Experimental Study of Process and Response Parameters in Abrasive Water Jet Machining of Aluminium and Mild Steel Workpiece

Anil Jindal, Sandeep Sangwan, Munish Kainth

Abstract— **Abrasive water jet machining is one of the major recent non conventional machining processes. Abrasive water jet machining used to machine the variety of materials from tough to soft. In our experimental study, the process parameters are taken as jet pressure, speed, stand-off distance and abrasive flow rate. The response parameters are Surface roughness and depth of cut. The materials used in this study are aluminium and mild steel work pieces. The result of experimental study reveals that the increase in jet traverse speed increases the surface finishing quality. The increase in abrasive flow rate increases the material removal rate and depth of cut but also has the adverse effect on the surface finishing quality.**

Index Terms— **Abrasive, Depth of cut, Pressure, Speed, Surface roughness.**

I. Introduction

Abrasive water jet machining is used to accomplish the material removal from the work piece without any contact between tool and work piece. The abrasive particles like sand (SiO_2), wineglass beads be added to water jet to improve its cutting ability. The abrasive particles are allowed to mix with the water jet to form an abrasive water jet with high velocity of 850 m/s. Such elevated velocity abrasive water jet can machine tough material easily. The cutting capability of abrasive water jet machining can be improved by adding abrasive particles into water jet. The abrasive water jet machining finds the suitable applications in paint removal, cleaning process, medical surgery, peening to remove unwanted residual stress, pocket milling process, turning, drilling process etc. The abrasive water jet machining can also be utilized in dismantle of nuclear power plants using advanced robotics technology. Since the majority of the metal cutting techniques produce high heat affected zones (HAZ), this system is free from heat affected zones (HAZ). In abrasive water jet machining, water is accelerated in the form of high kinetic energy and impacted to attain the superior elimination of the work piece material. The process is eco-friendly and has extensive applications. In Fig. 1, theabrasive water jet machining cutting top is shown used to accomplish the machining by means of the high pressure abrasive water jet into the work piece. In Fig. 2, the method utilizing the kinetic energy of abrasive water jet is shown which is impacted to the work piece eliminating the unnecessary material. In the Fig. 3, the machining arrangement is shown

Fig. 1 Abrasive water jet machining cutting head

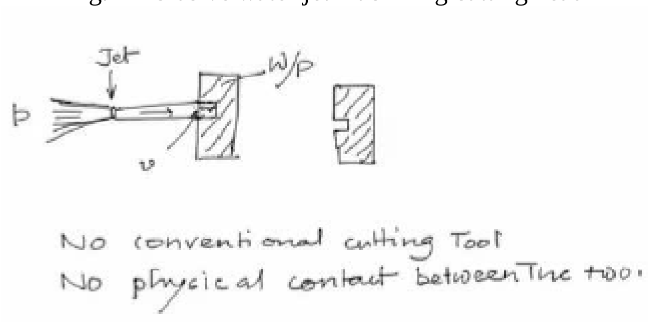

Fig. 2 Abrasive water jet machining process

which describe every component attached to the arrangement performing the exact task. The liquid supply division supplies the fluid water which is strained up by the pump and intensifier which pump the water to a collector where very high pressure of the water is formed and this under pressure water is permitted to flood into the nozzle through the control mechanism. Control valve is used to assist the operator to sustain quantity of water and to maintain the pressure of the water being flown into the nozzle system. This is where the pressure energy gets converted into the mechanical energy and the water at high pressure flow through the nozzle and will acquire the very high velocity. High pressure will be transformed into the high velocity as it comes out from the nozzle impacting on the work piece causing machining. Nevertheless, to improve the machining effectiveness, the abrasives are introduced in the water making abrasive water mixture for improved machining. The major components of AWJM are following:

Anil Jindal, Master of Technology Scholar, Mechanical Department, Universal Group of Institutes (UGI), Lalru, Punjab

Sandeep Sangwan, Head of Department, Mechanical Department, Universal Group of Institutes (UGI), Lalru, Punjab

Munish Kainth, Assistant Professor, Mechanical Department, Universal Group of Institutes (UGI), Lalru, Punjab

1. Pump
2. The Accumulator
3. The Intensifier
4. High pressurized tubing system
5. Nozzle
6. Orifice
7. Control system
8. Drain

To reach the pressure in the range of 5000-6000 bar in the pump, an electric motor of 60 HP rating is used. The intensifier collect the water at small pressure and discards it through a collector. It works through the hydraulic operational device. High pressure tubing is about 6 to 14 mm in diameter. It permits elastic movement of the cutting head. The jet cutting nozzle is utilized to translate the high pressure jet into the high velocity jet. Abrasive particles such as silicon carbide are added in the pressurized water for the additional material removal rate. The abrasives are discretely mixed in the nozzle with the water stream making it split from the water jet machining process in which only pure water is utilized for cutting means. The abrasive water jet cutting process is appropriate for machining diverse types of material from hard breakable ceramics to soft materials like rubber.

