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Influence of Abrasive water jet machining parameters on surface roughness & Material removal rate on different engineering materials- A Review

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Abstract —*Abrasive water jet cutting is widely used in manufacturing sector like aerospace industry, automobile industry, Nuclear plant dismantling etc. Current trends focuses on minimization of cost in each sector which can be directly related with MRR of different materials. Solution to this can be obtained by combination of manufacturing processes and optimization techniques in which maximize or minimize the process parameters which gives measurable effect MRR. This paper reviews the research work approved out from the inception to the development of AWJM within the previous decade. It reports on the AWJM research concerning to improving performance measures, monitoring and control of process, optimizing the process parameters. A comprehensive range of AWJM industrial uses for diverse category of material are described with variations. The paper also confers the future development of research work in the area.*

Keywords-*Abrasive water jet machining,Process optimization, Monitoring,Metal Removal Rate, Surface Roughness, optimization Techniques.*

I. INTRODUCTION

Non traditional methods refer to the process or group of processes which are used to remove the extra or unwanted material from the base material. Non traditional machining involved mechanical, thermal, electrical or combination of these energies for metal removal process. Generally the ultimate aim of the non traditional machining is to provide effective, efficient and economical solution for the manufacturing process.

Abrasive water jet cutting is advanced type of water jet cutting in which the mechanical energy of the water and abrasive particles are used for metal removal process. The abrasive particles are made up of silicon carbide, Aluminium oxide for increasing the material removal rate. By using abrasive water jet cutting process we can cut extreme soft as well as very hard material also of any shape, size and dimensions. This machining process is mostly suitable for material removal where the material is not removed by any simple traditional machining process or laser or thermal process.It is also an environmentally friendly technique that can be adopted for processing number of engineering materials particularly difficult-to-cut materials. However, AWJM has some limitations and drawbacks. It may generate loud noise and a messy working environment. It may also create tapered edges on the kerf characteristics, especially when cutting at high traverse rates. This paper is based on the study of parameters used in the abrasive water jet cutting. Analyzing and optimizing the process parameters, thus one can find optimized parameters for this process. In this review paper we tried to gather various peoples study on parameter optimization in abrasive water jet cutting. The objective of this paper will be helpful as guideline and more correct way to perform the research work.

1.1 ABJW Process Definition

A typical abrasive water jet system includes main four components: (1) the water purifying and storage system. (2) High pressure generating system. (3) Cutting head and (4) Abrasive delivery system and catcher as shown in Figure 1.

The Water Purifying and Storage System

The water purifying and storage system is used for supplying pressure to ultrahigh pressure pump continuously.

High Pressure Generating System

This system is equipped with intensifier and accumulator to generate high pressure and storage of high pressure water respectively. Intensifier includes double acting reciprocating pump which is operated by oil pressure. Accumulator stores the high pressure water energy to reduce the pressure loss in next stage.

Cutting Head

The cutting head equipped with focusing tube, orifice, nozzle and mixing chamber. High pressure tube carries the pressured water from accumulator to cutting head through focusing tube. High pressure water passes through orifice which converts pressure energy of water into kinetic energy of water particle due to convergent shape of orifice. The high speed water jet then passes through a mixing chamber, which is directly connected to orifice. Water loses its pressure energy as it passes through mixing chamber due to venturi effect which creates vacuum in mixing chamber. In mixing chamber high energy of water particle transfers to abrasive particle then mixer of water and abrasive pass through nozzle with act as saw to cut the material.

