

## STUDY OF ABRASIVE JET MACHINE

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**Abstract** - Abrasive Jet Machining (AJM) or Micro Blast Machining is a non-traditional machining process, wherein material removal is effected by the erosive action of a high velocity jet of a gas, carrying fine-grained abrasive particles, impacting the work surface. The process is particularly suitable to cut intricate shapes in hard and brittle materials which are sensitive to heat and have a tendency to chip easily. As Abrasive jet machining (AJM) is similar to sand blasting and effectively removes hard and brittle materials. AJM has been applied to rough working such as debarring and rough finishing. With the increase of needs for machining of ceramics, semiconductors, electronic devices and L.C.D., AJM has become a useful technique for micromachining. The experimental results of the present work are used to discuss the validity of proposed model as well as the other models. With the increase in nozzle tip distance (NTD), the top surface diameter and bottom surface diameter of hole increases as it is in general observation of abrasive jet machining process. As the pressure increases, the material removal rate (MRR) is also increased. The present study has been introduced a mathematical model and the obtained results have been compared with that obtained from the theoretical.

**Key Words:** Abrasive Jet Machine (AJM), LCD, Nozzle Tip Distance (NTD), Material Removal Rate (MRR)

### 1. INTRODUCTION

Abrasive jet machining (AJM) is a non-traditional machining process that can machine material without generating heat and shock and also without formation of chips. Abrasive processes are usually expensive, but capable of tighter tolerances and better surface finish than other machining processes chances, delectability, costs and safety aspect etc. Abrasive jet machining (AJM) is a process of material removal by mechanical erosion caused by the impingement of high velocity abrasive particles carried by a suitable fluid (usually a gas or air) through a shaped nozzle on to the work piece. Common examples include Cutting, Drilling, Surface finishing, Etching, grinding, honing, and polishing. The erosion phenomenon in an AJM study may be considered in two phases. The first phase consists of transportation problem, that is, the quantity of abrasive particles flow, and the direction and velocity of impinging particles as determined by the fluid flow condition of solid-gas suspension. The second phase of the problem is the determination of the material removal rate or the erosion rate.

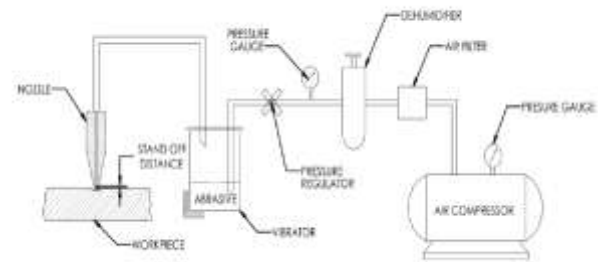


Fig -1: Schematic Layout of Abrasive Jet Machine

The erosion of a surface by impacting solid particles is a discrete and accumulative process. Hence, the models are first made on the basis of a single particle impact. The mechanism of erosion in such cases is complex, involving mechanical, chemical and material properties.

The erosion is a function of several variables such as:

- Speed and angle of impact;
- Ductility and/or brittleness the impinging particles;
- Elasticity of the material; of the material and
- Shape and geometry of impinging particles;
- Impinging particle diameter to work-material, thickness ratio;
- Average flow stress;
- Material and density; and
- Distance between the nozzle mouth and work piece

An AJM set-up may be of two types: one employing a **vortex-type** mixing chamber and the other employing a **vibratory mixer**. In the former, abrasive particles are carried by the vortex motion of the carrier fluid, whereas in the latter type abrasive particles are forced into the path of the carrier gas by the vibrating motion of the abrasive particle container.

