IJSRD - International Journal for Scientific Research & Development| Vol. 3, Issue 11, 2016 | ISSN (online): 2321-0613

Development of Abrasive Jet Machine

Jigarkumar P. Patel[1] Dr. K V. Modi[2]
[1]P.G. Student [2]Associate Professor
[1,2]Department of Mechanical Engineering
[1,2]Government Engineering College, Valsad

Abstract— Abrasive jet machining is the process of material removal process from a work piece by the application of a high speed stream of abrasive particles carried in gas medium from a nozzle. Aluminum oxide (AL_2O_3) as abrasive particle having size of 60 and 80 mesh is used and carrier gas as a carrier of abrasive particle. In this project model of abrasive jet machine is fabricated. Also the solid modelling is done using PRO-E. The machine is having 3 axes travel, Horizontal motion module (X-Y Table), and vertical motion module (Z-axes motion). By this configuration plate glass up to 3mm thickness can be cut and MRR of 14.28 mm3/min. is possible.

Key words: AJM, Abrasive Jet Machine

I. INTRODUCTION

Abrasive jet machining is the process of material removal process from a work piece by the application of a high speed stream of abrasive particles carried in gas medium from a nozzle. A focused stream of abrasive particles, carried by high pressure air or gas is made to impinge on the work surface of the work- piece through a nozzle and the work material is removed by erosion action by high velocity abrasive particles. Abrasive Jet Machining (AJM) is the removal of material from a work piece by the application of a high speed stream of abrasive particles carried in gas medium from a nozzle. The AJM process differs from conventional sand blasting in that the abrasive is much finer and the process parameters and cutting action are carefully controlled. Abrasive air-jet is an abrasive machining process widely used for surface cleaning, and cutting. The nozzle is the most critical part in the abrasive air-jet equipment. The process is used chiefly to cut intricate shapes in hard and brittle materials which are sensitive to heat and have a tendency to chip easily. The process is also used for deburring and cleaning operations. AJM is inherently free from chatter and vibration problems. The cutting action is cool because the carrier gas serves as a coolant. Abrasive processes are usually expensive, but capable of better surface finish than other machining process. The process can be easily controlled by varying the parameters such as Velocity, Flow rate, Pressure, Standoff distance, Grit size.

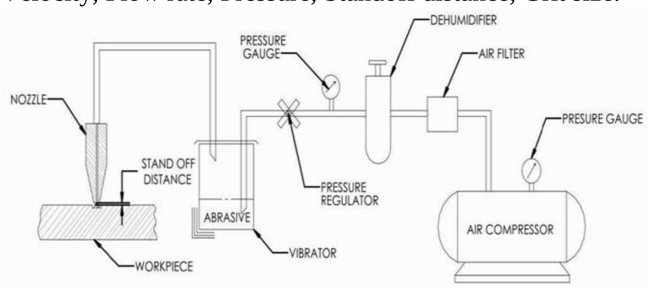

Fig. 1: Schematic diagram of Abrasive jet machine

Air from the atmosphere is compressed by the compressor and is delivered to the mixing chamber via filter and regulator. The mixing chamber contains the abrasive powders. Then the abrasive particles are passed into a connection hose leading to the nozzle. This abrasive and gas mixture emerges from the orifice of the nozzle at high velocity. The pressure regulator installed in the system controls the gas flow and pressure. The nozzle is mounted on a frame which is screwed to the frame. The work piece is moved by moving the x-y table to control the size and shape of the cut.

A. Conventional and Other Glass Cutting Methods

Conventionally, the plate glass cutting is usually done by using a diamond point tool. The step follow are: (a) marking and scribing (shallow cutting) on the plate glass surface as per the desired profile using a diamond point tool, and (b) application of an external force on the glass with extreme skill so that the glass breaks along the scribing. The cut surface obtained by the above methods is always irregular, wavy and with poor surface finish, in spite of the amount of skill used and the care taken. Hence grinding and polishing are required to bring the glass to required size, shape and surface finish. But this increase the fabrication cost and is highly time consuming. The glass damages are more likely during cutting. Also it is impossible to cut complex profiles (shapes other than a straight line).