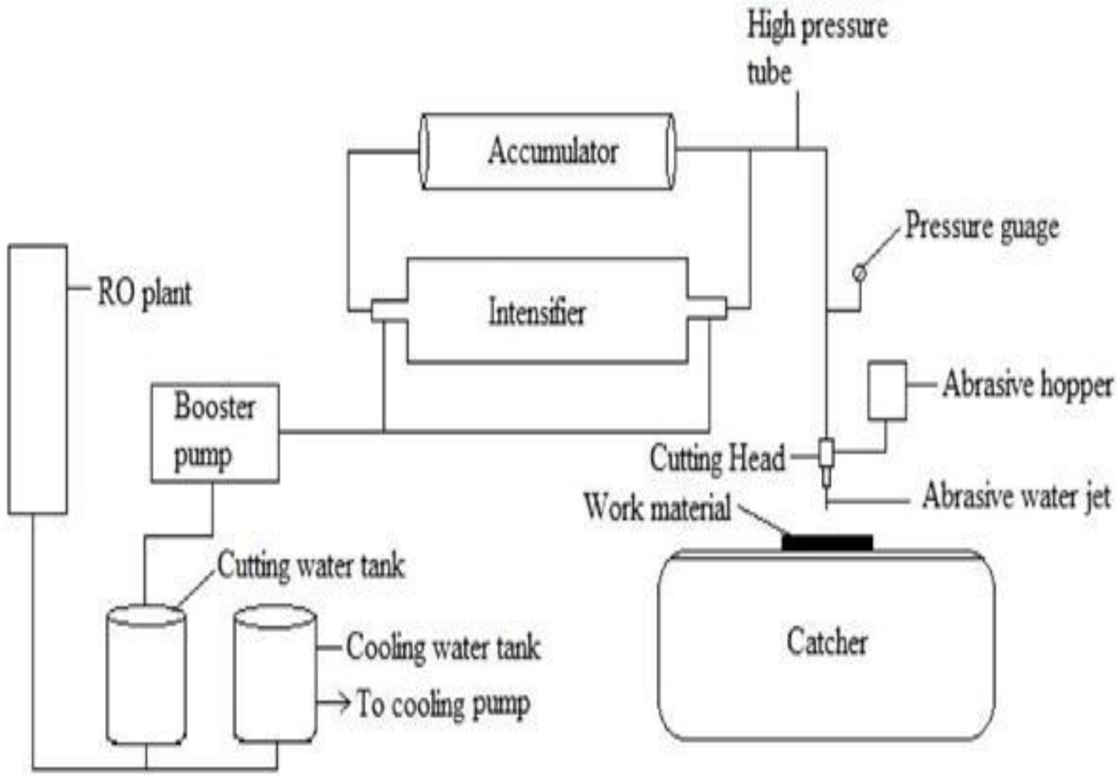

***Fig. 1 Abrasive water jet Machining process*[5]**

__Abrasive Delivery System and Catcher__

The abrasive delivery system includes abrasive hopper and pneumatically operated valve to control the abrasive mass flow rate.

2.2ABJW process parameters

Fig-2 Shows process parameters affecting Abrasive waterjet machining process.Some common process parameters affect the quality and nature of the machined surface and Material Removal Rate based upon its application. Surface roughness is one such parameter which determines the nature and quality of the machined surface. UsuallySurface roughness values determined according to the application of the machined surface. Surface roughness of the machinedsurface is normally affected by the following factors,

- Water pressure
- Standoff distance
- Abrasive mass flow rate
- Size of reinforced particle
- Time and cutting speed
- Traverse speed
- Feed rate

Cause and effect diagram or Ishikawa diagram, is a visualization tool for categorizing the potential causes of a problem in order to identify its root causes.Fig-3 Shows cause and effect diagrams of Abrasive water jet machining Process.

