STUDY OF EFFECT OF PROCESS PARAMETERS ON THE PERFORMANCE OF ABRASIVE JET MACHINING

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Abstract— Air abrasive jet machining is a non-traditional machining process in which a high pressure air stream and abrasive particles are impinged on a work surface through a nozzle. A model of AJM was designed, developed and fabricated to perform experimentation. In this paper drilling work is done on glass work piece and silicon carbide (SiC) as abrasive powder. The air pressure, abrasive size and nozzle tip distance are considered as controlling parameter. The L18 Orthogonal Array based on Taguchi method of design of experiment is selected based on different levels of controlling parameters. The effect of each controlling parameter on Material Removal Rate (MRR) and taper angle is analyzed by using Analysis of Variance(ANOVA) and graphs are plotted.

Keywords— Abrasive jet machining , Abrasive powder, Material removal rate , Nozzle tip distance , Taper Angle, Glass material, Analysis of Variance

INTRODUCTION

Air abrasive jet machining is a non-conventional manufacturing process used for machining brittle materials like glass, ceramic etc. The abrasive particle like silicon carbide (SiC), Aluminium Oxide (Al_2O_3) can be used. When the pressurized mixture impinges on the work piece material is removed by micro-cutting and brittle fracture. The amount of mass of air and abrasive particle is an important factor contributing towards the machining characteristic. The materials which are being machined by this process do not experience any hardening due to process because heat generated is very less. Also, since major cutting forces are directed in downward direction it can be used to machine materials with very small wall thickness.

Abrasive jet machining (AJM) process was introduced a few decades ago and experimentation work has been carried out in this time period. Ray and Paul [1] reported that SiC abrasive particle with grain size 80 micron and 120 micron is suitable for machining hard and brittle material like porcelain .Balasubramaniam et al. [2]reported that for abrasive jet deburring of cross drilled holes coarser abrasive particles are effective and it improves at higher nozzle tip distance .Manabu Wakuda et al. [3]reported that the material response to the abrasive impacts indicates a ductile behavior, which may be due to the elevated temperature during machining. Chipping at the peripheral region of the dimples was found for coarse-grained alumina samples. The use of synthetic diamond abrasive is a possible choice if high machining efficiency is desired..

El-Domiaty et al. [4]performed the drilling of glass 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. The large diameter of the nozzle lead to the more abrasive flow and which lead to more material removal rate and lower size of abrasive particle lead to the low material removal rete. They have introduced an experimental and theoretical analysis to calculate the material removal rate.Alireza Moridi et al. [5] presented an experimental study to understand the effect of process parameters on the cutting performance measures in abrasive jet micro-grooving of quartz crystals. It was concluded that groove depth increase by increasing the abrasive mass flow rate which lead to more particles impinging the target surface and gives more material removal. However, excessive abrasive flow-rate increases inter-particle collision which reduces the average removal rate per particle. Bhaskar Chandra et al [6]performed experiments on AJM test rig using alumina as abrasive particle. Experiments were done by changing pressure, nozzle tip distance on glass plates of different thickness. It was observed that increase in nozzle tip distance increases the top surface diameter ant the results were graphically plotted..The concluded from the test result that increase in pressure increase the material removal rate.

Jukti Prasadn Padhy [7] reported that the pressure and stand-off distance both are significant for MRR and only pressure is significant for overcut when glass is used as work piece material and aluminium oxide as abrasive particle. Park et al.[8] have examined the AJM process for glass etching and grooving in micro-systems parts Fan and Wang[9]developed a mathematical model for erosion rate in glass by abrasive jet machining using dimensional analysis technique and compared the results with the experimental data .It was shown that model prediction are in good agreement with experimental data with just 1% deviation thus providing a basis for optimization in micro machining technology. Barletta et al. [10] reported that lower abrasive mesh size lead to better roughness while polishing the tubular sections using fluidized AJM .The fluidized bed improves the characteristics of fluidized jet and hence uniform surface finish is available. U. D. Gulhane et al [11] performed experiments and Analyzed the influence of process parameters on MRR and Kerf width. The results of experiments are Analyzed by Taguchi, Characterized the influence of Factors on MRR and Kerf by Analysis of Variance (ANOVA)

In this paper Taguchi technique is used to optimize the AJM process its multiple performance characteristics: material removal rate (MRR) and taper angle. The results obtained are analyzed using ANOVA tool in MINITAB 16 software.

