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DESIGN AND FABRICATION OF ABRASIVE JET MACHINING (AJM) AND STUDY OF EFFECT OF VARIOUS PROCESS PARAMETERS OF AJM BY USING SILICON CARBIDE AS ABRASIVE MATERIAL

RAM THAPA, BIBEK SHAKYA, KHAGENDRA GAUTAM, DARSHAN SONEJI

B. Tech Final Year Students of Mechanical Department, Suresh Gyan Vihar University, Jaipur, Rajashthan

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Abstract: Abrasive jet machining, also known as micro machining, is a new approach in machining field discovered a few decades ago. Abrasive jet machining is a material removal process in which abrasive particles (silicon carbide, aluminum oxide etc.) act as cutting tool, carried by high pressurized fluid medium (air or water) through a nozzle. The high velocity of abrasive jet impinged to the work surface by the nozzle causes a brittle facture on the material work surface & as a result material removal takes place by the process of erosion. Abrasive jet machine is highly applicable in machining hard and brittle material as well as highly heat sensitive material like glass, quartz, ceramic, semiconductor etc. This paper deals with design and fabrication of AJM. Various parts of AJM were designed by using AutoCAD and CATIA software. The parts were then fabricated as per designed parameters inside the college workshop. The machine thus fabricated has been particularly used for drilling on glass slab with silicon carbide (sic) as the abrasive particle. The process variables considered here includes abrasive mixing ratio, abrasive flow rate, stand-off distance and fluid pressure. Experiments were conducted by varying these parameters for drilling the glass slab of different thickness.

Keywords: Abrasive jet machining, Stand-off distance, Material removal rate, Glass, Silicon Carbide

Corresponding Author: RAM THAPA

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INTRODUCTION

Abrasive jet machining is one of the non-conventional machining methods for carrying out operations like drilling, honing, rough cleaning, deburring & etching on the surface of hard and brittle materials like cast iron, ceramics, semiconductor, glass etc. without heat, stress and vibration.

In AJM, mixture of abrasive particles (typically having size of 10 -70 µm) and pressurized carrier gas is impinged on work surface through a nozzle made of sapphire or tungsten of diameter 0.2 to 8 mm under controlled conditions. According to investigation and advancement for cutting of hard and brittle material sharp and coarse abrasive is required. Silicon carbide & aluminum oxide are most preferred abrasive for cutting purposes. Other abrasive particles like boron carbides, crushed glass, sodium bicarbonate are also used in AJM according to the operation that is to be performed.

Ascertaining the influence of all operational parameters on the process effectiveness including abrasive type, size and concentration, impact speed and angle of impingement, nozzle pressure, mixing ratio and abrasive size are insignificant and express the overall process performance in terms of material removal rate with geometrical tolerance. The Stand-off Distance(SOD) was found to be the most crucial factor on the size of the diameter generated at the edges. As the SOD increases the diameter of hole increases. [1]

The effects of abrasive grain size and mixing ratio on performance is that as the abrasive grit size and mixing ratio increase, the MRR and penetration rate increase but the surface finish decreases. When deburring the external surface by abrasive jet, different edge condition viz taper edge, concave edge was obtained which depends upon the parameter of jet height, velocity, size of nozzle as well as the impingement angle of nozzle. Several investigations concluded that as the particle size increases, the MRR at the center line of the jet drastically increases; but MRR nearer to periphery is very less [2]

As the stand-off distance increases up to a certain limit, MRR drastically increases. Beyond that limit MRR is found to decrease with an increase of stand-off distance. The jet flares out with an angle less than seven degree thereby increasing the diameter of the cutting section. As SOD increases, jet particles are imparted with less kinetic energy on the work piece [3]. The increase of the nozzle diameter increases the MRR due to the increase in the flow rate of the abrasive particles.