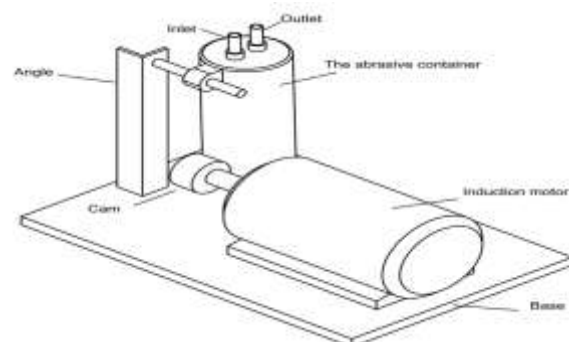


Fig -2: The vibrator assembly

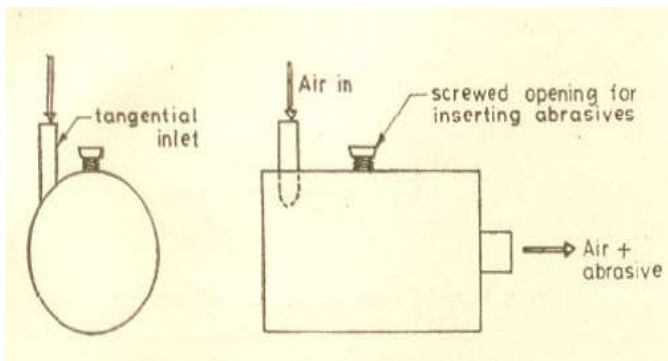


Fig -3: Vortex type mixing chamber

### 1.1 PROCESS PARAMETERS OF AJM

#### 1.1.1 CARRIER GAS (MEDIUM):

- (a) Carbon dioxide,
- (b) Nitrogen,
- (c) Air: Air is most widely used. But oxygen never used as a carrier gas due to fire hazards.

#### 1.1.2 ABRASIVE:

Abrasives are available in many sizes ranging from 10 micron to about 1.3 mm. the smaller sizes produce a finish cut and are suitable for polishing, cleaning and grooving.

The larger sizes are more suitable for cutting and peening because of their faster cutting action.

- a. Aluminium oxide suitable for cutting, grooving and debarring operations.
- b. Silicon carbide used for similar operation but for harder material.
- c. Sodium bicarbonate is useful for light duty work like cleaning, cutting and debarring for soft materials.
- d. Dolomite also is suitable for fine etching or polishing work only.
- e. Glass beads can be used for polishing surface to a matte finish and debarring work.

#### 1.1.3 VELOCITY OF ABRASIVE:

The jet velocity is a function of nozzle pressure & design. The range of jet velocity is 150-300 m/min.

#### 1.1.4 WORK MATERIAL:

It is recommended for processing of hard, brittle, and glass sheets material.

#### 1.1.5 NOZZLE:

AJM nozzles generally made of WC or Sapphire to resist abrasive wear due to the high velocity abrasive stream. The nozzle have either a right angled or straight edge shape.

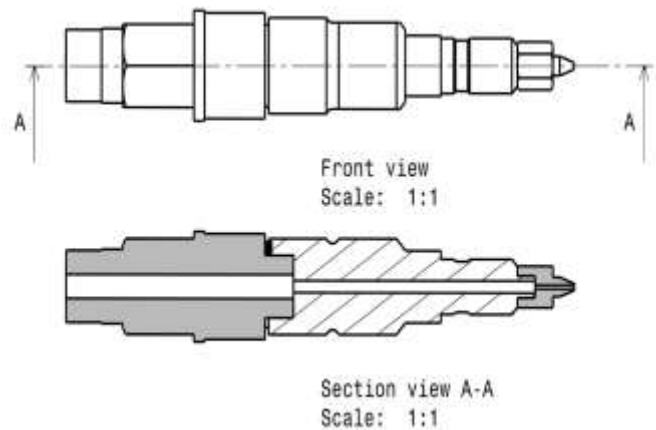


Fig -4: Nozzle

#### 1.1.6 NOZZLE TIP DISTANCE (NTD):

It is the distance between the nozzle tip & work material. It is also called as Standoff Distance (SOD).

#### 1.1.7 VARIABLES INFLUENCING THE RATE OF METAL REMOVAL:

The variables that influence the rate of metal removal are:

Table -1: Various Process Parameters of AJM

S. No	Process Parameter
1	Carrier gas
2	Nozzle tip distance
3	Type of abrasive
4	Size of abrasive grains
5	Velocity of abrasive jet
6	Mixing ratio
7	Work material
8	Nozzle design
9	Shape of cut

