

## ***The Impact of the Abrasive Jet Machine on Different Process Parameters on Different Materials***

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### ***Abstract***

*Abrasive jet machining is a viable option for cutting fragile materials such as single crystals, glasses, and polycrystalline ceramics, as well as performing critical machining to create complex forms and workpiece profiles. This machining method is non-thermal, non-chemical, produces no changes in the work piece's microstructure, chemical, or physical properties, and produces machined surfaces that are nearly stress-free. As a result, it is widely utilized in the machining of hard and brittle materials that are difficult to cut using standard methods. Many process parameters affect the performance of an abrasive jet machine, including abrasive mass flow rate (AMFR), stand of distance (SOD), nozzle diameter, pressure, abrasive particle size, and traverse speed. Many reaction characteristics, such as Material Removal Rate (MRR), surface roughness, depth of cut, radial overcut, and taper angle, can be obtained as a result of all of these process factors. In this work, we look at how those characteristics affect various materials such as Alumina ceramic, Glass fibre, Nickel 233 alloys, Kevlar epoxy composites, porcelain tiles, and soda-lime glass. This research presents a literature review to better understand the impact of several process parameters on different materials, such as abrasive grain size, pressure, and SOD, in order to achieve good quality and precision on an abrasive jet machine.*

***Keywords:*** *Stand of Distance (SOD, MRR, Abrasive mass flow rate (AMFR), Pressure*

## INTRODUCTION

Abrasive jet machining is a constructive non-conventional method for machining hard and brittle materials like glass, ceramics, quartz, GFRP composites, and other engineering materials, where abrasive particles are made to impinge on the work material at a high velocity.

The high-speed abrasive particles' kinetic energy causes brittle fractures in the target material, which propagate both lateral and longitudinally to remove the material. Although numerous attempts have been made by researchers in various parts of the world to identify machining characteristics and related process parameters in order to control the requirements of abrasive jet machining, more research is required to analyze the effects of various abrasive jet machining parameters in order to increase the material's effectiveness.

Gas pressure, nozzle diameter, abrasive variables (mass flow rate, particle size), standoff distance, and other factors all influence the cutting process behaviour in AJM. Due to the dynamic behaviour of the abrasive jet machining process, the suitable combination, as well as proper exploitation of pre-cited machining process parameters, are critical for achieving good grade and circularity of

hole, which generally wastes valuable time and effort. Various studies have used RSM (response surface methodology), ANN (Artificial Neural networks) for mathematical modelling in order to forecast responses, and Taguchi technique GA (genetic algorithm) for multi-response optimization in order to regulate the process parameters of the AJM process.

This literature review was conducted to better understand the impact of various process parameters on various materials in order to achieve high quality and precision using an abrasive jet machine.

## OBJECTIVES AND SCOPE OF THE STUDY

The study's major goal is to see how process variables like pressure, abrasive grain size, standoff distance, and workpiece material thickness affect material removal rate, taper angle, kerf, and overcut in drilling.

- a) To investigate the impact of these variables on the rate of material removal and dimensional correctness in terms of radial overcut and taper.
- b) Develop a mathematical model based on experimental data to represent the link between control factors such as pressure, standoff distance, and

abrasive particle size and reaction parameters such as material removal rate, overcut, and taper.

## LITERATURE REVIEW

Prasad et al. [I] looked at how well the improved air abrasive jet machining performed (MAAJM). In their research, they devised a new method for producing hole-within-hole measurements in nickel 233 alloys. When compared to a stationary work table, the taper angle was evenly created, indicating that suitable parameters were maintained to accomplish the necessary cylindricity. Maximum MRR 0.046, minimum surface roughness 0.92, and taper angle  $7.47^\circ$  were among the output parameters they discovered.

According to Dhanawade et al., abrasive water jet machining was used on carbon epoxy composite material. The effect of process parameters on surface roughness was studied using an analysis of variance. Surface roughness decreases by up to 11-32 percent as hydraulic pressure and AMFR (Abrasive mass flow rate) increase, while TR (Traverse rate) and SOD decrease (Standoff Distance).

Tomy et al. carried out A set of input machining parameters – air pressure, abrasive grit size, and standoff distance –

were used to machine holes in fabricated multidirectional HFRC (Hybrid fibre Reinforced composite). The output responses chosen for the experiment were material removal rate (58.7g/s), Taper Angle (TA) (1), and Surface Roughness (Ra) (4.95  $\mu\text{m}$ ), and the results also indicated the absence of defects such as delamination, burr formation, and heat-affected zones in the machined samples.