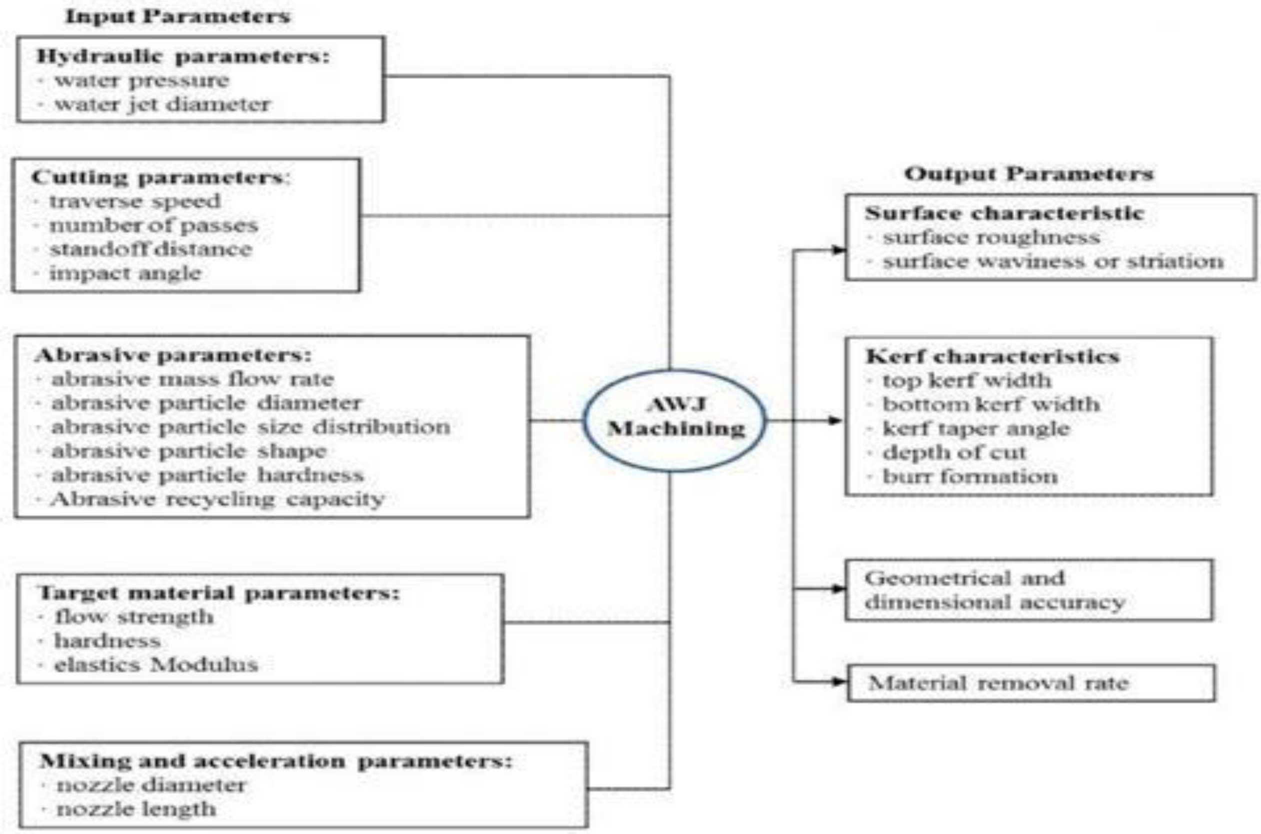

Fig 2 AWJM process parameters[9]