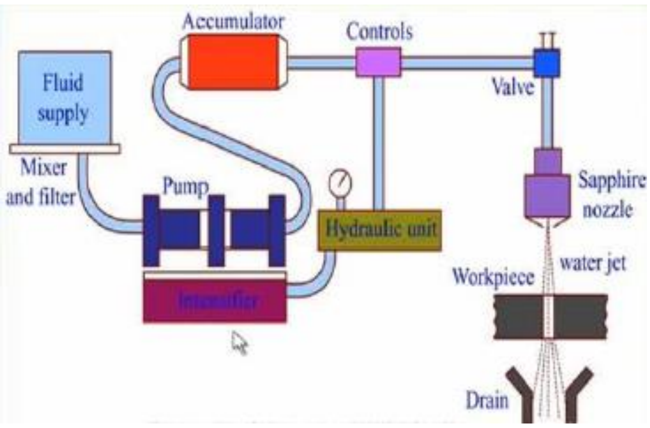

Fig. 3 Abrasive water jet machining setup

Experimental Procedure

Before experimental study, a trial and error method was utilized to attain finest process parameters. On the basis of which the different levels were considered for experimentation use.

Table 1
Process parameters with their levels considered for experimentation purpose

Abbreviation	L1	L2	L3	L4	L5
WP	5000	5250	5500	5750	6000
AFR	10	12.5	15	17.5	20
TS	1	2.5	4	5.5	7
SOD	5	8	11	14	17

Where, WP = Water pressure
AFR=Abrasive flow rate,
TS=Traverse speed,
SOD=Stand-off distance.

The sample was fixed in wooden block for machining with the use of cutting stand and RO unit.

Table 2
Specification of components of AWJM

S. No.	Components	Specification
1	Cutting table	1m x 1m
2	Nozzle tip diameter	0.76 mm
3	Controller	Siemens 702D Senumerik
4	Pump	KMT streamline pro-II, 60 HP
5	Abrasive feeder	Abraline II, KMT
6	RO unit	Purfeel 400 LPH

In the testing, water pressure, abrasive flow rate, traverse speed and SOD (stand-off distance) altered ranging 4000-5000 bar at 250 bar interval, 10 gm/min-20 gm/min at an 2.5 gm/min interval, 1mm-7mm at an interval of 1.5 mm and 5mm-17 mm at an interval of 3 mm respectively. The tungsten carbide focus tube with internal diameter of 0.66 mm was used for 10 operations to lessen the effect of incremental nozzle diameter by SiC particle abrasives. The succession of machining action was programmed by an advanced software CAM and the surface roughness (R_a) was calculated by the non-contact type profiler.

II. Results and Discussions

Surface roughness help in formative how rough a work piece material is machined. In all the investigation, it is established that machined surface becomes rougher towards the jet exit and is smoother close to the jet entrance. This is owing to the fact that as the particle moves down they drop their kinetic energy with cutting ability fading. By analyzing, it has been found i.e. water pressure, abrasive flow rate, nozzle traverse speed and stand-off distance are especially important parameters on calculating the response such as surface roughness.

Effect of water pressure on surface roughness

The effect of water pressure on the surface roughness is shown in Fig. 4. As the jet pressure increase, surface becomes rougher. With increase in jet pressure, brittle abrasives break down into minor ones which again eat away the inner surface of the material. With the drop of size of the abrasives the surface becomes rougher. Due to boost in jet pressure, the kinetic energy of the particle increases which outcome in smoother machined surface.

Effect of abrasive flow rate on surface roughness

With the increase in abrasive flow rate, surface roughness decrease for the reason that of more amount of impacts and cutting edges existing per unit area with the elevated abrasive flow rate. Abrasive flow rate determine the capacity of impacting abrasive particles as well as total kinetic energy available. Therefore, higher abrasive flow rate, high should be cutting capability of the jet.

