Abrasive Water Jet Machining – The Review

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ABSTRACT

Abrasive water jet machining (AWJM) is a relatively new machining technique. Abrasive Water Jet Machining is extensively used in many industrial applications. AWJM is a non-conventional machining process where material is removed by impact erosion of high pressure high velocity of water and entrained high velocity of grit abrasives on a work piece. There are so many process parameter affect quality of machined surface cut by AWJM. Important process parameters which mainly affect the quality of cutting are traverse speed, hydraulic pressure, stand of distance, abrasive flow rate and types of abrasive. Important quality parameters in AWJM are Material Removal Rate (MRR), Surface Roughness (SR), kerf width, tapering of kerf. This paper reviews the research work carried out so far in the area AWJM.

Keywords*:* AWJM, Kerf width, MRR, surface roughness, traverse speed**1.**

INTRODUCTION

AWJM is a well-established non-traditional machining process. Abrasive water jet machining makes use of the principles of both abrasive jet machining and water jet machining. AWJM is a non-conventional machining process where material is removed by impact erosion of high pressure high velocity of water and entrained high velocity of grit abrasives on a work piece [1].

In the early 60's O. Imanaka, University of Tokyo applied pure water for industrial machining. In the late 60's R. Franz of University of Michigan, examine the cutting of wood with high velocity jets. The first industrial application manufactured by McCartney Manufacturing Company and installed in Alto Boxboard in 1972. The invention of the abrasive water jet in 1980 and in 1983 the first commercial system with abrasive entrainment in the jet became available. The added abrasives increased the range of materials, which can be cut with a Watergate drastically. [2]

This technology is most widely used compare to other non-conventional technology because of its distinct advantages. It is used for cutting a wide variety of materials ranging from soft to hard materials. This technique is especially suitable for very soft, brittle and fibrous materials. This technology is less sensitive to material properties as it does not cause chatter. This process is without much heat generation so machined surface is free from heat affected zone and residual stresses. AWJM has high machining versatility and high flexibility. The major drawback of this process is, it generate loud noise and a messy working environment [1].

AWJM have certain advantageous characteristics, which helped to achieve significant penetration into manufacturing industries. [3]

- Extremely fast set-up and programming
- Very little fixturing for most parts
- Machine virtually any 2D shape on any material
- Very low side forces during the machining
- Almost no heat generated on the part
- Machine thick plates

AWJM is normally used for Paint removal, Cutting soft materials, Cutting frozen meat, Mass Immunization, Surgery, Cutting, Nuclear Plant Dismantling, Pocket Milling, Drilling, Turning, Textile, Leather industry.

Materials which are cut by AWJM are Steels, Non-ferrous alloys, Ti alloys, Ni- alloys, Polymers, Honeycombs, Metal Matrix Composite, Ceramic Matrix Composite, Concrete, Stone – Granite, Wood, Reinforced plastics, Metal Polymer Laminates, Glass Fibre Metal Laminates

2. LITERATURE SURVEY

H. Hocheng and K.R. Chang [4] has carried out work on the kerf formation of a ceramic plate cut by an abrasive water jet. There is a critical combination of hydraulic pressure, abrasive flow rate and traverse speed for through- out cut 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 they find kerf width increases with pressure increase, traverse speed increase, abrasive flow rate increase and abrasive size increase. Taper ratio increases with traverse speed increases and decreases with pressure increases and abrasive size increases. Taper ratio has no effect with increase in abrasive flow rate.

Cutting results	Cutting parameters			
	Pressure ↑	Traverse speed ↑	Abrasive flow rate ↑	Abrasive size ↑
Kerf width	↑	↓	↑	↑
Taper ratio	↓	↑	x	↓
Surface roughness	x	↑	↓	↑
Material removal rate	↑	↑	↑	↑
Through-cut capability	↑	↓	↑	↑

(↑) Increase; (↓) decrease; (x) not obvious.

