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Design and Fabrication of Abrasive Jet Machine (AJM) & Analyzing its Performance

V. Mahesh Kumar Reddy[1*], M. leela Ramesh[1], B. Malsoor[1], Sai Teja[1]

[1]Asst Professor, Dept of Mech Engg, Holy Mary Institute of Technology and Science, Telangana, India.

**Corresponding author E-Mail ID: maheshvaddhi03@gmail.com, Mobile: 9951867656*

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ABSTRACT

Abrasive Jet Machining (AJM) is the process of material removal from a work piece by the application of a high speed stream of abrasive particles carried in a gas medium from a nozzle. The material removal process is mainly by erosion. The AJM can principally be wont to cut shapes in arduous and brittle materials like glass, ceramics etc. In this concept, a model of the Abrasive Jet Machine is proposed to design by taking into consideration of commercially available components. Care will be taken to use less fabricated components rather than directly procuring them, because, the lack of accuracy in fabricated components would lead to a diminished performance of the machine. To analyse its performance, Drilling of glass sheets with different abrasives and different nozzles will be carried out by Abrasive Jet Machining process (AJM) in order to determine its machinability.

Keywords: Abrasive Jet Machining, Nozzles, Al_2O_3 Abrasive, Sic Abrasive, Abrasive Powder.

1. INTRODUCTION

The new technological processes can be classified into various groups according to (a) type of energy required to shape materials- mechanical, thermal and electro thermal, or chemical and electrochemical ; (b) basic mechanism involved in the processes- erosion, ionic dissolution, vaporization ; (c) source of energy required for material-hydrostatic pressure, high current density, high voltage, ionized material ; (d) medium for transfer of these energies-high velocity particles, electrolyte, electron, hot gases.

In thermal and electro thermal methods, heat energy is concentrated on a small area of the work piece, to melt and vaporize the tiny bits of work material. The required shape is machined by a repetition of this process. (EDM, ECG, PAM, EBM, IBM). In chemical and electrochemical machining the work piece material I contact with a chemical solution is etched (anodic dissolution) in a controlled manner (ECG, ECM, ECH and ECD). In mechanical methods, the material is removed by mechanical erosion of the work piece material (USM, AJM and WJM).

These methods have been listed below and discussed in the following articles:

- Electro Discharge Machining (EDM) Electro Chemical machining (ECM)
- Electro Chemical Grinding (ECG) Electro Chemical Honing (ECH)
- Electro Chemical Deburring (ECD) Chemical milling (CHM)
- Laser Beam Machining (LBM) Abrasive Jet Machining (AJM)
- Water Jet Machining (WJM) Ultrasonic Machining (USM)
- Hot Machining High Velocity Forming of Metals (HVF)

- Explosive Fabrication (High Energy Rate Forming, (HER)
- Electro-hydraulic Forming Magnetic Pulse Forming (MPF)
- Plasma Arc Machining (PAM) Electron Beam Machining (EBM)
- Ion Beam Machining (IBM)

All methods are not suitable for all the materials. Depending on the material to be machined, following methods can be used shown against each material, the choice for further selection depending on other factors.

- For non-metals like ceramics, plastics and glass- USM, AJM, EBM, LBM
- Refractories- USM, AJM, EDM, EBM Titanium- EDM
- Super alloys- AJM, ECM, EDM, PAM Steel- ECM, CHM, EDM, PAM

The application of the non-conventional methods is also influenced by the shape and size of the workpiece to be produced.

For microholes, LBM is best suited, whereas for small holes EBM is also well suited. For deep holes, ECM is best suited, while for shallow holes USM and EDM are also suited. For precision through cavities in work pieces, USM and EDM are very well suited. For etching small portions (pocketing) ECM and EDM are best suited. For surfacing (double contouring), ECM is best suited. For through cutting, ECM and PAM are good for any depth but AJM, CHM, EBM and LBM can also be used for shallow through cutting. For applications like grinding, AJM and EDM are suited. For honing- ECM, deburring- USM and AJM, and for threading EDM is suited.