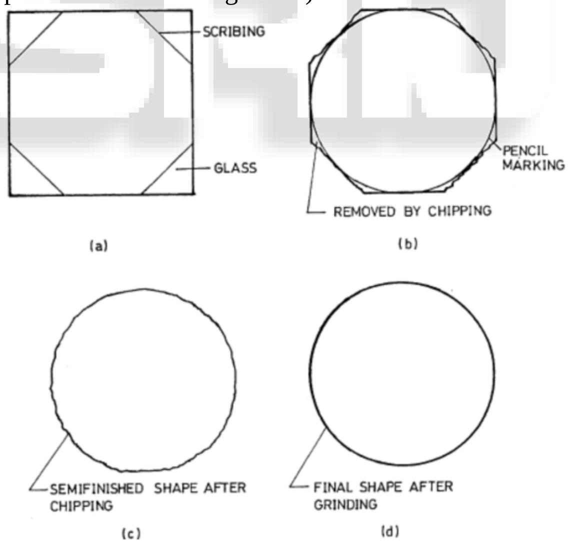

Fig. 2: Steps for cutting by Conventional method

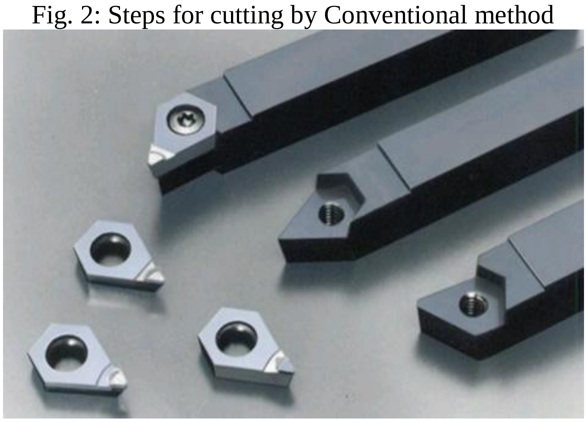

Fig. 3: Diamond point cutting tool

Sr No.	Cutting method	Disadvantages
1	Diamond point tool	Time consuming process, More wastage of glass, Non straight profiles cannot be cut in a single stage.
2	Laser Cutting	Very high initial capital equipment, Leaves a heat affected zone, Micro cracks at the cut surface.

Table 1: Disadvantages of Conventional Glass Cutting Method

To overcome the above disadvantages of glass cutting Abrasive jet machine is used. This method is relatively simple one and has several comparable advantages. It makes use of low cost, simple x-y table for glass movement for its operation. The process is safe and does not involve very high temperature. This process is clean and does not generate glass powder. Any complex shape is easy to cut to very close tolerance. The surface finish is smoother than the one obtained by diamond tool.

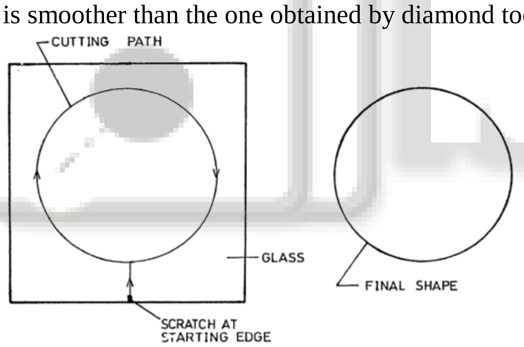

Fig. 4: Cutting by AJM in a single step

For an easy initiation of cutting, a shallow cut or scratch (of approx. 2mm length) on the glass surface at the starting edge is required. The scratch can be made using a diamond point tool or a hacksaw. A rotary table can be used for circular cutting.

B. *Objectives*

- Development of experimental setup of abrasive jet machine.
- Solid modeling.
- Cutting of glass of thickness 2-5 mm, Study of various parameters on its performance.

C. *Advantages*

- High surface finish can be obtained depending upon the grain sizes.
- It provides cool cutting action, so it can machine delicate and heat sensitive material.
- Process is free from chatter and vibration as there is no contact between the tool and work piece.
- It is easy to maintain and operate.
- It has the capability of cutting holes of intricate shape in brittle material.
- No secondary finishing is required in most of the cases.
- No coolant or lubrication is required.

D. *Disadvantages*

- Material removal rate (MRR) is low and hence its application is limited to small scale machining.
- The abrasive material may accumulate at nozzle and fail the process if moisture is content in the air.
- Embedding of the abrasive particles in the work piece surface may occur while machining softer material.
- Nozzle life is limited.
- Abrasive powders cannot be reused as the sharp edges are worn and smaller particles can clog the nozzle.
- Short standoff distances when used for cutting, damages the nozzle.