Table 1: Comprehensive result of the present paper

M.A. Azmir, A.K. Ahsan [5**]** had done a practical for surface roughness and kerf taper ratio of glass/epoxy composite laminate machined by AWJM. They considered six process parameters of different level and use Taguchi method and ANOVA (analysis of variance) for optimization. Parameter used are abrasive types (two-level), hydraulic pressure (three-level), standoff distance (three-level), abrasive flow rate (three-level), traverse rate (three-level) , cutting orientation (three-level). Kerf taper ratio is the ratio of top kerf width to bottom kerf width. Types of abrasives and traverse rate are insignificant for surface roughness while hydraulic pressure is most significant for that. Standoff distance, cutting orientation and abrasive mass flow rate is equally significant for surface roughness. For kerf taper ratio hydraulic pressure, abrasive mass flow rate and cutting orientation are insignificant. Types of abrasives are most significant for kerf taper ratio while Standoff distance and traverse rate are almost equally significant for that. By increasing the kinetic energy of AWJM process better quality of cut produce.

Ahmet Hascalik, Ulas Aydas, Hakan Gurun [6] has carried out study on effect of traverse speed on abrasive water jet machining of Ti–6Al–4V alloy. They perform practical by varying traverse speeds of 60, 80, 120, 150, 200, and 250 mm/min by abrasive water jet (AWJ) machining. They studied the effect of traverse speed on the profiles of machined surfaces, kerf geometries and microstructure features of the machined surfaces. The traverse speed of the jet is a significant parameter on the surface morphology. The features of different regions and widths in the cutting surface change with the change in traverse speed. They also found that kerf taper ratio and surface roughness increase with traverse speed increase in chosen condition. This is because the traverse speed of abrasive water jet allows fewer abrasives to strike on the jet target and hence generates a narrower slot. They identify three different zone in cutting surfaces of samples are (1) an initial damage region (IDR), which is cutting zone at shallow angles of attack; (2) a smooth cutting region (SCR), which is cutting zone at large angles of attack; (3) a rough cutting region (RCR), which is the jet upward deflection zone.

A.A. Khan, M.M. Hague [7] analyse the performance of different abrasive materials during abrasive water jet machining of glass. They make comparative analysis of the performance of garnet, aluminium oxide and silicon carbide abrasive in abrasive water-jet machining of glass. Their hardness of the abrasives was 1350, 2100 and 2500 knoops, respectively. Hardness is an important character of the abrasives that affect the cut geometry. The depth of penetration of the jet increases with the increase in hardness of the abrasives. They compare the effect of different of abrasive on taper of cut by varying cutting parameter standoff distance, work feed rate, pressure. It is found that the garnet abrasives produced the largest taper of cut followed by aluminium oxide and silicon carbide abrasives. For all kinds of abrasives, the taper of cut increases with SOD. For all the types of abrasives used taper of cut decreases with increase in jet pressure. Taper of cut is smaller for silicon carbide abrasives followed by aluminium oxide and garnet.

J. John Rozario Jegaraj, N. Ramesh Babu [8] had worked on strategy for efficient and quality cutting of materials with abrasive water jets considering the variation in orifice and focusing nozzle diameter in cutting 6063-T6 aluminium alloy. They found the effect of orifice size and focusing nozzle diameter on depth of cut, material removal rate, cutting efficiency, kerf geometry and surface roughness. The ratio of 3:1 between focusing nozzle diameter to orifice size was suggested as the best suited combination out of several combinations of focusing nozzle to orifice size in order to achieve the maximum depth of cut in cutting they suggest the ratio of 5:1 and beyond cause ineffective entrainment of abrasives in cutting head. It is noticed that with an increase in hydraulic pressure for different combinations of orifice and focusing nozzle size the depth of cut increased. The material removed increased with an increase in the size of focusing nozzle up to 1.2 mm diameter but with further increase it is reduced. The abrasive flow rate is found to be less significant on kerf width. This study suggests maintaining the orifice size and focusing nozzle size within certain limits say 0.25–0.3 mm and 1.2 mm, respectively, for maintaining less taper on kerf. Any increase in the size of orifice and focusing nozzle is not much effect the surface quality but larger size of orifice produce a better surface finish on cut surface

J. Wang, W.C.K. Wong [9] had done study of abrasive water jet cutting of metallic coated sheet steels based on a statistically designed experiment. They discussed relationships between kerf characteristics and process parameters. They produce empirical models for kerf geometry and quality for the prediction and optimization of AWJ cutting performance. They perform three-level four-factor full factorial designed experiment. Process parameter used are water jet pressure, traverse speed, abrasive flow rate and standoff distance. The top and bottom kerf widths increase as the water pressure increase. The top and bottom kerf widths increase as the standoff distance increase but the rate of increase for the bottom kerf width is smaller. The traverse speed produces a negative effect on both the top and bottom kerf widths but the kerf taper increase as the traverse speed increase. The surface roughness decreases with an increase in the abrasive flow rate. They show the burr height steadily decreases with a decrease in the traverse speed.