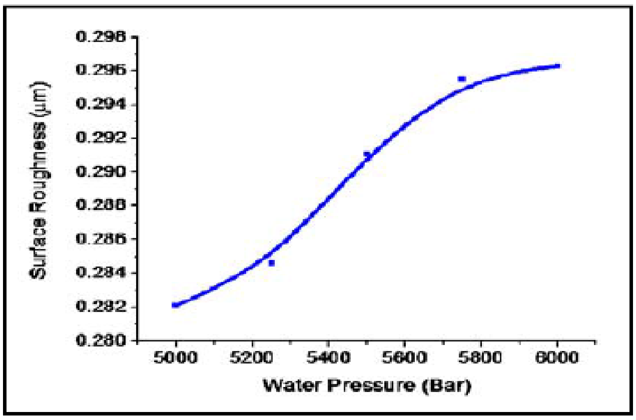

Fig. 4 Surface roughness Vs Water pressure in case of aluminium work piece

But for higher abrasive flow rate, abrasives smash together and drop their kinetic energy. It is established that the surface is smoother close to the jet entry and steadily the surface roughness decrease towards the jet outlet. The cause of abrasive flow rate on surface roughness is given away in Fig. 5.

Effect of traverse speed on surface roughness

Traverse speed didn't illustrate a tough influence on surface roughness of aluminium. But with increase in work feed rate the surface roughness increased. This is owing to the information that as the nozzle moves more rapidly, less amount of particles are existing for non homogeneous cut on the surface.

Effect of stand-off distance on surface roughness

Surface roughness increases with increase in stand-off distance in case of aluminium work piece because the elevated stand-off distance allows the jet to enlarge before impingement.

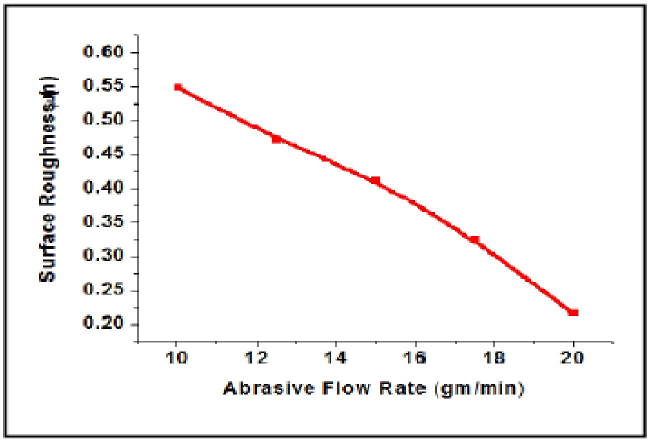

Fig. 5 Surface roughness Vs Abrasive Flow rate in case of aluminium workpiece

Therefore, increase in stand-off distance outcome in an increased jet diameter as cutting is initiate ensuing in reduction of the kinetic energy of the jet at the impingement. So, surface roughness increases with the increase in stand-off distance. It is advantageous to have low stand-off distance which might generate a smoother surface due to enhanced kinetic energy. The machined surface is smoother near the top of the surface and becomes rougher at depths from the top surface.

From the parametric studies on surface roughness (R_a) of cut edge, it is practical that the better surface finish (R_a) 0.2921 µm is obtain at 5000 bar water pressure in case of aluminium work piece.

Effect on the mild steel work piece

In case of mild steel work piece, depth of cut decreases with rising traverse speed and decreasing abrasive size as shown in the Fig. 6. On the other hand, increase of the abrasive mass flow rate and water pressure outcome in increase in depth of cut. The water from the abrasive jet has an inclination to acquire into the micro cracks causing the hydrodynamic pressure which causes the crack enlargement. When the micro crack grows the material lose from the parent material and depth of cut increases. So, it can be recognized that longer is the moment of abrasive water jet maintaining on the work piece, extra will be the depth of cut in case of mild steel work piece since the stream of jet will contain the enough time to cut the material, though, increase in abrasive mass flow rate also increases the depth of cut. It was investigated by maintaining the pressure, traverse speed and SOD at stable.