Best surface finish is produced by AJM, ECG, and ECD (0.2 to 0.8μm), followed by USM. EDM, and ECM (0.4 to 1.6 μm), EBM and LBM (0.8 to 6 μm), CHM (1.6 to 6 μm), PAM (6 to 12 μm).

In this concept a ‘‘Abrasive Jet Machine (AJM)’’ was selected for design and fabricating. Abrasive Jet Machining is also called Abrasive Micro-blasting is the removal of material from a work piece by the application of a high speed stream of finer abrasive particles carried in gas medium from a nozzle. The AJM method differs from typical sand blasting therein the abrasive is far finer and therefore the method parameters and cutting action are rigorously controlled. The process is employed principally to chop convoluted shapes in arduous and brittle materials that ar sensitive to heat and have a bent to chip simply. The process is additionally used for deburring and cleansing operations. AJM is inherently free from chatter and vibration issues. The cutting action is cool as a result of the carrier gas is a fluid.

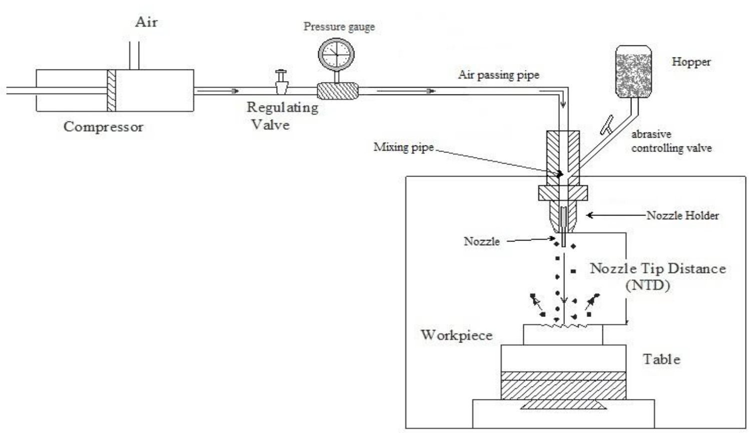


Fig 1.Abrasive Jet Machine (AJM)

Common examples include grinding, honing, and polishing. Abrasive processes ar typically big-ticket, but capable of tighter tolerances and better surface finish than other machining processes chances, delectability, costs and safety aspect etc. Most of the studies argue over the fluid mechanics characteristics of abrasive jets, hence ascertaining the influence of all operational variables on the process effectiveness including abrasive type, size and concentration, impact speed and angle of impingement. Other things found new problems concerning carrier gas typologies, nozzle shape, size and wear, jet velocity and pressure, Stand off Distance (SOD) or Nozzle Tip Distance (NTD). These things express the overall process performance in terms of material removal rate, geometrical tolerances and surface finishing of work pieces, as well as in terms of nozzle wear rate.

The AJM is considered as an attractive and effective machining method for hard and brittle materials. Machining mechanisms and characteristics of abrasive jet machining ar major topics of the many analysis works within the recent years. In recent years abrasive jet machining has been gaining & increasing acceptability for deburring (a finishing method used in industrial settings and manufacturing environments) applications.

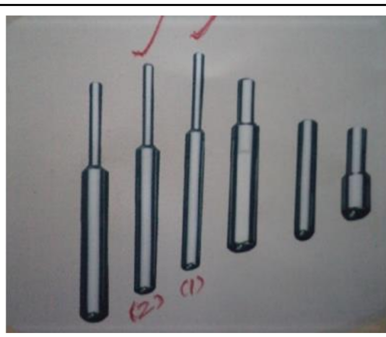
2. Variables in AJM

The variables that influence the speed (rate) of metal removal and accuracy of machining in this process is:

- Carrier gas
- Type of abrasive
- Size of abrasive grain
- Flow rate of abrasive
- Work material
- Stand off Distance (SOD) or Nozzle Tip Distance (NTD)
- Operation type