E. *Applications*

- Used for drilling, cutting, and polishing of hard and brittle material.
- The machining of essentially brittle materials and heat sensitive materials like glass, ceramic, plastic etc.
- Applicable where better surface finish is the major requirement.

II. COMPONENTS AND ITS DETAIL

A. *Air Compressor*

Air compressors collect and store air in a pressurized tank, and use pistons and valves to achieve the appropriate pressure levels within an air storage tank that is attached to the motorized unit.

Fig. 4: Air compressor

B. *Pressure Regulator*

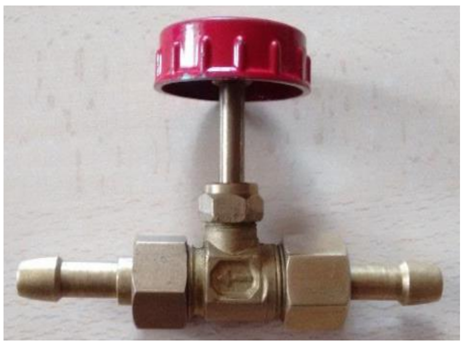

Fig. 5: Pressure Regulator

The line pressure is regulated by pressure regulator. A pressure regulator's primary function is to match the flow of gas through the regulator of gas place upon the system. A pressure regulator includes a restricting element, a loading element and a measuring element.

C. Pressure Gauge

Pressure gauge is used to measure the gas pressure which indicates on the dial. A change in pressure causes the measuring element into a deflection. This deflection of the free end of the bourdon tube is proportional to the applied pressure and will be transmitted to a rotary geared movement. This movement carries a pointer and indicates the pressure on a dial.

Fig. 6: Pressure gauge

D. Nozzle


Fig. 7: Nozzle

The abrasive particles are directed into the work surface at high velocity through nozzles. The rate of material removal and the size of machined area are influenced by the distance of the nozzle from the work piece

E. Piping System


Fig. 7: Hose pipe

The piping systems are required for carrying the compressed air from the compressor to the mixing chamber and from the mixing chamber to the nozzle orifice via the regulator. It is required to maintain the pressure in the line without eroding the pipe.

F. Guide Ways (X-Y Table)

X-Y table is the most important part of the AJM over which the work piece has to be kept and machined. The main function of the guide way is to make sure that the machine tool operative element move along predetermined path. The guide way provides a smooth and linear motion in machine tool due to which higher accuracy and precision can be obtained. Guide way have a mechanism to bear the load and to guide their linear motion simultaneously.

G. Abrasives

An abrasive is a material that is used to shape or finish a work piece through rubbing which leads to part of the work piece being worn away. While finishing a material often means polishing it to gain a smooth surface. Various abrasives used are Silicon oxide (SiO2), Silicon carbide (SiC), Aluminium oxide (Al2O3) of different sizes for cutting and drilling operation.


Fig. 8: Abrasive particles

III. SOLID MODELLING

Solid modelling is done using PRO-E.

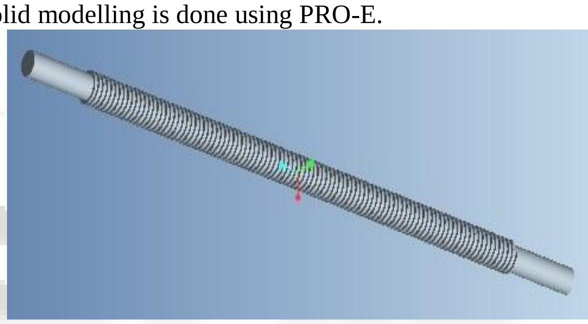
Fig. 9: Screw

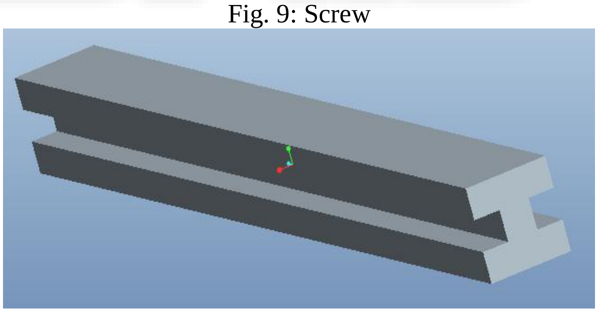
Fig. 10: Rail of guide way

A. Screw Length Calculation

X-Y table is the most important part of the AJM over which the work piece has to be kept and machined. The travel of X-Y table has been decided to be 300 x 250 mm.