For machining soft and ductile material, the abrasive particles with very high velocity must be embedded on the workpiece. These embedded particles are responsible for the shielding from next impinging particles which lead to low machining efficiency. To augment the efficiency, one need to remove these abrasive particles. For this reason, ductile material is not recommended for machining in abrasive jet machine. [4]

In the context of our study, the required variables were stand-off distance or nozzle tip distance, work feed rate and jet pressure. The evaluating criteria of the surface produced were width of cut, taper of the cut slot and surface roughness. It was found that in order to minimize the width of cut; the nozzle should be placed close to the work surface. Increase in jet pressure results in widening of the cut slot both at the top and at the exit of the jet. However, the width of cut at the bottom (exit) was always found to be larger than that at the top. [5]

The jet pressure does not show significant influence on the taper angle within the range of work feed and the stand-off distance considered. Both stand-off distance and the work feed rate show strong influence on the roughness of the machined surface. Increase in jet pressure shows positive effect in terms of smoothness of the machined surface. With increase in jet pressure, the surface roughness decreases. This is due to fragmentation of the abrasive particles into smaller sizes at a higher pressure and due to the fact that smaller particles produce smoother surface So, within the jet pressure considered, the work surface is smoother near the top surface and gradually it becomes rougher at higher depths. [6]

Principle

In AJM, the atmospheric air is compressed in the compressor. Pressurized gas is then passed through filters and control valves into the mixing chamber where it is mixed with abrasive particles and a stream of abrasive passes through the nozzle, thereby generating high kinetic energy at the expense of pressure energy. High velocity of abrasive jet is then impinged on the workpiece. Kinetic energy of the abrasive jet gets converted into mechanical energy and thus the material is removed by micro cutting and indentation is created on the work surface. As shown in fig 1. the material removal rate from the workpiece in AJM is low but accuracy is higher.

AJM is free from heating problem as the high velocity of jet takes away the heat produced during machining.

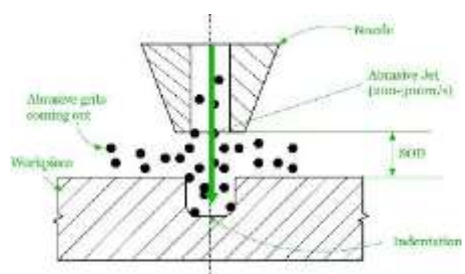

Fig 1: Micro cutting of brittle material in AJM

It is clear from the figure2 that at a particular pressure MRR increases with increase in abrasive flow rate and is influenced by the size of the abrasive particles. But after reaching optimum value, MRR decreases with further increase in abrasive flow rate. This is owing to the fact that mass flow rate of gas decreases with increase of abrasive flow rate and hence mixing ratio increases causing a decrease in material removal rate because of decreasing energy available for erosion.

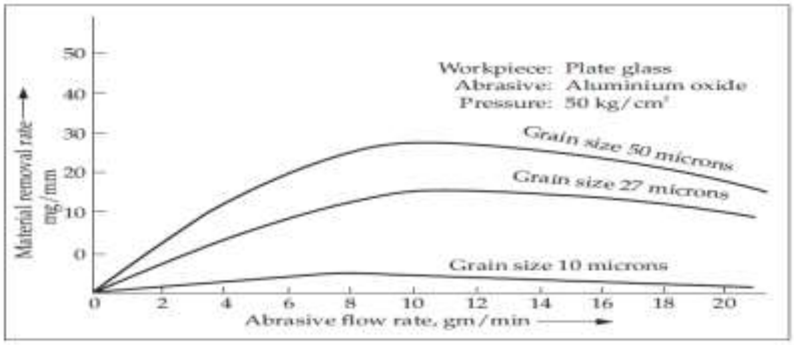

Figure 2 Effect of abrasive flow rate on material removal rate (MRR)

The abrasive flow rate can be increased by increasing the pressure of the carrier gas. This is only possible by increasing the internal gas pressure as the internal gas pressure increases abrasive mass flow rate increases and thus MRR increases.
Kinetic energy of the abrasive particles is responsible for the material removal rate by erosion process. The abrasive must impinge on the work surface with minimum velocity for machining glass by SIC particle is found to be around 150 m/s. [6] The effect of NTD or SOD on material removal rate (MRR) is shown in figure 3 as the SOD increases the diameter of hole increases which is general observation in abrasive jet machining.