2.1: Characteristics of different variables

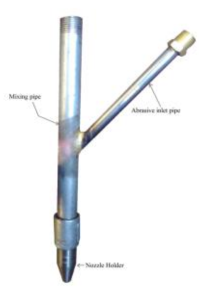
The variables that influence the speed of metal removal square measure as follows:



Nozzles

Nozzle Holders

Hopper



Aluminium Oxide Abrasive Powder

Silicon Carbide Abrasive Powder

Fig 2. AJM Variables

Table 1. Input Conditions

Medium	Air, CO2, N2
Abrasive	Silicon carbide (SiC), Aluminum oxide (Al2O3) (of size 20µ to 50µ)
Flow rate of abrasive	3 to 20 gram/min
Velocity	150 to 300 m/min
Pressure	2 to 8 bar
Nozzle size	0.07 to 0.40 mm
Material of nozzle	Tungsten Carbide (WC), Sapphire
Nozzle life	12 to 300 hr
Standoff distance	0.25 to 15 mm (8mm generally)
Work material	Glass, ceramics and granites. Metals and alloys of exhausting materials like germanium, silicon etc.,
Part application	Drilling, cutting, deburring, cleaning

3. ANALYSING PROCESS PARAMETERS

In this concept, two parameters are taking for experimental work. These are:

1) Nozzle Tip Distance (NTD) or Standoff Distance (SOD)
2) Pressure

— In the first experiment, how the SOD effecting the diameter of the hole?

‘‘SOD Vs Hole diameter’’

— In the second experiment, how the pressure of air effecting on the machining time?

‘‘Pressure Vs Time’’

3.1: SOD Vs Hole diameter

In this experiment the glass sheets are drilled by using AJM. In this experiment different SOD’s, different abrasive powders and constant air pressure, same thickness of glass sheets are used. After conducting the drilling operation, measure the hole diameter by using Traveling microscope.

OBSERVATION-1: Here pressure is kept constant at 4bar, glass sheet thickness is taken as 5mm and nozzle diameter is 0.6mm.

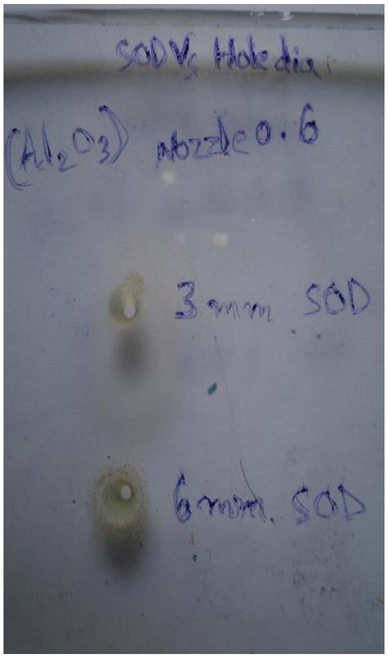


Fig 3 (a). SOD Vs Hole diameter using of 0.6 nozzle & Al_2O_3

Table 2. Al_2O_3 Abrasive

SOD Vs Hole diameter using of 0.6 nozzle & Al_2O_3		
Pressure: 4 bar; **Glass thickness:** 5mm; **Abrasive:** Al_2O_3		
SOD (mm)	*Top surface diameter (mm)*	*Bottom surface diameter (mm)*
3	4	1
6	5.5	1.5