The X-Y table consists of two parts: (a) Upper table, (b) Lower table. The upper table is responsible for X-movement and has a travel of mm. The lower has a travel of mm and is responsible for the Y-motion of the work piece.

Travel of X-Y table has been decided to be 300 x 250 mm.

So screw of x- axis:

= 300mm + 200 mm + 140mm (Travel) (Upper table breadth) (Allowance for pedestal Bearing)

= 640 mm

Screw length Y-axis screw:

= 250 mm + 250 mm + 140mm (Travel) (Upper table breadth) (Allowance for pedestal Bearing)
= 640 mm

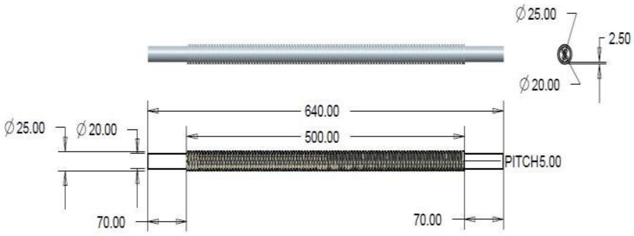

Fig. 11: Screw

B. Rail Length Calculation

Length of the rail should be approximately 50 mm longer than that of corresponding screw.
Hence in X- Axis rail length = 550mm.
Y- Axis rail length = 550mm.

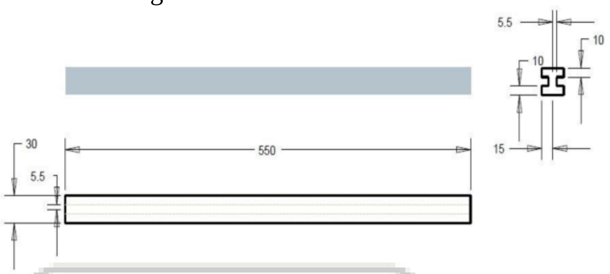

Fig. 12: Rail of guide way

C. Final Assembly

The assembly of the abrasive jet machine can be represented as follows. It can be noted that the components like air compressor, mixing chamber and piping system have not been shown in the drawing.

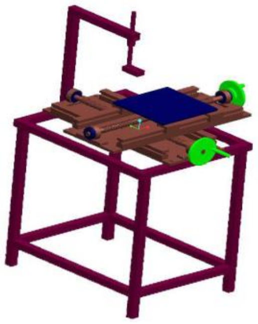

Fig. 13: Final Assembly

IV. Experimental Setup

Fig. 14: Experimental setup of abrasive jet machining

A. Working of Abrasive Jet Machine

Air from atmosphere enters the reciprocating compressor where it get compressed by continuous motion of the piston and gets stored in the air chamber at a pressure of 8 kg/cm^2. The abrasive particles are then poured through the side of the chamber. When the control valve of the compressor opens the compressed air enters the mixing chamber through the piping system at the inlet of chamber provided on the top surface and mixes with the abrasive particles.

The pouring of abrasive from the side of the chamber creates the swirling effect and good mixing of air and abrasive. The mixture of air and abrasive particles flows through outlet of chamber to the nozzle inlet through the same pipe at a pressure of 6 kg/cm2. This mixture comes out from nozzle at high velocity and impinges on the glass surface placed on the guide way and erosion of the glass takes place. For initiation of cutting action a crack at the edge is to be provided with the help of hacksaw.

The guide way is provided for the movement of the workpiece screwed on the machine frame and there is also a provision for the nozzle movement to maintain stand-off distance.

B. Material Removal Rate (MRR)

The material removal rate is the parameter which is affected by the air pressure, nozzle diameter, velocity of jet, abrasive size and stand-off distance.

Material removal in AJM takes place due to brittle fracture of the work material due to impact of high velocity abrasive particles.