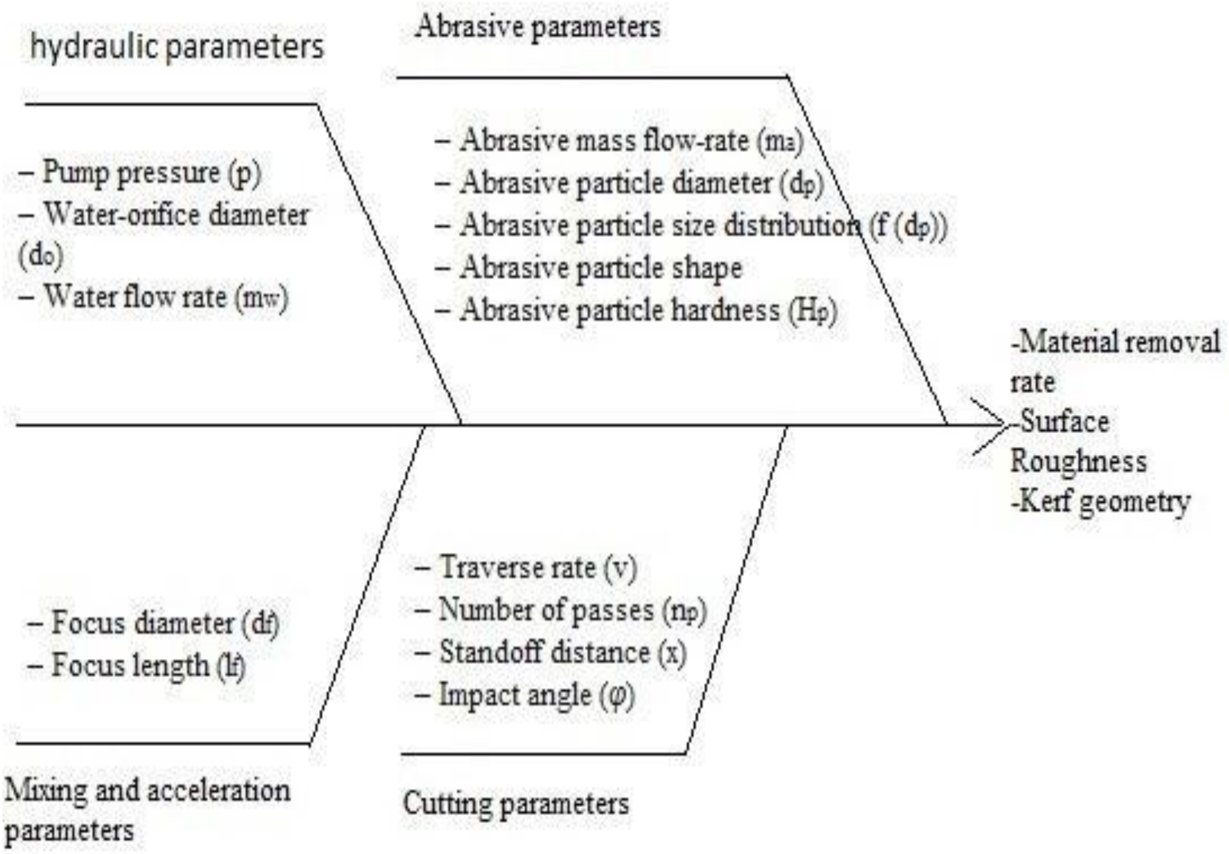

Fig 3 Cause and effect diagram of AWJM process parameters[7]

3.Literature Survey

J. Wang, W.C.K. Wonget al.[1] 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.

LeeladharNagdeve, VedanshChaturvedi, JyotiVimal et al.[2] performed experiment on Abrasive water jet machine to find out optimum process parameter for supreme Material removal rate and quality surface finish after cutting. Before this the work has performed in this field that Previous examination indicated even that through some efforts have been made to increase the material rate , the taper of the drilled holes was not being decrease. This effort has been made to amplify MRR and to decrease the taper by varying standoff distance with different chemical setting and chemical concentration. Methodology used is Taguchi approach L9 array, ANOVA & F-Test, they have taken four parameters Pressure, Stand of distance, Abrasive flow rate, Traverse rate, and T material for experimentation is Aluminum. Conclusions from this they got are, Pressure is the most important factor on MRR throughout AWJM, In case of surface Roughness Abrasive flow rate is most major control factor.

D. Sidda Reddy, A. Seshu Kumar, M.SreenivasaRaoet al [3] had conducted the experimental research of process parameters effect on material removal rate & surface roughness of the machined component. The process parameters are Traverse rate, Abrasive flow rate and Standoff distance by using ANOVA, F test.With the help of S/N ratio.Authors have got the optimum combination of parameters for maximum material removal rate and surface roughness and Traverse Speed plays a major part on impelling material removable rate and In case of surface Roughness Standoff distance and Transverse speed plays major implication.

M. Chithiraiponselvan, N Mohanasundararaju, H.K.sachidanandaet al [4] have done experiment on Aluminium Material For the effect of process parameters on surface roughness which is a significant cutting performance measure in abrasive water jet cutting of aluminium. Taguchi's design of experiments was agreed in order to gather surface roughness values. Experiments were conducted in varying water pressure, abrasive flow rate, nozzle traverse speed, and standoff distance for cutting aluminium using abrasive water jet cutting method. Conclusions which they got are pressure is the most effective factor in improving and reducing the surface roughness quality, as the pressure increases the surface roughness decreases. Abrasive flow rate is the second most significant factor.

Ahmet Hascalik, Ulas Aydas, Hakan Gurun et al [5] 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.

H. Hocheng and K.R. Changet et al [6] 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.

M.A Azmir and A.K Khan et al[7] studied that the influence of abrasive water jet machining (AWJM) process parameters on surface roughness (Ra) of glass fiber reinforced epoxy composites. It was found that the type of abrasive materials, hydraulic pressure, standoff distance and traverse rate were the significant control factors and the cutting orientation was the insignificant control factor in controlling the Ra.They finally concluded that Abrasive types is the most significant controlling factor on surface roughness(Ra), hydraulic pressure and traverse rate are the equally significant factor while Standoff distance, abrasive material flow rate and cutting orientation are the insignificant factor.

Samir Kumar PANDA,Saumyakant PADHEE,et al [8] done experimental work on five important process parameters of FDM such as layer thickness, orientation, raster angle, raster width and air gap to study their effects on three responses viz., tensile, flexural and impact strength of test specimen Of material acrylonitrile butadiene styrene (ABS P400) by using central composite design (CCD) and empirical models relating each response and process parameters have been developed and models are validated using analysis of variance (ANOVA).After that they appliedbacterial foraging technique to suggest theoretical combination of parameter settings to achieve good strength simultaneously for all responses.They finally came to conclusion after experimental work thatIf number of layers is more, it will result in high temperature gradient towards the bottom of part. This will increase diffusion between adjacent rasters and strength will improve. Small raster angles are not preferable as they will results in long rasters which will increase the stress accumulation along the direction of deposition resulting in more distortion and hence weak bonding. Thick rasters results in high temperature near the boding surfaces which may improve the diffusion and may result in strong bond formation. And this study can also extended in the direction of studying compressive strength, fatigue strength and vibration analysis.