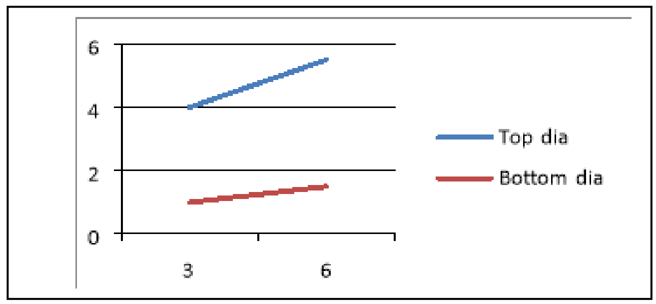


Fig 3(b) . Graph of Al_2O_3 Abrasive

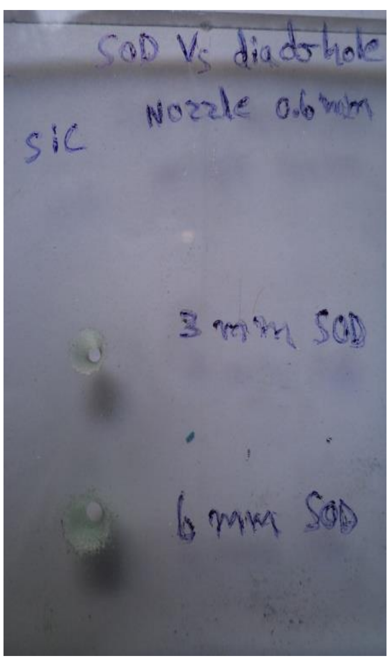


Fig 4 (a). SOD Vs Hole diameter using of 0.6 nozzle & SiC

Table 3. SiC Abrasive

SOD Vs Hole diameter using of 0.6 nozzle & SiC		
Pressure: 4 bar; Glass thickness: 5mm; Abrasive: SiC		
SOD (mm)	*Top surface diameter (mm)*	*Bottom surface diameter (mm)*
3	5	1.5
6	6.1	2

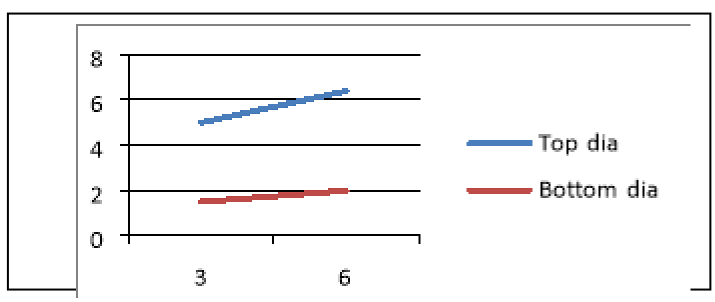


Fig 4 (b) . Graph of SiC Abrasive

3.2 Pressure Vs Time

In this experiment, the glass sheets are drilled by AJM. In this experiment different air pressures and different abrasive powders used at constant SOD and same glass thickness. The machining time was measured by the use of stop watch.

OBSERVATION-2.1: Here SOD is kept constant at 3mm, glass sheet thickness is taken as 3.5mm and nozzle diameter is 0.6.

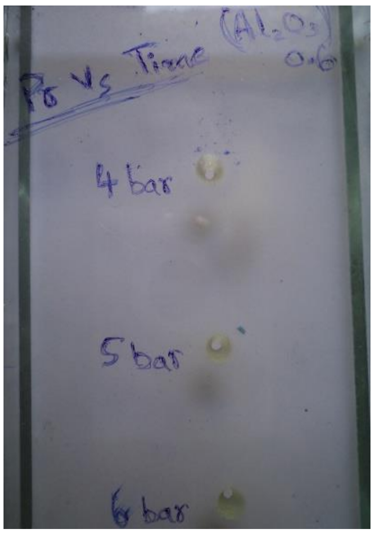


Fig 5(a).Pressure Vs Time using of 0.6 nozzle & Al_2O_3

Table 4. Pressure Vs time using of 0.6 nozzle & Al_2O_3

Pressure Vs time using of 0.6 nozzle & Al_2O_3	
SOD: 3mm; Glass thickness: 5mm;	Abrasive: Al_2O_3
Pressure (bar)	**Time (min/sec)**
4	2.16
5	1.53
6	1.36