	Water pressure	Standoff distance	Abrasive flow rate	Traverse speed
Kerf width	increase	increase	not significant	decrease
Kerf taper	not significant	increase	not significant	increase
Surface roughness	with a minimum	increase	decrease	increase
Burr height	decrease	increase	not significant	increase

Table 2: Kerf characteristics in terms of process parameters

Mahabalesh Palleda [10] investigated the effects of the different chemical environments like acetone, phosphoric acid and polymer (polyacrylamide) in the ratio of 30% with 70% of water and stand off distance on the taper angles and material removal rates of drilled holes in the abrasive water jet machining process. Material removal is highest when slurry added with polymer compare to three slurries. MRR increase with increase of stand off distance because momentum of impacting abrasive particles on the work surface creating craters of more depth. Taper holes of drilled holes reduce as the stand off distance increase. Taper holes observed less in case of phosphoric acid combination with slurry than the plain water slurry and the slurry with acetone combination. Taper observed in case of polymer is almost nil. The material removal rate is increasing with increase of chemical concentration of acetone and phosphoric acid in the slurry up to a certain level and then reducing. In case of polymer with the slurry in material removal increases continuously. the taper of the hole is less in phosphoric acid combination compare to acetone combination. In polymer combination taper of the hole is very less or almost nil.

P K Ray and Dr A K Paul [11] had investigated that the MRR increases with increase of air pressure, grain size and with increase in nozzle diameter. MRR increases with increase in stand off distance (SOD) at a particular pressure. They found after work that initially MRR increases and then it is almost constant for small range and after that MRR decreased as SOD increases. They 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 decreases 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 number of inter particle collisions and hence more loss of energy.

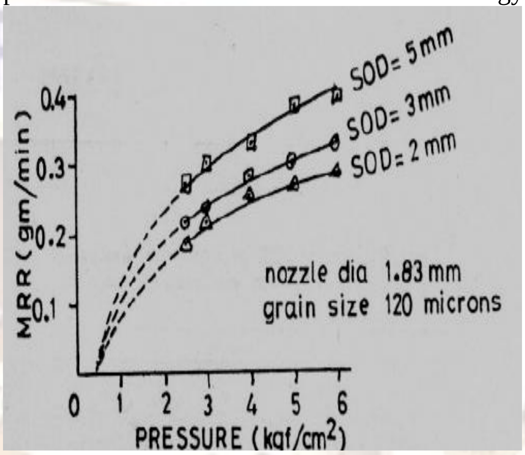

Figure 1: **MRR** vs pressure at grain size 120 micron

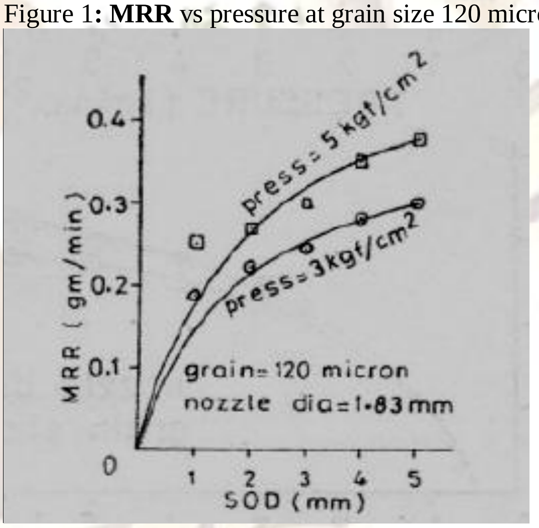

Figure 2: MRR vs SOD

3. SUMMARY

So many investigations had done on AWJM process. MRR or production is improved by improving the traverse speed but major problem with increasing traverse speed is that surface roughness and kerf quality are decreased. Types of abrasive and abrasive flow rate are also affect the MRR. By increasing abrasive flow rate MRR is increased but it decrease the surface roughness.

4. CONCLUSION

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, Stand off 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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