Effect of Pressure on Material Removal Rate on Glass Using Abrasive Jet Machining

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***Abstract*—The human race has distinguished itself from all other forms of life by using tools and intelligence to create items that serve to make life easier and more enjoyable. Through the centuries both tools and the energy sources to power these tools have evolved to meet the increasing sophistication and complexity of mankind's ideas. Every time new tools, tool materials and power sources are utilized, the efficiencies and capabilities of manufacturers are greatly enhanced. The introduction of non-traditional manufacturing processes have been adopted to increase productivity either by reducing the number of overall manufacturing operations required to produce a product or by performing operations faster than the conventional methods. The paper presents the working of abrasive jet machining on brittle material that is glass by the application of high speed stream of abrasive particles carried by a gas medium through the nozzle. It also tells about the impact of gas pressure on material removal rate in abrasive jet machining.**

Keywords—Abrasive jet machining, gas pressure, Material removal rate and glass

I. INTRODUCTION

Abrasive jet machining (AJM) also known as abrasive micro-blasting, pencil blasting and micro-abrasive blasting is a process that uses abrasives propelled by a high velocity gas to erode material from the workpiece. Common uses include cutting heat sensitive, brittle, thin or hard materials. Specially, it is used to cut intricate shapes or form specific edge shapes. Machining complicated shapes of fragile components, accurate and economical forming of very hard, high strength materials which are being extensively used in aeroplane and nuclear industries have forced the scientists, engineers and technologists to search for new techniques of machining which can readily provide an effective solution to these problems. After research and development for the last forty years, several new methods have been emerged and one such method being abrasive jet machining.

Abrasive jet machining removes material through the action of a focused stream of abrasive laden gas. Micro-abrasive particles are propelled by inert gas at velocities upto 300m/s. When directed at a workpiece, the result in erosion can be used for cutting, etching, cleaning, deburring, polishing and drilling. Material removal occurs through a chipping action which is especially effective on hard and brittle materials such as glass. No workpiece chatter or vibration occurs within the process. In addition, because the heat is carried away by the abrasive propellant gas, workpieces experience no thermal damage.

First of all the power supply is switched on to energize the D.C motor. Then the air is allowed to pass through the mixing chamber. Due to vibrating motion, the abrasive particles get momentum and then the air-abrasive mixture is made to flow to the working chamber. The nozzle produces a high velocity flowing fluid mixture and exactly below the nozzle the workpiece, normally glass is kept with all clamping arrangements. The air-abrasive mixture which impinges with great velocity has erosive power that removes the materials from the surface of work material like glass. After drilling operation is over the abrasive particles are collected on the tray below the table. The workpiece is weighed before and after the process. The time taken to drill the hole is noted, with this above value the material removal rate (MRR) is calculated.

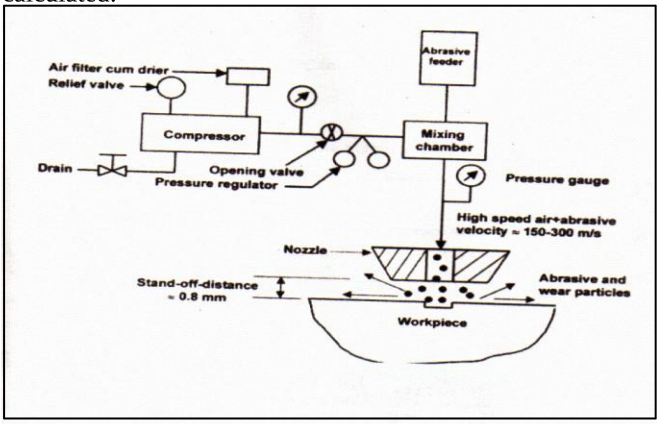

FIG 1 Diagram of abrasive jet machining process

II. COMPONENTS OF AJM

A. Nozzle

The AJM nozzles are typically made of either tungsten carbide or sapphire. Tungsten carbide nozzles are with either round or rectangular holes are available and have a life for an average of 33 hours but are 3 to 8 times more expensive. Round nozzles are available with diameters ranging from 0.12mm to 1.25mm. The nozzle is a tapering mouthpiece, which is fitted to the outlet of the pipe and generally is used to give a high velocity of fluid as it converts pressure head into kinetic head at its outlet.

B. Masks

Masks are used to control overspread or to produce large holes and intricate details without moving the nozzle and trace the shape. First the mask is produced with open areas where the material removal is desired, and then it is moved on the AJM stream which is passed over the exposed areas, cutting or etching takes place on a selective basis. Masks can be fabricated from rubber or metal, having its advantage and disadvantage.