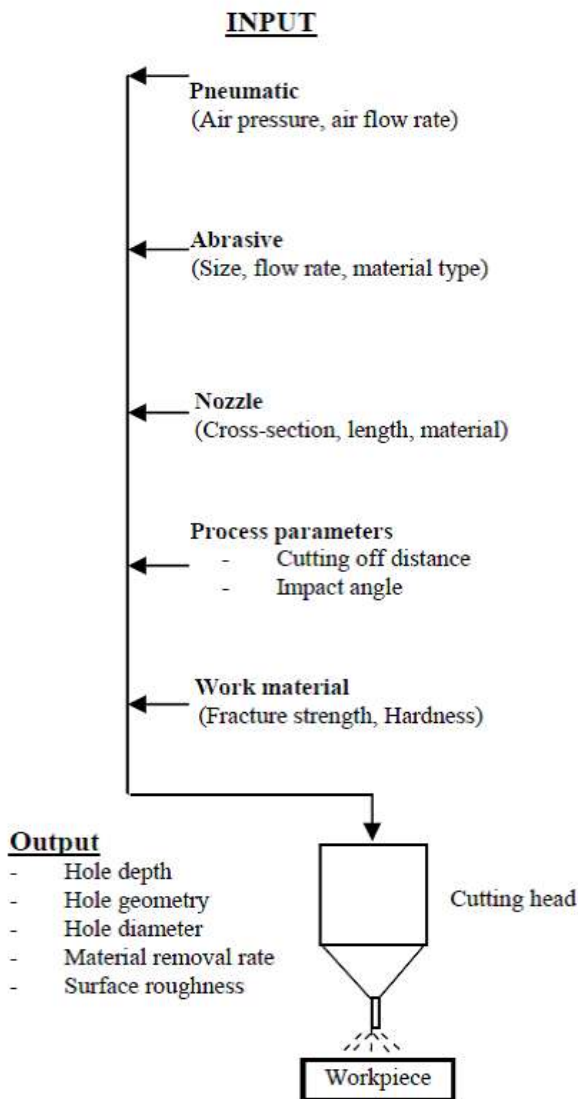


Fig -5: Input & Output Parameter

1.2 CHARACTERISTICS OF PARAMETERS

Table -2: Characteristics of parameters

Medium	Air, CO <sub>2</sub> , N <sub>2</sub>
Abrasive	SiC, Al <sub>2</sub> O <sub>3</sub> (of size 20µ to 50µ )
Flow rate of abrasive	3 to 20 gram/min
Velocity	150 to 300 m/min
Pressure	2 to 8 kg/cm <sup>2</sup>
Nozzle size	0.07 to 0.40 mm
Material of nozzle	WC, Sapphire
Nozzle life	12 to 300 hr

Stand off distance	0.25 to 15 mm (8mm generally)
Work material	Non Metals like glass, ceramics, and granites. Metals and alloys of hard materials like germanium, silicon etc
part application	Drilling, cutting, deburring, cleaning

1.3 COMPONENTS OF AJM

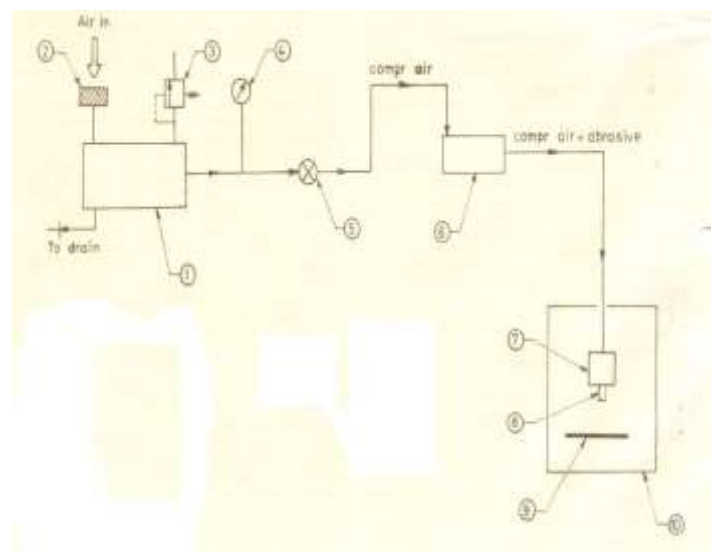


Fig -6: Components of AJM

- Compressor
- Air filter cum drier
- Relief Valve
- Pressure Gauge
- Opening Valve
- Mixing Chamber
- Nozzle Holder
- Nozzle
- Work piece
- Working Chamber