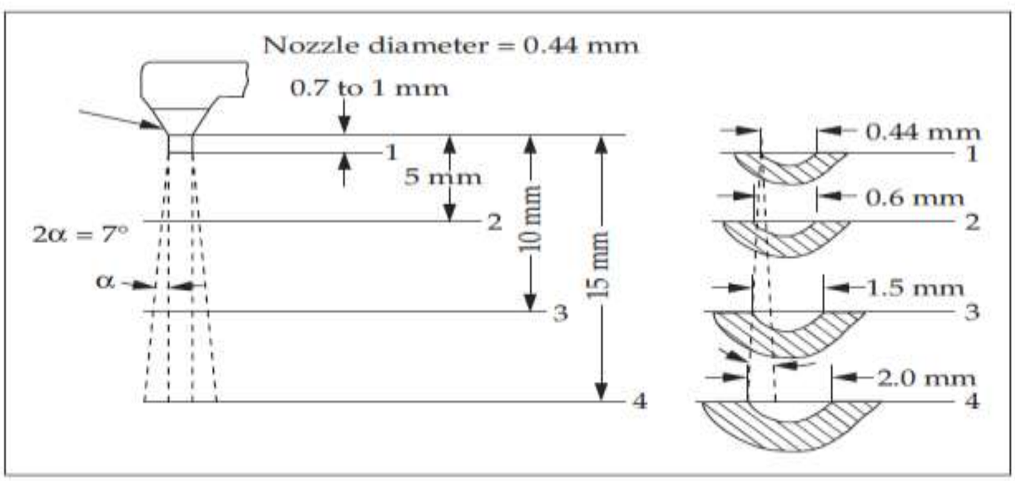

Figure 3: Effect of stand-off distance on the width of the cut

METHODODLOGY

Different components like mixing chamber, abrasive feeder, nozzle, work holding device and glass enclosing chamber have been designed using AutoCAD & CATIA software and fabricated in the institute workshop with required raw materials and procured components.

The reciprocating air compressor and filter regulator (FR) unit have been used as accessories of the AJM.

Air compressor

In this experiment reciprocating air compressor (maximum pressure= 11 kgf/ cm2) has been used for compressing the atmospheric air from low pressure to high pressure by taking input energy from electric motor. The outlet pressure of compressor is controlled by valve mechanism which is manually controlled. Air compressor is shown in the figure 4. For AJM experimental set up air pressure of 4 to 7 kgf/cm^2 were taken for experiment.

Engine rpm =2875

Capacity =60 liter

Power= 2 HP

Fig: 4 Reciprocating compressor

FRL unit

FRL stands for filter regulator and lubricator. It is compulsory to remove moisture and dust particle present in pressurized air so FRL unit is used for filtering the air and regulating the air pressure and lubrication of component. It is necessary to remove the moisture from air otherwise accumulation of abrasive particle can occur in the pipeline and the nozzle resulting in failure of the machining process. This is the major issue in AJM especially during the winter season. The desired pressure can be controlled through the FRL unit by rotating the top screw of FRL unit. For experiment we have taken air pressure from 4 to 7 kgf/cm2.

Figure 5: FLR unit

Mixing chamber:

It is used for mixing of abrasive grains and compressed air. Abrasive chamber has been fabricated as per dimensions. The diameter and height of the abrasive feeder chamber were kept 100 mm and 160mm respectively. The mixing cylinder is hinged on the working table. The mixing cylinder was made up of mild steel. The cylinder has three ports. One is used for inserting the abrasive particles and is closed by a bolt of 12mm diameter, the second one is used as an inlet to the compressed air & the third one is used as an outlet for mixing of abrasive particles and compressed air.