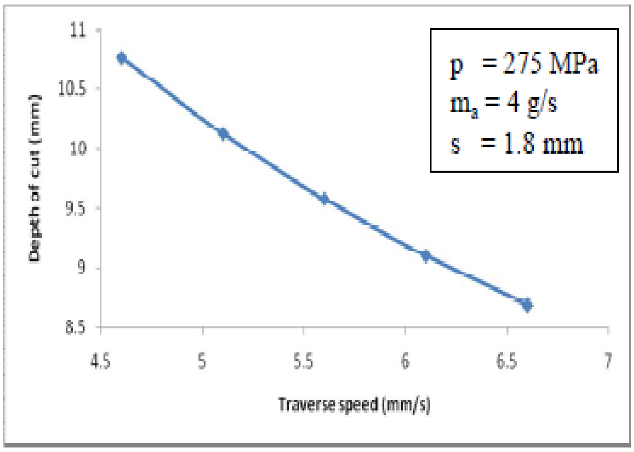

Fig. 6 Depth of cut Vs Traverse speed in case of mild steel work piece

The impact between the abrasive particle and material determine the capability of the abrasive water jet to slice the material.

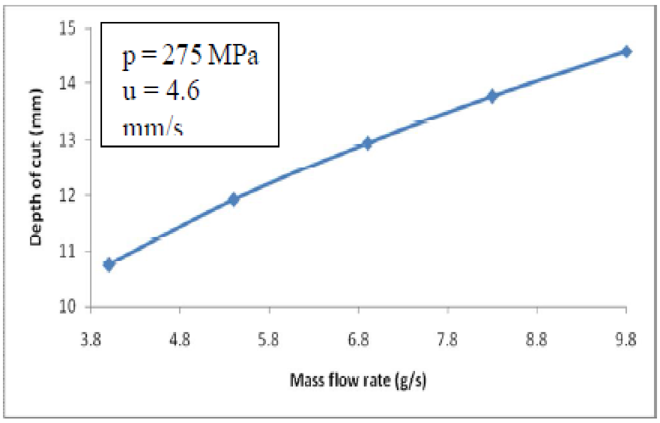

Fig. 7 Depth of cut Vs Mass flow rate in case of mild steel workpiece

The traverse rate is a significant factor as abrasive mass flow rate. With an increasing speed of abrasive cutting head the taper increases. The smaller speed be, the longer abrasive water jet leftovers at the high erosion base location, cause the flow having the more moment in time to cut the work piece. The regression examination is applied in order to build up the response surfaces. Roughness average as a function of feed rate and material thickness for steady value of abrasive flow rate of 300 g/min is given in Fig. 8. This three dimensional surface plot

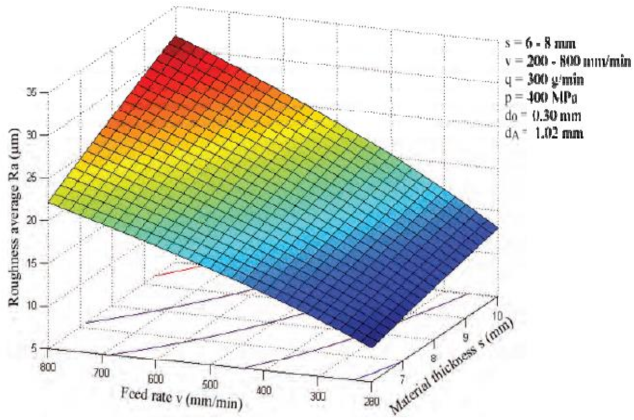

Fig. 8

Predicted typical roughness at a function of feed rate (mm/min) and material thickness (mm) under given situation shows predicted cut surface roughness at a function of free variable factors. The water and abrasives phases after addition achieve the same velocity as of abrasive water jet.

Conclusions

1. In case of aluminium workpiece, the raise in water pressure increases the surface roughness.
2. With the increase in abrasive flow rate, the surface roughness decrease for aluminium workpiece.
3. The boost in traverse speed and decreasing abrasive size results in the decrease of depth of cut for mild steel workpiece.
4. On maintaining the abrasive water jet for longer time on the mild steel workpiece, the depth of cut increase.
5. The increase in mass flow rate increases the depth of cut in case of mild steel workpiece.
6. From the parametric study on surface roughness (R_a) of cut edge, it is practical that the superior surface finish (R_a) 0.2921 µm is obtained at 5000 bar water pressure in case of aluminium workpiece.
7. Surface roughness increases with increase in stand-off distance in case of aluminium workpiece.
8. The traverse rate is more susceptible factor as abrasive mass flow rate.
9. With an increasing speed of abrasive cutting top the taper increases.
10. The slighter speed is, the longer abrasive water jet remains at the higher erosion base site, and then the stream has the more time to wear away the workpiece.
11. The collision between the abrasive particle and material determines the ability of the abrasive water jet to cut the material.
12. The water and abrasives phases after combination attain the same velocity as of abrasive water jet.

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