### 1.4 PROCESS

Glass was used as a test specimen, was cut into square and rectangular shape for machining on AJM. Specimens were cleaned using air jet and weighed on a sensitive scale, accurate to 0.001 gm. The compressed air from the compressor enters the mixing chamber partly pre-filled with fine grain abrasive particles. The vibratory motion of the air created in the mixing chamber carries the abrasive particles to the nozzle through which it is directed on to the work-piece. The nozzle and the work-piece are enclosed in a working chamber with a Perspex sheet on one side for viewing the operation. The abrasive particles used were SiC, Al<sub>2</sub>O<sub>3</sub>, Sodium Bicarbonate (grain size 60 microns and 120 microns). The nozzle material was stainless steel and the nozzles used were of different diameters. This type of set-up has the advantage of simplicity in design, fabrication and operation. The equipment cost is much less except the compressor. The machine work-piece was then removed, cleaned and weighed again to determine the amount of material removed from the work piece. The size of hole at the top surface and bottom surface was measured and the results were tabulated.

### 1.5 ADVANTAGES

- Ability to cut intricate holes shape in materials of any hardness and brittleness.
- Ability to cut fragile and heat sensitive material without damage.
- No change in microstructure as no heat is generated in the process.
- The process is characterized by lower consumption and capital investment.
- There is no contact between the tool and work-piece.
- Good surface finish of 10 to 50 microns is possible with the process using finer abrasive.
- Cutting action is cool because the carrier gas serves as a coolant.

### 1.6 DISADVANTAGES

- Material removal rate is low about 15 mm<sup>3</sup> / min.
- The parts manufactured by this process have to be cleaned.
- Embedding of the abrasive in the work-piece surface may occur while machining softer material.
- The abrasive material may accumulate at nozzle and fail the process if moisture is present in the air.
- It cannot be used to drill blind holes.
- Nozzle wear rate is high and abrasive particles may get embedded in the work surface.

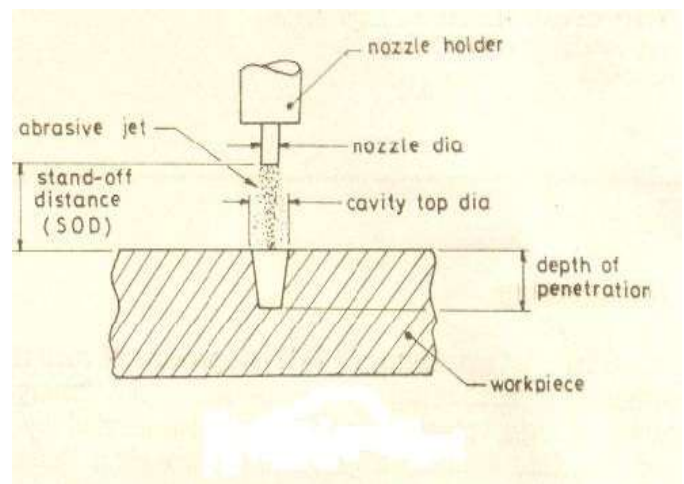
### 1.7 APPLICATIONS OF AJM

- Machining of hard and brittle materials like ceramics, quartz, glass, sapphire, mica etc.
- Fine drilling and micro-welding.

- Machining of semi-conductors.
- Production of intricate profiles on hard and brittle materials.
- Cleaning and finishing of plastic compounds. Ex. Nylon, Teflon.

## 2. WORKING PRINCIPLE OF AJM

Fine particles are accelerated in gas stream. The particles are directed towards the focus of machining. As the particle impacts the surface, it causes a small fracture, and the gas stream carries both the abrasive particles and the fractured (wear) particles away.



**Fig -6:** Working principle of AJM

Abrasive jet machining (AJM), also known as abrasive micro-blasting, pencil blasting and micro-abrasive blasting.

“Abrasive blasting machining process that uses abrasives propelled by a high velocity gas to erode material from the work piece.” The working principle of Abrasive jet machining (AJM) is similar to sand blasting in which AJM effectively removes hard and brittle materials. AJM has been applied to rough working such as debarring and rough finishing.

Common uses include cutting heat-sensitive, brittle, thin, or hard materials. Specifically it is used to cut intricate shapes or form specific edge shapes. A machining operation is basically a material removal process, where material is removed in the form of chips. In a machining operation, the output parameter is achieved by controlling various input parameters. Drilling of glass sheets with different thicknesses have been carried out by Abrasive Jet Machining process (AJM) in order to determine its machinability under different controlling parameters of the AJM process.