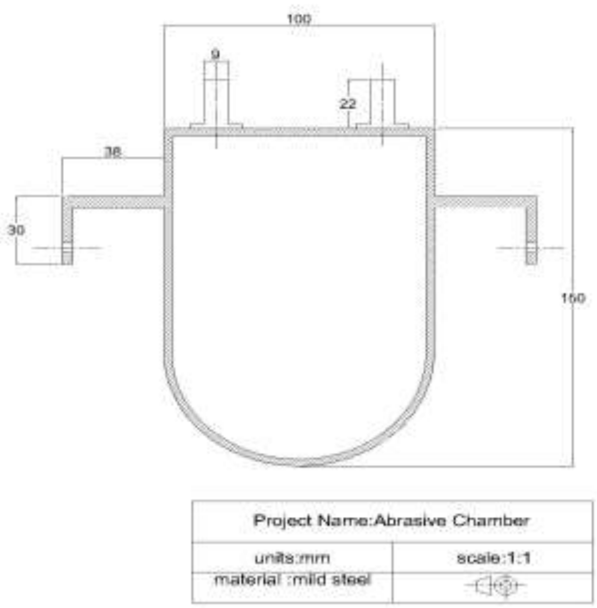

Figure: 6 AutoCAD drawing of abrasive chamber

Nozzle

The mixture of air and abrasive particles is directed into the work surface at high velocity through a nozzle. Therefore, the material of the nozzle is also subjected to abrasion wear. The nozzle wear is a big issue in AJM. Hence the nozzle material should be hard and tough such as tungsten carbide or synthetic sapphire. Sapphire nozzles have longer life and can cut only circular sections, but Tungsten carbide nozzle can cut square, rectangular and circular section. Dimension and life hour is as shown in the table

Table 1: Dimension and life hour of sapphire and tungsten carbide nozzle

Nozzle material	Round shape nozzle diameter (mm)	Rectangular shape slot Dimension(mm)	Life hour
Tungsten carbide (WC)	0.2 to 1.0	0.75 × 0.5 to 0.15 × 2.5	12 – 30
Sapphire	0.2 to 0.8	0.60X0.75 to 0.20 X 2.5	300

In the fabrication die carbon alloy nozzle was used with following specification:

SOD = 2 mm to 15 mm.