MRR in AJM of brittle material can be expressed as,

$$\mathrm{MRR_B} = \frac{\mathrm{m_a V^{3/2}}}{\mathrm{\rho_g^{1/4} H^{3/4}}}$$

Where, V = Velocity of abrasive particle
= 80 m/s
m_a = Mass of abrasive delivered
= 3 gm/min
H = Hardness of work material (soda lime glass)
= 5935.05 * 10^6 N/m^2
ρ_g = Density of the grit
= 2440 kg/m^3

$$\mathrm{MRR_B} = \frac{3 * 10^{-3} * 80^{3/2}}{60 * 2440^{1/4} * (5935.06 * 10^6)^{3/4}}$$

= 0.2380 × 10^{-9} m^3/s
= 0.2380 mm^3/s
= 0.2380 × 60 mm^3/min
= 14.80 mm^3/min

V. Conclusion and Future Scope

A. Conclusion

In this project, a complete model of abrasive jet machine is fabricated. This method is used to cut plate glass of 2-5mm thickness. Also non-straight profiles can be cut by moving the guideway (x-y table). Glass fumes or powder is not generated during drilling. Also the surface finish obtained is better than the diamond tool. The process is non-contact, simple and clean. But, the material removal rate is low. The time required to drill a glass of 3 mm is 2 min by using nozzle size of 1.2 mm and nozzle tip distance of 8 mm. The MRR obtained is 14.28 mm^3/min.

B. Future Scope

The project can go beyond its current position and capabilities by employing automation into it. 2-D profiles can be converted into G-codes and M-codes and can be sent to the machine to perform machining operation. This can be done by using stepper motors or DC motors interfaced with standard PLC controllers. Accuracy can also be increased by using controllers.

References

[1] Bhaskarchandra and Jagtar singh. ‘A study of effect of process parameters on abrasive jet machining’.

[2] Deng Jianxin, Wu Fengfang, Zhao jinlong. ‘Wear mechanism of gradient ceramic nozzles in abrasive air jet machining’ Department of mechanical engineering, Shandong University, Jinan 250061, Shanlang province, PR China.’

[3] D.V. Srikantha and Dr. M. SreenivasaRaob. ‘Metal removal and Kerf analysis in abrasive jet drilling of glass sheets’ Procedia Materials Science 6 (2014) 1303 – 1311.

[4] E.S. parekh, K Sadashivapa, Vince Joseph, M singaperumal ‘Non-conventional cutting of plate glass using air jet: Experimental studies’.

[5] Ghobeity, a. Spelt, j. K. Papini. ‘Abrasive jet micro-machining of planar areas and transitional slopes’ publication: journal of micromechanics and micro engineering, volume 18, issue 5, pp. 055014.

[6] Gyanendra Prasad Bagri, Sanjeev kumar gupta, Manvendra pratap singh, Vikas singh. ‘Design and fabrication of abrasive jet machine’ International journal of applied engineering research ISSN 093-4562 volume 9, number 4 (2014) pp.379-384.

[7] Hajara Chaudhary. ‘Workshop Technology’ Vol – 2

[8] Khan, ahsan Ali awang, Mohd efendee bin, Annuar, Ahmad azwari bin. ‘Surface roughness of carbides produced by abrasive water jet machining’ publication: journal of micromechanics and micro engineering, volume 18, issue 5, pp. 055014.

[9] K. Kowsari, H. Nouraei, D.F. James, J.K. Spelt. ‘Abrasive slurry jet micro-machining of holes in brittle and ductile materials’ Journal of material processing technology 214 (2014) 1909-1920.

[10] M.L.Neema and P.C. pandey. ‘Erosion of glass when act upon by an abrasive jet’ Proceeding on international conference on wear of materials, 1977.

[11] R. Balasubramanium, J Krishnan, N.ramakrishnan. ‘A study on the shape of the surface generated by abrasive jet machining’ Central workshop, Bhabha atomic research centre, Mumbai, India Department of mechanical engineering, Indian institute of technology, Bombay, India.

[12] S. Naveen and Aslam Hirani. ‘Design and fabrication of abrasive jet machining’ International journal of mechanical and production engineering research and development ISSN (P): 2249-6890; ISSN (E): 2249-8001.

[13] Umberto Prisco, Maria Carmina D’Onofrio. ‘Three-dimensional CFD simulation of two-phase flow inside the abrasive water jet cutting head’ publication: International journal of computational methods in engineering science and mechanics 9 (5), pp. 300-319.