Kumar UA et al. [IV] presented the cutting of glass fibre reinforced polymer on an abrasive water jet machine, with the machining parameters standoff distance, water jet pressure, abrasive mass flow rate, and traverse rate all being taken into account for the machining operation. The experiment resulted in an increase in material removal rate from 12.789 to 18.664  $\text{mm}^3/\text{s}$ , kerf width from 1.164 to 1.181 mm, and kerf taper angle from  $0.037^\circ$  to  $0.085^\circ$ .

Ceritbinmez F et al. demonstrated abrasive water jet machining of multi-walled carbon nanotubes (MWCNTs)-doped composite sheets using parameters such as cutting speed, fixed nozzle diameter, cutting pressure, and abrasive garnet. The composite materials produced with 0.1 wt. Percent MWCNTs additive was found to be stronger than the pure samples. The

hole circularity deteriorated as the cutting speed increased, and the cutting surface became indented. The rapid movement of the water jet resulted in an increase in the kerf taper angle and hole diameter due to the increased cutting speed.

Paul et al. presented Silicon Carbide (SiC) with grit sizes of 60 m, and 120 m was chosen to investigate the effect of grit size on process parameters (nozzle diameter, standoff distance, and pressure) during the drilling of holes in ceramic tiles using an abrasive jet machine. Maximum MRR value of 0.019 gm/sec was obtained at optimum parameters such as gas pressure of 4.2 kgf/cm<sup>2</sup>, SOD of 9 mm, and Nozzle Diameter of 2.5 mm, and minimum taper value of 0.02 mm was obtained at optimum parameters such as the pressure of 4.2 kg/cm<sup>2</sup>, SOD of 5 mm, and Nozzle Diameter of 2 mm by using the abrasive size of 120 m during AJM process. As abrasive particle size increases, MRR increases and Taper decreases.

Jesthi et al. investigated the mechanical characteristics of ordinary glass (G), carbon (C), and hybrid composites ([CG2CG]S) in dry and seawater ageing conditions. We determined the material removal rate (MRR), the surface roughness (Ra), and the depth of cut

(DOC). The flexural strength of dry hybrid composite [CG2CG]S was 22.9 percent greater than composites aged in seawater. The rate of material loss is greater for seawater-aged composites than for dry composites.

Kumar, Puneet, and colleagues investigated the application of abrasive water jet machining on Kevlar Epoxy Composites. The effect of process factors on surface roughness and kerf taper was explored. These parameters included standoff distance, traverse speed, and abrasive mass flow rate. It was discovered that by combining high water pressure and slow traverse speed, a smooth surface with less kerf taper could be achieved.

Behera et al. investigated the effects of different grades of silicon carbide abrasives on hot, abrasive jet machining (HAJM) and precision drilling operations on flat surfaces of K-60 alumina ceramic material. Four parameters were used in the experiments: pressure, standoff distance, abrasive temperature, and particle size. The material removal rate increased to 0.005 gm/s, and the flaring diameter grew to 6.382 mm as a result of the experiment. Prasad et al. presented a multi-objective optimization technique based on the WASPAS method for optimizing the

following machining parameters in the abrasive jet machining (AJM) process: pressure, nozzle to tip distance (NTD), an average grain diameter on NICKEL 233 alloy. Three competing objectives, Material Removal Rate (MRR), surface roughness (Ra), and taper angle (Ta), were considered at the same time.

Anjaneyulu et al. investigated the P, AFR (abrasive flow rate), SOD (standoff distance), and T (thickness) on abrasive air-jet machining of Al<sub>2</sub>O<sub>3</sub> work material using a new technique (Taguchi Technique). They conclude that the percentage contributions of Pressure, Stand of Distance, Time, and Abrasive Flow Rate to Surface Roughness were approximately 87.1 percent, 6.79 percent, 3.75 percent, and 2.8 percent, respectively. Potom et al. investigated variable abrasive water jet parameters such as water pressure, nozzle diameter, standoff distance, and abrasive flow rate. Experiments on carbon fibre reinforced polymer composites were carried out by varying these parameters.

Maximum abrasive jet pressure increases material removal rate up to 6.7 gm/min, while minimum standoff distance (SOD) decreases kerf angle in carbon fibre composites.

Jadav and colleagues discussed The amount of material removed by AJM is affected by a variety of process parameters such as nozzle bore diameter, operating pressure, standoff distance, and so on. It is very difficult to obtain the required amount of bore diameter on the workpiece while drilling a micro-hole. The experiment yielded the following results: material removal rate, kerf width, and kerf taper angle.