Length of nozzle = 70 mm

Nozzle diameter = 2 mm

Design of nozzle is made in AutoCAD as shown in figure.7

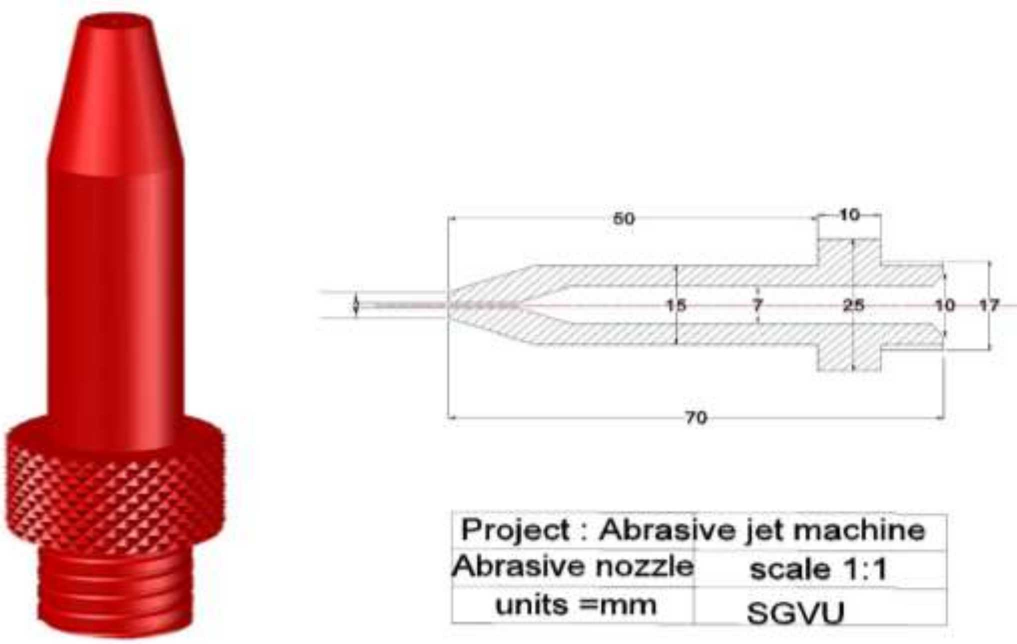

Figure 7: 3D view and side view of abrasive nozzle

EXPERIMENTAL SETUP & PROCEDURE

For performing the experimental work on silica glass, the work piece was taken having the dimensions of 120mm x120mm and thickness 3mm,4 mm and 5mm. Silicon carbide having grit size 25-50 µm was used during the experiment. First of all, the glass piece was set on the vice and clamped. Setting of nozzles was done with the help of ring clamp with stand-off distance 2mm to 15 mm. This setting is maintained for all the operation by varying SOD and pressure of gas medium. After the complete setting of the nozzle, the compressor builds up the pressure to the required level. Then the valve is slowly opened, and the gauge pressure is checked.

Table 2: Drilling of glass having thickness 4mm

s.no	AJM parameter	Condition
1	Type of abrasive	Silicon carbide (SIC)
2	Size of abrasive	25-50 µm
3	Jet pressure	4-7 kg\cm^2
4	Stand-off distance	2-15mm
5	Nozzle angle	90’

Several readings were taken varying stand-off distance and pressure on glass specimen with different thickness and all results were tabulated. All results were compared with the theoretical results also to check the validity of our results which were listed in the table.

Figure 8: complete set up of abrasive jet machine

Table 3: Parameter affecting the material removal rate

s.no	Parameter
1	Carrier gas
2	Type of abrasive particle
3	Size of abrasive particle
4	Stand-off distance
5	Mixing ratio
6	Velocity
7	Shape of nozzle