## 2.1 EXPERIMENTAL SET-UP

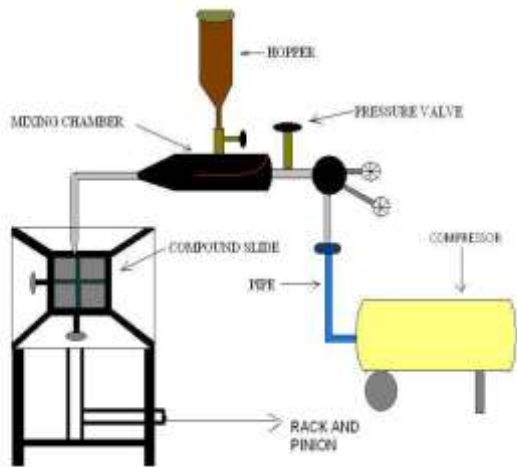


Fig -7: Schematic Diagram of Experimental Set-Up

The compressed air from the compressor enters the mixing chamber partly prefilled with fine grain abrasive particles. The vortex motion of the air created in the mixing chamber carries the abrasive particles to the nozzle through which it is directed on to the work-piece. The nozzle and the work-piece are enclosed in a working chamber with a Perspex sheet on one side for viewing the operation. The nozzle and mixing chamber are shown below.

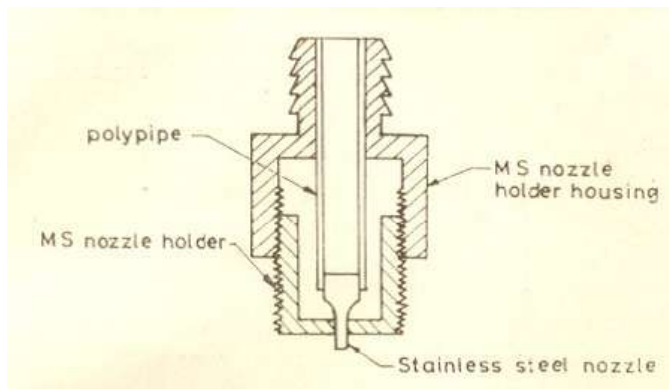


Fig -8: Nozzle Assembly

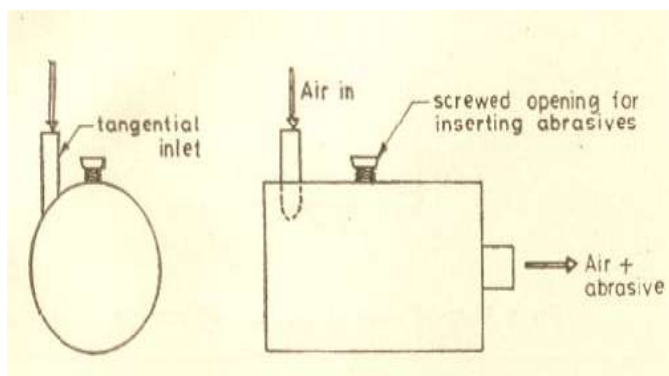


Fig -9: Vortex Type Mixing Chamber

The abrasive particles used were SiC (grain size 60 microns and 120 microns). The nozzle material was stainless steel and the nozzles used were of diameters 1.83 mm and 1.63 mm. This type of set-up has the advantage of simplicity in design, fabrication and operation. The equipment cost is much less except the compressor. The mixture ratio is controlled by the inclination of the mixing chamber.

The mixture ratio is defined as:

$$\alpha \text{ (mixture ratio)} = \frac{\dot{m}_p}{\dot{m}_a + \dot{m}_p}$$

Where  $m_p$  is the mass flow rate of the abrasive particles and  $m_a$  the mass flow rate of air.

## 3. CONCLUSION

It is very clear that AJM is greater Non-conventional machining process which is used as a multipurpose system. It is also a most effective among various affordable systems. This system is eco-friendly. Even some of the companies in India like ABB, L & T and ESSAR are already using this system with CNC programming. This system is also use as Water Jet Machining (WJM) in which abrasives such as garnet, diamond or powders can be mixed into the water to make slurry with better cutting properties than straight water. Further development in WJM is called Hydrodynamic Jet Machining (HJM) which combines the principle of Water Jet Machining and Abrasive Jet Machining process. AJM is also used as Abrasive Flow Machining (AFM), Ultrasonic Machining (USM).

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