputs as a function of input conditions.

2. LITERATURE SURVEY:

A.A. Khan and M.M. Hague [4] 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 aluminum 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.

M.A. Azmir, A.K. Ahsan [5] conducted a practical study for analyzing the surface roughness and kerf taper ratio of glass/epoxy composite laminate machined using abrasive water jet machine. The various process parameters considered are abrasive types (2-level), hydraulic pressure (3-level), standoff distance (3-level), abrasive flow rate (3-level), traverse rate (3-level), cutting orientation (3-level). The optimization of AWJM was done with the use of Taguchi method and ANOVA (analysis of varience). The ratio of top kerf width to bottom kerf width is called Kerf taper ratio. Types of abrasives and traverse speed are insignificant parameter for surface roughness while hydraulic pressure is most significant factor that influences surface roughness in AWJM. Standoff distance (SOD), cutting orientation and abrasive mass flow rate are equally significant factors that influence surface roughness, but the kerf taper ratios are influenced by hydraulic pressure, abrasive mass flow rate and cutting orientation. Abrasives type, standoff distance and traverse speed are most significant factors that had significant influences on kerf taper ratio. The quality of cutting in AWJM can be increased by increasing the kinetic energy of the water jet.

Ahmet Hascalilk, Ulas Aydas, Hakan Gurun [6] has carried out the study of effect of traverse speed on AWJM of Titanium alloy. The width of cutting, changes with changes in traverse speed.

The study also reveals that the kerf taper ratio and surface roughness increases with increases in traverse speed. The increase in traverse speed reduces the interaction of abrasives particles and the work piece thus narrow kerf widths with a greater kerf taper ratio can be cut with AWJM.

J. John Rozario Jegaraj, N. Ramesh Babu [7] worked on 6063-T6 aluminum alloy to find efficient strategy and quality cutting of materials with abrasive water jets considering the variation in orifice and focusing nozzle diameter in cutting. The study found that the effect of orifice size and focusing nozzle diameter on depth of cut, material removal rate, cutting efficiency, kerf geometry and surface roughness. The study suggested that a ratio of 3:1 between focusing nozzle diameter to orifice size was best suited combination to achieve the maximum depth of cut out of several combinations of focusing nozzle to orifice size. They suggest that the ratio of 5:1 and beyond cause ineffective entrainment of abrasives in cutting head. The investigation also analyze that the increase in hydraulic pressure for different combinations of orifice and focusing nozzle size the depth of cut increases. The material removal rate also increases with an increase in the size of focusing nozzle up to 1.2 mm diameter and further increase tends to decrease the material removal rate. The abrasive flow rate has less significant on kerf width. This study suggests that taper of kerf can be minimized by maintaining the orifice size and focusing nozzle size within certain limits raging from 0.25–0.3 mm and 1.2 mm, respectively. The surface quality does not depend on the increase in the size of orifice and focusing nozzle but larger size of orifice, produce a better surface finish on cut surface.

J. Wang, W.C.K. Wong [8] 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 analyzing 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 a 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.

Mohemed Hashish [9] 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 thn 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.

H. Hocheng and K.R. Chang [10] 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.

Mahabalesh Palleda [11] investigated the influence of the different chemical such as acetone, phosphoric acid and polymer (polyacrylamide) in the ratio of 30% chemicals with 70% of water. He also analyzes the effect of standoff distance on the taper angles and material removal rates (MRR) of drilled holes in the abrasive water jet machining process. It found that the Material removal increases with slurry added with polymers compare to the other three slurries. The study also reveals that the MRR increase with increase of standoff distance, because momentum of impacting abrasive particles on the work surface creating craters of more depth. As the standoff distance increase the taper holes of drilled holes decreases. The use of phosphoric acid combination and the slurry with acetone combination with slurry observes less taper in drilled holes than with the plain water slurry. Taper in drilled holes are almost nill by using polymer additives. The study also found that the material removal rate increases with increase in chemical concentration of acetone and phosphoric acid in the slurry up to a certain limit and then decreases. In case of polymer with the slurry the material removal is found to increases continuously.

P K Ray and Dr A K Paul [12] had investigated the effect of air pressure, grain size and nozzle diameter on material removal rate. MRR is found to increases 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.

Alberdi, A. Suarez, T. Artaza, G.A. Escobar-Palafox, K. Ridgway, [13] studied the behavior of a machinability model in composite materials. The machinability index of different composite materials is very different, so they have to be studied separately. The machinability index may be related to the tensile modulus and/or to the fibre content of the composite materials, but still now there is no solid evidence to relate mahinability index with the material property and researches are required to relate the machinability index with the material properties. The separation speed has to be re-defined for this kind of material as the traverse rate at which the material can be cut without delamination.

C. Ma, R. T. Deam [14] studied the kerf geometry of cut in abrasive waterjet machining using an optical microscope. The kerf width developed on the work has shown that there are two regions, called the developing stage and the fully developed stage. The first region is the developing stage, and it ends after about 2 mm of the cutting depth. The developing stage is due to the velocity profile of the jet changing from a uniform profile to a fully developed flow in a groove. The velocity profile developed is similar to the velocity profile developed when flow enters a pipe from a large tank.

In the second section, the fully developed stage which starts from 2 mm to the cutting depth and the cutting width varies with depth, depending on the cutting speed. The kerf width increases with low cutting speed and narrows down at high cutting speeds.

M. Chithirai Pon Selvan, Dr. N. Mohana Sundara Raju, Dr. R. Rajavel [15] 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.

3.SUMMARY:

The investigation on various process parameters of AWJM shows that MRR increases with increase in water pressure, but the major drawback is that the surface roughness and sub-surface damage increases with increase in pressure. Types of abrasives and traverse speed also effects the various quality parameters of work part. See Table 1 for a comparative analysis and a summary of results.

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	Taper of cut	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							
WORK FEED RATE	Increases						↑	↓
	Decreases							

4.CONCLUSIONS:

Quality of cutting surface in AWJM is depending on so many process parameters. Process parameter which affect less or more on quality of cutting in AWJM are hydraulic pressure, Standoff distance, types of abrasive, size of abrasives, abrasive flow rate, nozzle diameter, orifice size, and traverse speed. Quality of cutting surface is measured by material removal rate, surface roughness, kerf width, kerf taper ratio. From the literature review compare to above all mentioned parameter traverse speed is most effective parameter for MRR. Abrasive flow rate is also an important parameter for increasing MRR. But beyond some limit with increase in abrasive flow rate and traverse speed the surface roughness decreases. Increasing traverse speed also increase the kerf geometry. So it is required to find optimum condition for process parameter to give better quality of cutting surface. Traverse speed is directly proportional to productivity and should be selected as high as possible without compromising kerf quality and surface roughness.

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