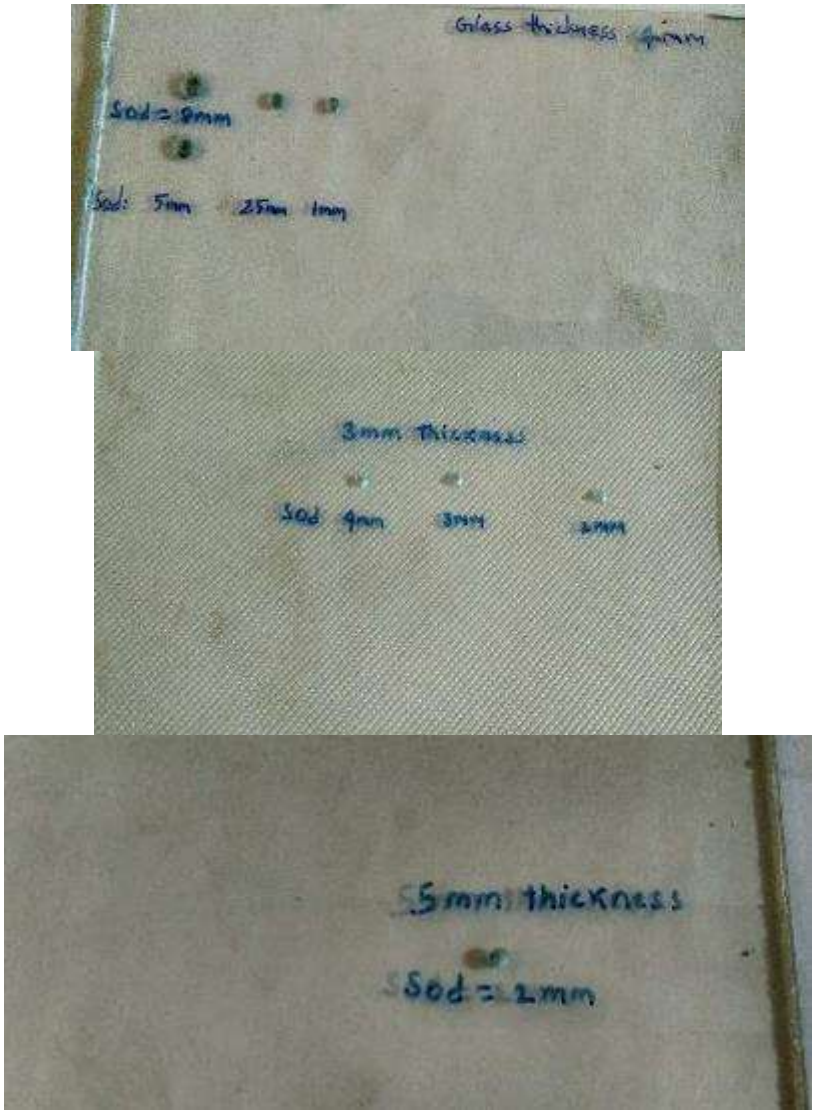

Figure 9: Experiment on glass slab of thickness 4mm, 3mm& 5mm respectively with 5kgf\cm2 pressure

RESULT & DISCUSSION

Thus, in our experiment, the effect of varying SOD on the diameter of the holes & the effect of varying gas pressure on material removal rate (MRR) was observed and studied. Readings were taken at different nozzle tip distance (SOD) and different pressures. After taking the readings, the results were plotted in the form of graphs as shown below.

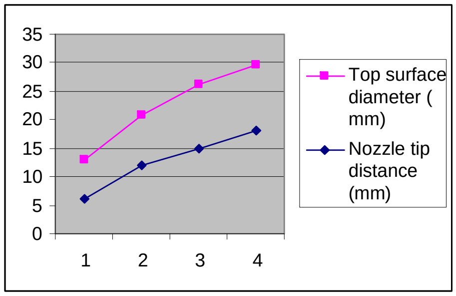

Fig.10 Graph showing the relationship between nozzle tip distance and top surface diameter of hole at a set pressure of 5.5 kg/ cm ^{2}

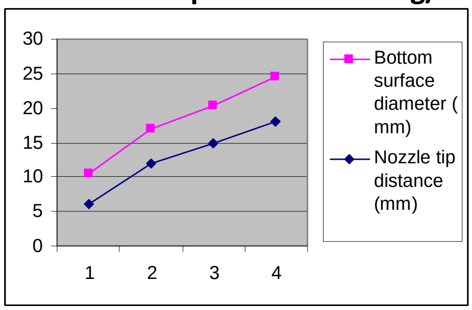

Fig.11 Graph showing the relationship between nozzle tip distance and bottom surface diameter of hole at a set pressure of 5.5 kg/ cm 2

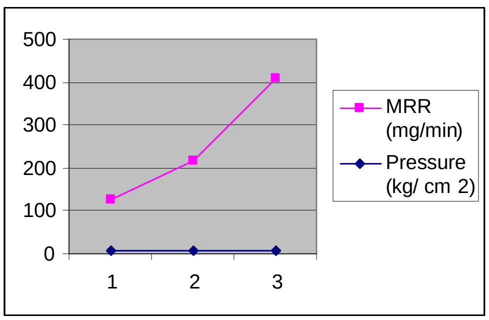

Fig.12 Graph showing the Relationship between pressure and material removal rate (MRR) at thickness 8 mm and NTD 12 mm[3]

Thus from the graphs, it can be inferred that, as the nozzle tip distance increases, the diameter of hole also increases. This is because larger nozzle tip distance allows the jet to expand before impingement which in turn may increase vulnerability to external drag from the surrounding environment. Hence, it is desirable to have a lower nozzle tip distance so that a smoother surface can be produced due to increased kinetic energy.

Results of experimental work by Roopa Rani and S.Seshan.
They have conducted some experiments on AJM test rig. at department of mechanical engineering, Indian institute of science, Bangalore. These results are shown here in tables 9-10

and graphs (Fig.14-15) which shows the effect of pressure on the material removal rate and effect of NTD on diameter of hole in AJM process.