C. Abrasives

Aluminium oxide, one of the most commonly used abrasive, is used to clean, cut and deburr. Silicon carbide, a harder abrasive, is effective for the same applications as aluminium oxide, but is usually applied only when the workpiece material is very hard. Polishing surfaces to a Matt finish or peening surfaces is accomplished with glass beads and can therefore be used for heavier cleaning and peening operations. Because the abrasive particle size is important, abrasives are available in many sizes ranging from 10μ to 50μ. The smaller sizes are most useful for polishing and cleaning, while the larger sizes are best for cutting and peening.

D. Mixing Chamber

The air enters through the control valve from air compressor where the flow of air is corrected and the required amount of air is opened out. There is a pressure measuring instrument fitted with the air compressor, which gives us the operating or working pressure of the air. The air from compressor next passes through the flexible tube to mixing chamber. The mixing chamber is the main part of the fabrication work and it is fitted on the horizontal bed. There is one opening on either side of the mixing chamber. The abrasives and dry air are made to mix in the mixing chamber and then are made to flow out to the working chamber through the outlet opening.

E. Working Chamber

It is a cuboidal metal casing in which the machining operation will be performed. In order to prevent the splashing, the chamber is enclosed in three sides. To the bottom of the cuboidal structure a conical funnel is welded to collect the used abrasives and chips. The working chamber consists of a vice which is fitted with a lead screw. The lead screw is mounted on the base of the cuboidal structure. The cross feed movement of vice enables the cutting operation. To vary the nozzle distance a flange and thread pipefitting is fitted on the top of working chamber which is made with mild steel sheet.

III. STAGES OF ABRASIVE JET MACHINING

The AJM system consists of five major sub-systems:

A. Gas propulsion system

This system provides the steady supply of clean and dry gas used to propel the abrasive particles. Depending upon the demands of the installation, either an air compressor or bottled gas may be used. If an air compressor is used, proper line filters must be installed to avoid water or oil contamination of the abrasive powders. The least expensive, and thus the most common gases to use are nitrogen and carbon dioxide. Oxygen should never be used as it may cause fire hazard.

B. Metering system

This system must inject a uniform, adjustable flow of abrasive particles into the gas stream. Generally, a powder hopper that fits into a vibrating chamber, causes the powder to be metered uniformly into the jet stream accomplishes this. The powder, flow rate is directly adjustable by varying the amplitude of vibration.

C. Delivery system

This system consists of the rubber hoses that connect the gas propulsion system that is the air compressor to the working chamber through the mixing chamber.

D. Cutting or machining system

This system consists of the nozzle through which the abrasive laden gas flows and machines the workpiece.

E. Dust collection system

This system is incorporated into AJM systems when found necessary to maintain the operator’s exposure to dusts within the permissible limits. Special considerations must be given to the dust collection system if toxic materials such as beryllium are being abraded.

IV. SPECIFICATIONS OF THE SET-UP OF TEST RIG

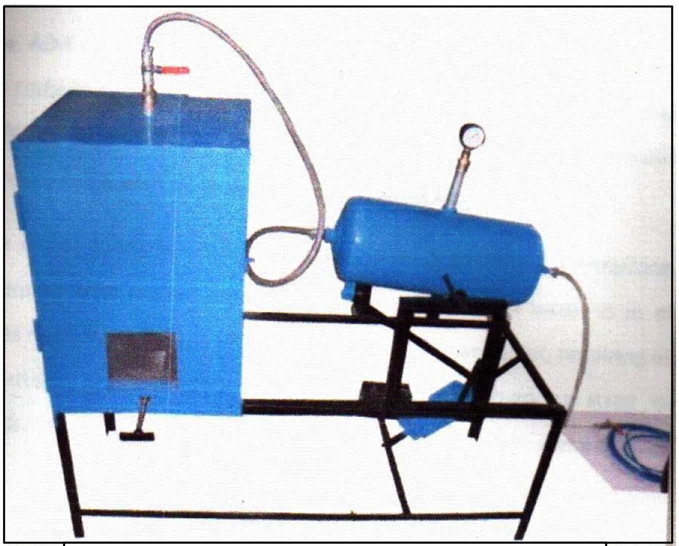

FIG 2 Experimental set-up test rig model

A. Air Compressor

Type	Two Stage
Diameter of low pressure piston	70 mm
Diameter of high pressure piston	50 mm
Stroke length	90 mm
Working/operating pressure	8 Kg/cm^2
Speed	700 rpm
Power	3 H.P.