EXPERIMENT METHODOLOGY

Experimental Set-up

Design of experiments using Taguchi method was developed and conducted. L18 orthogonal array was selected for the experiments. The process parameter considered was air pressure, abrasive size and nozzle tip distance and its performance was measured on the material removal rate and dimensional accuracy.

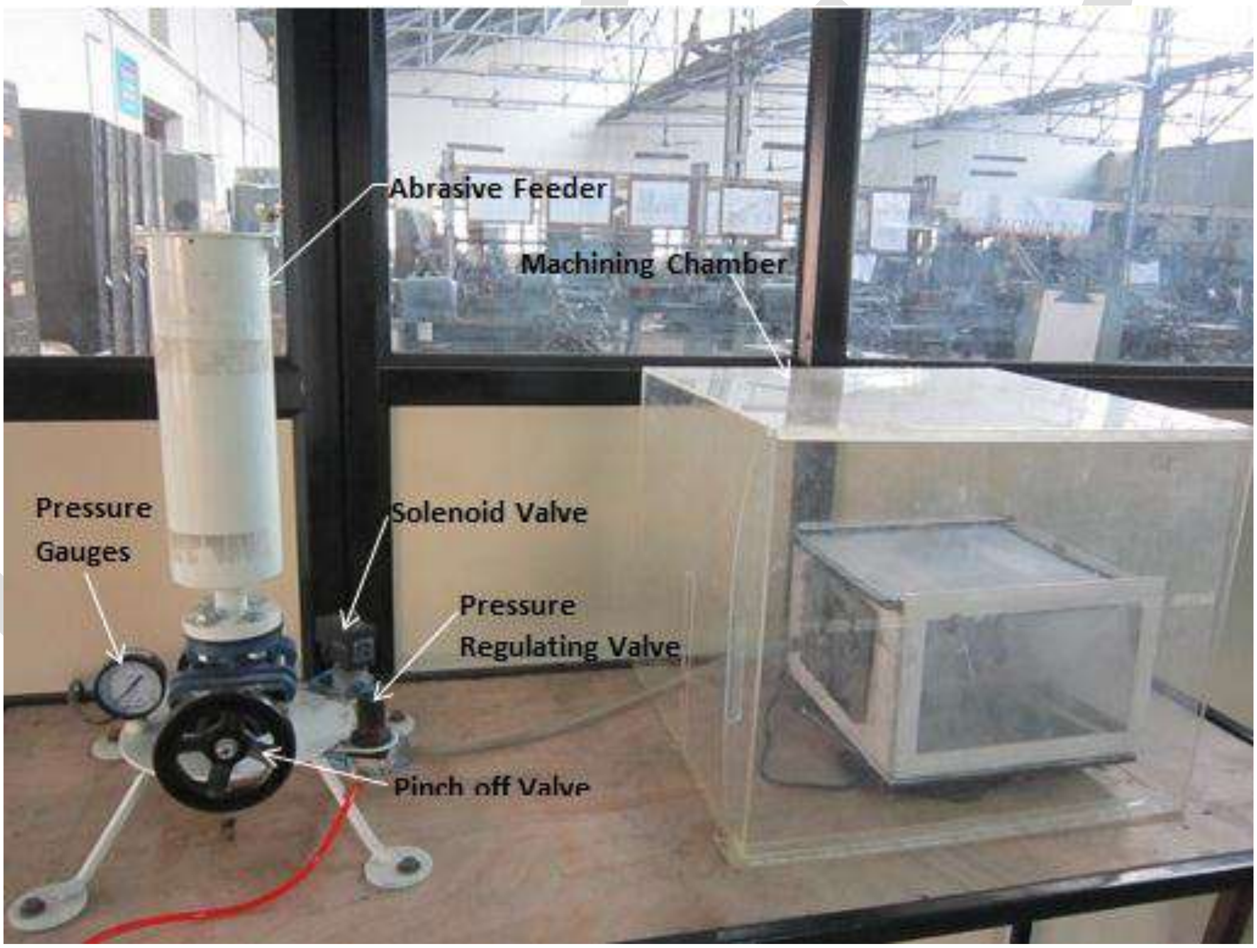

Fig. 1 Experimental set-up

Choice of factors and levels:

The experiment on Abrasive jet machining consisted of three process parameters namely-pressure, NTD and abrasive size. The different levels and values of experiments were set on the basis of sample experiments carried out initially and the theory of abrasive jet machining.