Table 4 Effect of pressure on material removal rate (MRR)

s.no	Gas pressure	Material removal rate (mg\min)
1	5	18
2	6	21
3	7	23
4	8	26

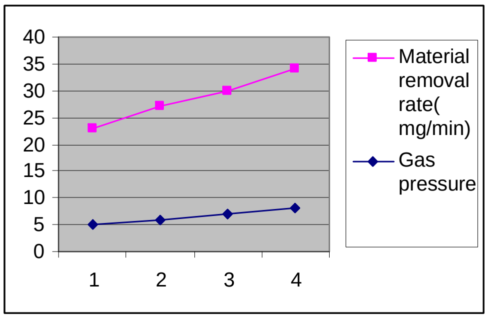

Fig.13 Graph showing the Relationship between pressure and material removal rate (MRR)

Table 5 Effect of NTD on diameter of hole

s.no	Nozzle tip distance (mm)	Diameter of hole(mm)
1	0.79	0.46
2	5.00	0.64
3	10.01	1.50
4	14.99	2.01

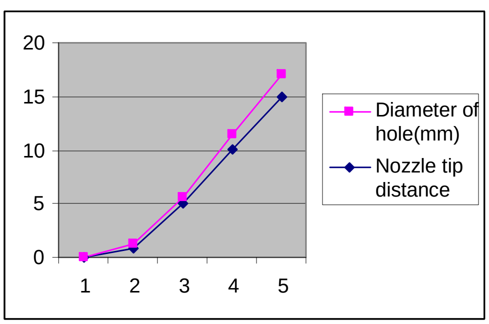

Fig.14 Graph showing the Relationship between NTD and diameter of hole

CONCLUSION

The experimental results of the present work have been conducted by changing pressure, nozzle tip distance on different thickness of glass slab, With the increase in nozzle tip distance (SOD), 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. These were compared with the Roopa Rani and S.Seshan results [2]

REFERENCE

1. Ghobeity, A.; Spelt, J. K.; Papini Abrasive jet micro machining of planar areas and transitional slopes , M. Publication: Journal of Micromechanics and Micro engineering, Volume 18, Issue 5,
2. M. Roopa Rani & S. Seshan "AJM - Process Variables And Current Applications", Publication- Journal of Metals Materials & Process,1995 Vol.7 No. 4
3. A. Ghobeity, M. Papini and J.K. Spelt, "Abrasive jet micro-machining of planar areas and transitional slopes in glass using target oscillation", Journal of Materials Processing Technology, 11 February 2009,
4. A_Study_of_effect_of_Process_Parameters_of_Abrasiv.pdf
5. A. P. Verma and G. K. Lal Publication "An experimental study of abrasive jet machining", International Journal of Machine Tool Design and Research, Volume 24, Issue 1, 1984,
6. R. Balasubramaniam, J. Krishnan and N. Ramakrishnan "A study on the shape of the surface generated by abrasive jet machining", Publication: Journal of Materials Processing Technology, Volume 121, Issue 1, 14February 2002
7. Sarkar, P.K., Pandey, P.C., "Some investigations on abrasive jet machining", Journal of Inst. Eng.(56),1976
8. Hand book on "Non-conventional machining", Department of mechanical engineering, Version 2 ME, IIT Kharagpur, 2009.
9. C.N. Ingulli, "Abrasive jet machining", Tool Manuf. Engg. 59 (5) (1967) 284.
10. R. Balasubramaniam, J. Krishnan and N. Ramakrishnan "A study on the shape of the surface generated by abrasive jet machining", Publication: Journal of Materials Processing Technology, Volume 121, Issue 1, 14February 2002
11. M. Wakuda, Y. Yamauchi and S. Kanzaki "Effect of work piece properties on machinability in abrasive jet machining of ceramic materials", Publication: Precision Engineering, Volume 26, Issue 2, April 2002
12. Divyansh Mittal, Shankar Sehgal, and H. Kumar, "abrasive jet machining and its applications," Int. J. Sci. Res., vol. 2277