B. Air Filter Unit

This is fitted in between compressor and mixing chamber in order to absorb water and oil content from theair. This is because aluminium abrasives have the property to absorb the water and oil content.

Dimensions (L×W×H)	(163×160×142) mm
Weight	0.934 kg
Mounting Type	Snap-in
Operating pressure (min/max)	0.5 bar/ 16 bar
Secondary pressure range (min/max)	0.2 bar/ 8 bar
Activation type	Manually through hand wheel

C. Motor

In this set-up a d.c motor is used since it is noiseless and it is used to vibrate the mixing chamber to mix the air and abrasive particles properly.

Type	D.C motor
Voltage	12 V
Speed	60 rpm
Power	180 watt

D. Battery

It is used to drive the d.c motor.

Voltage	12 V
Current	7 Ampere

E. Mixing Chamber

It is a cylindrical container where the air and abrasive are mixed.

Length	450 mm
Circumference	660 mm
Diameter	210 mm
Thickness	3.5 mm
Operating pressure	4-6 bar

F. Working Chamber

It is the chamber where different machining operations like deburring, drilling, polishing can be done.

Height of the working chamber from floor	430 mm
Dimensions (L×W×H)	(430×430×630) mm
Dust collector funnel flow angle	35^0
Materials used	Mild steel for working chamber and aluminium sheet for dust collector funnel

G. Abrasives

Sand and aluminium oxide are used as abrasives. Abrasives having small particle size are used for polishing and cleaning, while the larger sizes are best for cutting and peening.

Abrasive	Silicon carbide (SiC), Sand (size 20µm to 150µm)

H. Vice

It is the clamping device under the nozzle where workpiece is kept.

Dimensions (L×W×H)	(108×105×25) mm

I. Horizontal feed screw

It's main function is to provide the movement of the guideways in order to have adjustment in the horizontal direction.

Material	Mild steel rod of diameter 12 mm
Length	160 mm
Thread	Right hand thread (5/8 of inch) – British Standard Whiteworth (BSW)

J. Vertical feed rod

It's main function is to provide the movement for the nozzle in order to alter the nozzle tip distance which is the distance between nozzle and work surface.

Material	Mild steel rod
Length	560 mm

H. Nozzle

The high pressure air coming from the compressor after passing through various devices particularly mixing chamber, at last reaches the nozzle inlet. Due to the gradual reducing cross sectional area of nozzle the high pressure abrasive mixture slowly gets momentum in terms of kinetic energy and at the exit it comes out at a great velocity which is directly used for drilling the required workpiece of different thickness.

Type of Material	Brass
Nozzle inlet diameter	4.0 mm
Nozzle outlet diameter	1.5 mm
Angle of taper	2^0
Length of Nozzle	55 mm

V. EXPERIMENTAL RESULTS

TABLE 1 EFFECT OF VARYING PRESSURE ON MRR

S.No.	***Pressure (bar)***	***Initial weight (gm)***	***Final weight (gm)***	***Time (sec)***	***Weight difference (gm)***	***MRR (gm/sec)***
1	4.2	53.98	53.93	3.6	0.05	0.01388
2	4.5	53.93	53.87	3.4	0.06	0.01764
3	4.7	53.87	53.79	3.1	0.08	0.02580
4	5.0	53.79	53.69	3.2	0.10	0.01764

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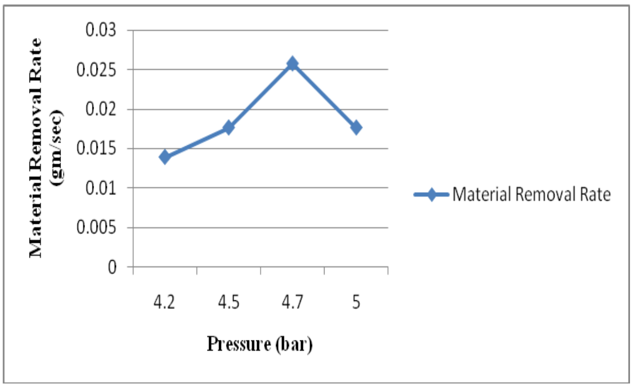