P. P. Badgujar, M. G. Rathi et al [8] optimize the input parameters of AWJM, such as pressure within pumping system, abrasive material grain size, stand-off distance, nozzle speed and abrasive mass flow rate for machining SS304. The Taguchi design of experiment, the signal-to noise ratio, And analysis of variance are employed to analyze the effect of the input parameters by adopting L27 Taguchi orthogonal array (OA). In order to achieve the minimum surface roughness (SR), five controllable factors, i.e. the parameters of each at three levels are applied for determining the optimal combination of factors and levels. The results reveal that the SR is greatly influence by the abrasive material grain size. Experimental results affirm the effectiveness of the solving the stated problem within minimum number of experiments as compared to that of full factorial design.

Ahsan Ali Khan, Mod Efendee Bin awing and Ahmad Azwari Bin Annur, **et al [9]** aims to evaluate the effect of jet of pressure, abrasive flow rate and work feed rate on smoothness of the surface produced by abrasive water jet machining of carbide of grade P25 is a very hard and cannot be machined by conventional machining techniques. Cutting was performed on a water jet machine model WJ 4080. The abrasive used in investigations was garnet of mesh size 80. It was found from the investigations that with increase in jet pressure the surface becomes smoother due to higher kinetic energy of the abrasives. But the surface near the jet entrance is smoother and the surface gradually becomes rougher downwards and is the roughest near the jet exit. Increase in abrasive flow rate also makes the surface smoother which is due to the availability of higher number of cutting edges per unit area per unit time. Feed rate didn’t show any significance influences on the machined surface, but it was found that surface roughness increase drastically near the jet entrances. Finally they have concluded that a jet Pressure And Abrasive Flow rate are the Most influencing parameter on the surface roughness, the work feed rate is less insignificant as compared to jet pressure and abrasive flow rate.

M.Sreenivasa Rao, S.Ravinder and A. Seshu Kumar et al [10] investigated the study the effect of parameters, viz watepressure, Traverse speed, and Standoff distance, of Abrasive Waterjet Machine (AWJM) for mild steel (MS) on surface roughness (SR) .Further Taguchi’s method, analysis of variance and signal to noise ratio (SN Ratio) were used to optimize the considered parameters of abrasive Water Jet Machining. In Taghuchi‟s design of experimentation, L9orthogonal array was formulated and it can be concluded that water pressure and transverse speed were the most significant parameters and standoff distance is sub significant parameter.

Vaibhav.j.Limbachiya, Prof Dhaval.M.Patel et al [11] did investigation of Different Material on Abrasive water jet machine,Theoretical MRR found equal to the experimental MRR. Investigation for three different materials like en8, acrylic and aluminum was carried out using Taguchi design of experiment method. Experiments were carried out using L25 Orthogonal array by varying Material traverse speed and abrasive mass flow rate for each material respectively. ANOVA carried out for identifies significant parameters. Both factor, Traverse speed and Abrasive mass flow rate were affecting MRR of each material. Clearly define that increasing Traverse speed and abrasive mass floe rate, will directly increasing MRR.

M. Chithirai Pon Selvan, Dr. N. Mohana Sundara Raju, Dr. R. Rajavel et al[12]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 was found to decrease with increase in traverse speed because the contact of abrasive particle over the work piece was for shorter duration. It was also found that the depth of cut decreases with increase in the standoff distance between nozzle and work piece keeping other operational parameters constant.

P. J. Singh, W. L. Chen, J. Munoz et al[13] experimentally studied the effect of traverse speed, water jet pressure, abrasive flow rate and size, size of water orifice and mixing tube on AWJ cut, surface finish for different materials (aluminium, steel, glass and rubber). It was found that better surface finish is obtained at the top part of the cut surface of lower water jet pressure and by increasing abrasive flow rate decreasing traverse speed.

Ramulu and Arola et al[14] conducted an experimental investigation to study the effect of machining parameters on the surface roughness (R_a) and kerf taper in AWJM of graphite/epoxy laminates. Taguchi method (TM) and analysis of variance (ANOVA) indicated that grit size and standoff distance have the most significant influence on Ra. Abrasive flow rate and water jet pressures have the least influence on Ra at any machining depth.

T. U. Siddiqui, M. Shukla et al[15] used a hybrid Taguchi and response surface method approach for optimization of surface finish in AWJM of Kevlar composites. It was found that quality level and water jet pressure were the most significant factors affecting R_a in comparison to abrasive flow rate.

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