Madhu et al. presented experimental results for abrasive jet machining of glass fibre reinforced polymer laminates for various parameters in terms of average surface roughness (Ra). This paper investigates the drilling of holes in glass fibre reinforced polymer composite material with and without an internal thread using a newly designed nozzle. The surface roughness (Ra) of GFRP laminates was 0.531 m when machined with an internally threaded nozzle and 0.802 m when machined with an unthreaded nozzle. The whirling effect of abrasive particles caused by internal threads within the nozzle improves the surface quality of glass fibre reinforced polymer composites more than an unthreaded nozzle.

Ghara et al. describe experimental investigations on the performance of

abrasive jet machining on cutting various materials such as glass and tiles with machining parameters such as abrasive carrier gas pressure, flow rate, and SOD on machined holes. It was discovered that SiC abrasive has a greater cutting ability than silica sand. The machined hole diameters increase in proportion to the increase in SOD at a given pressure.

Kumar et al. investigated the details of a developed micro-abrasive jet machine prototype as well as experimental studies on the influence of mixing chamber design on material removal rate in borosilicate glass machining. Control factors included pressure, standoff distance, nozzle diameter, abrasive type (Al<sub>2</sub>O<sub>3</sub> and SiC), and abrasive size. Experiments were carried out using an L16 orthogonal array and were optimized using Taguchi's method. When a fixed mixing chamber was used instead of an oscillating mixing chamber, the spread of abrasive particles was greater. The depth of abrasive particle penetration was greater in the oscillating mixing chamber than in the fixed mixing chamber.

Abhishek et al. focused on a novel approach for machining holes in brittle material-quartz, employing an in-house developed micro-abrasive jet machine with

a feed rate equal to the average rate of change of the workpiece thickness. Experiments were carried out to investigate the effect of this novel approach on the shape of the machined hole by measuring the entrance and exit diameters and thus calculating the taper angle. The obtained experimental results show that the hole's entrance diameter is reduced by approximately 29 percent, while the taper angle is reduced by approximately 58 percent, resulting in improved cylindricity.

Srikanth et al. presented a study that highlights the influence of different abrasive jet machining parameters such as pressure, SOD, and abrasive flow rate on metal removal and kerf width on ceramic tiles. The type of abrasive particle used in this experiment was Al<sub>2</sub>O<sub>3</sub>. The experiments were carried out using the TAGUCHI method of L9 orthogonal array and RSM, and the results of ANOVA were compared using STATGRAPHICS. The Optimal Range of Machining of Stat graphics ANOVA was comparable to the results obtained by Taguchi and RSM.

Routara et al. presented the Taguchi method for optimizing machining parameters for abrasive jet machining (AJM) of glass workpieces for individual

responses such as material removal rate and surface roughness. With the help of grey relational analysis, the multi-response performance characteristic was used to optimize process parameters such as pressure, nozzle-tip-distance, and abrasive grain size. Material removal rate (MRR) and surface roughness were increased as response parameters.

Chandra et al. discussed various results of experiments conducted on an Abrasive jet machine by varying pressure and nozzle tip distance on different thicknesses of glass plates. The effect of their process parameters on the material removal rate (MRR), top surface diameter, and bottom surface diameter of the hole obtained was measured, and it was discovered that as the nozzle tip distance increases, so do the top surface diameter and bottom surface diameter of the hole. As the pressure increased, so did the material removal rate (MRR).

## RESEARCH GAP

According to a review of published work titled Effect of Various Process Parameters on Various Materials by Abrasive Jet Machine-A Review, many parameters are responsible for research, such as

- Choosing the appropriate abrasive grain size for the application.

- Choosing the appropriate nozzle diameter.
- Improved dimensioning for use as a standoff distance or nozzle tip distance to achieve a high metal removal rate.
- Appropriate cutting speed selection to increase kerf size.

## CONCLUSIONS

The major conclusions drawn from Effect of Various Process Parameters on Various Materials by Abrasive Jet Machine-A Review are as follows.

- Statistical and computational approaches used RSM (response surface Methodology), and ANN (Artificial Neural networks) for mathematical modelling to predict responses.
- The Taguchi method and GA (genetic algorithm) are used for multi-response optimization to control the process parameters during the AJM process.
- With abrasive jet machining, we can achieve dimensional tolerances of 0.05 mm and surface finishes ranging from 0.5 to 1.2 m.
- This abrasive jet gets machining process is also used to clean and machine semiconductors such as

silicon, gallium, or germanium, as well as to make holes and slots in glass, quartz, mica, and ceramics.

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