FIG 3 Material removal rate v/s varying pressure

TABLE 2 EFFECT OF CONSTANT PRESSURE ON MRR

S. No.	*Pressure (bar)*	*Initial weight (gm)*	*Final weight (gm)*	*Time (sec)*	*Weight difference (gm)*	*MRR (gm/sec)*
1	4.5	54.50	54.44	2.9	0.06	0.02068
2	4.5	54.44	54.37	3.0	0.07	0.02333
3	4.5	54.37	54.27	2.9	0.10	0.03448
4	4.5	54.27	54.21	2.8	0.06	0.02142
5	4.5	54.21	54.18	3.1	0.03	0.00960

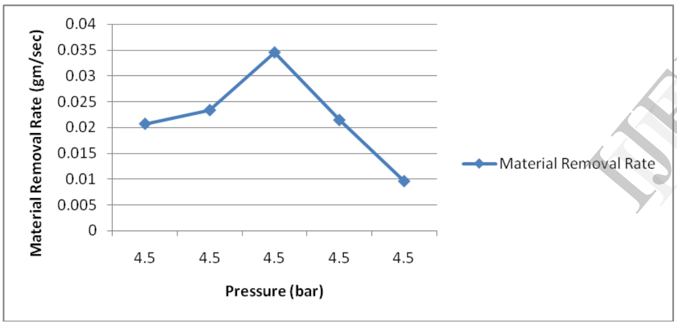

FIG 4 Material removal rate v/s constant pressure

TABLE 3 EFFECT OF VARYING PRESSURE ON MRR
(when thickness of glass is 1.54 mm)

S. No.	*Pressure (bar)*	*Average diameter (cm)*	*Area (cm^3)*	*Volume (cm^3)*	*Time (sec)*	*MRR (cm^3/sec)*
1	4.0	0.55	0.2376	0.0366	2.0	0.01830
2	4.2	0.55	0.2376	0.0366	1.7	0.02152
3	4.5	0.55	0.2376	0.0366	1.5	0.02440
4	4.8	0.525	0.2165	0.0333	1.3	0.02560
5	5.0	0.525	0.2165	0.0333	1.4	0.02370

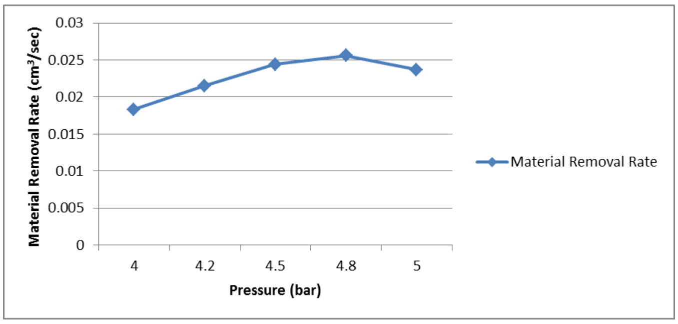

FIG 5 Material removal rate v/s varying pressure
(when thickness of glass is 1.54 mm)

TABLE 4 EFFECT OF VARYING PRESSURE ON MRR
(when thickness of glass is 1.73 mm)

S. No.	*Pressure (bar)*	*Average diameter (cm)*	*Area (cm^3)*	*Volume (cm^3)*	*Time (sec)*	*MRR (cm^3/sec)*
1	4.0	0.475	0.177	0.0306	2.1	0.0146
2	4.3	0.45	0.159	0.0275	1.8	0.0152
3	4.6	0.45	0.159	0.0275	1.7	0.0161
4	4.8	0.475	0.177	0.0306	1.5	0.0204
5	5.2	0.525	0.216	0.0374	1.3	0.0288

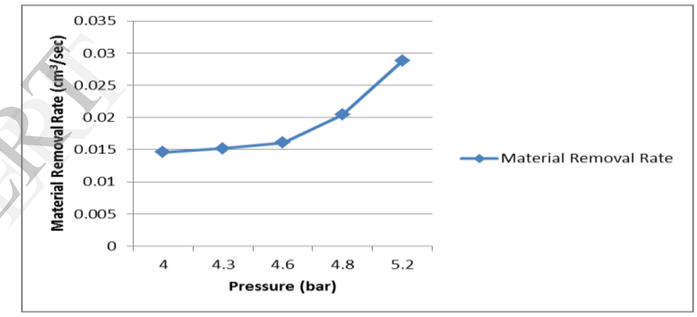

FIG 6 Material removal rate v/s varying pressure
(when thickness of glass is 1.73 mm)

VI. CONCLUSION

The drilling of glass sheets with different thickness and varying pressure have been carried out through abrasive jet machining in order to determine its machinability. Experimental results and graphs shows that gas pressure has a direct impact on material removal rate. Hence, when the pressure increases, material removal rate also increases.

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