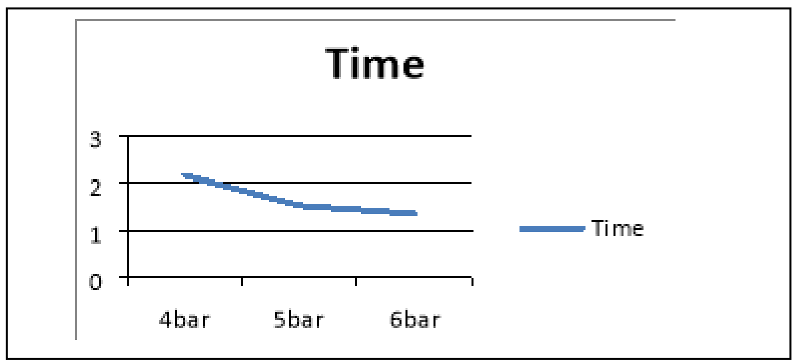


Fig 5 (b). Time Vs Pressure Graph

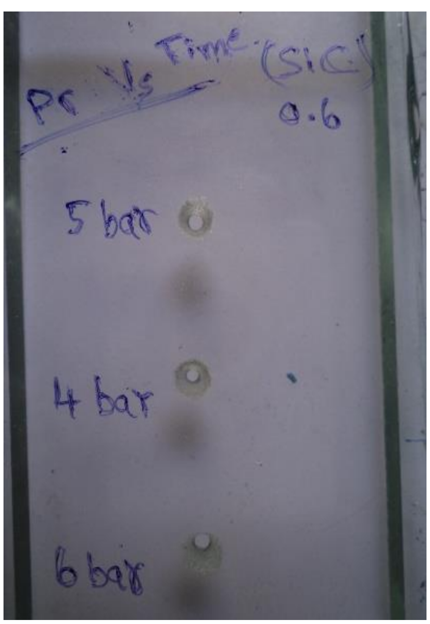
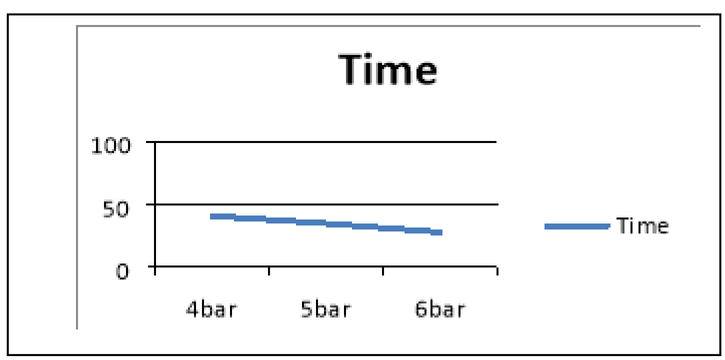


Fig 6 (a). Pressure Vs Time using of 0.6

Table 5 . Pressure Vs time using of 0.6 nozzle & Sic

Pressure Vs time using of 0.6 nozzle & Sic	
SOD: 3mm; Glass thickness: 5mm;	Abrasive: SiC
Pressure (bar)	**Time (min/sec)**
4	41
5	35
6	28



nozzle & SiC

Fig 6 (b). Time Vs Pressure Graph

The Brake Thermal Efficiency is defined as brake power of a heat engine as a function of the thermal input from the fuel. It is accustomed assess however well Associate in Nursing engine converts the warmth from a fuel to energy. From the graph shows that initially all the test samples were same, on increasing the load the rate of increase of efficiency varied for each.

4. CONCLUSION

Abrasive Jet Machine was fabricated with following specifications.

1. Diameter of nozzles : 0.6 – 2 mm.
2. Type of abrasive particles : Aluminum oxide (Al_2O_3), Silicon carbide (SiC)
3. Pressure range : 3 to 8 bar
4. Carrier gas used : Dry air

This project presents various results of experiments conducted by changing the parameters such as pressure, Nozzle Tip Distance (NTD) or Stand-off Distance (SOD) and glass plates with varying thickness. The impact of their method parameters on the fabric Removal Rate (MRR), high surface diameter and bottom surface diameter of hole obtained were measured and planned.

With it was observed that as NTD or SOD increases, the top surface diameter and bottom surface diameter of hole increases. When compare to the diameter of bottom surface of glass hole, diameter of top surface diameter is more. This is due to deflection and reflection of the abrasive particles. It is the general observation in the Abrasive Jet Machining process. As the pressure increases Metal Removal Rate (MRR) was also increased.

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Conflict of Interest

None of the authors have any conflicts of interest to declare.

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