Table 1. Process parameters

	Level 1	Level 2	Level 3
Pressure(in bar)	7	7.5	8
NTD(in mm)	6	8	10
Abrasive size (in micron)	50	90	-

Design of experiments

Design of experiment is a method of experiment where a selected number of experiments are to be performed .L_{18} orthogonal array is selected for conducting experiments since the number of process parameters are three and two process parameters has three levels and one parameter with two levels. The values of response variables will be analyzed using MINITAB 16 software.

Experimentation Work:

Glass was used as work piece. The test specimen was into square of one inch and 2 mm thickness. The nozzle tip distance is varied by moving the work piece attached to the cross-slide. First the abrasive powder is fed to the feeder having a storage capacity of 1.5 kg. The air flow from the compressor is controlled by a solenoid valve which can be switched using a foot pedal valve. The abrasive powder passes through the pinch valve and mixes with the air at the inlet of nozzle .Then the mixture passes to the nozzle and impacts on the glass specimen with high velocity. As soon as the hole is drilled on work piece, the solenoid valve is closed. The time for drilling is noted down using a stopwatch.

For calculating initial and final weight electronic balance weight machine with 0.001gm accuracy was used. The hole diameter of drilled glass piece, before experiment and after experiment was measured by travelling microscope. Air was used as carrier gas and silicon carbide as abrasive powder. The glass plates were 2mm thick.

The material removal rate (MRR) was measured by noting down the time required for drilling the hole and the material removed.

$$\text{MRR (gm/min)} = \frac{\text{Wt of material removed} * 60}{\text{Time in sec}}$$

In order to measure taper angle following trigonometric expression was used

$$\text{Taper angle (deg)} = \frac{\tan^{-1}(\text{D0} - \text{Di})/2}{L}$$

Where

Do-top surface diameter of glass

D_i-bottom surface diameter of glass

L-thickness of glass i.e. 2mm

As per the experimentation design the different experiments are carried out and the result is tabulated in the observation table below.

Table 2. Observation table

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Sr. No.	Abrasive Size (microns)	Pressure (bar)	Nozzle Tip Distance (mm)	Time (sec)	Wt. material removed (gms)	MRR (gm/min)	Taper Angle(in degree)
1	50	7	6	130	0.019	0.00877	31.49
2	50	7	8	100	0.0159	0.00954	29.9
3	50	7	10	120	0.0127	0.00635	27.25
4	50	7.5	6	135	0.0119	0.00529	27.14
5	50	7.5	8	165	0.0157	0.00571	32.42
6	50	7.5	10	100	0.0209	0.01254	32.11
7	50	8	6	58	0.0162	0.01676	15.38
8	50	8	8	50	0.0134	0.01608	14.84
9	50	8	10	51	0.0724	0.08518	29.47
10	90	7	6	26	0.0188	0.04338	25.99
11	90	7	8	6	0.0055	0.05100	40.69
12	90	7	10	24	0.0271	0.06775	43.3
13	90	7.5	6	22	0.0206	0.05618	29.79
14	90	7.5	8	29	0.0316	0.06480	19.42
15	90	7.5	10	32	0.03752	0.07072	45
16	90	8	6	23	0.029	0.07565	32.11
17	90	8	8	19	0.0261	0.08443	27.14
18	90	8	10	18	0.0264	0.09021	24.7

EXPERIMENTAL RESULTS AND DISCUSSION

The following section detail the result from the experiments that were conducted .MINITAB 16 software was used and analysis was performed using Analysis of Variance(ANOVA)tool available in it.

Analysis of Experiments using Minitab:

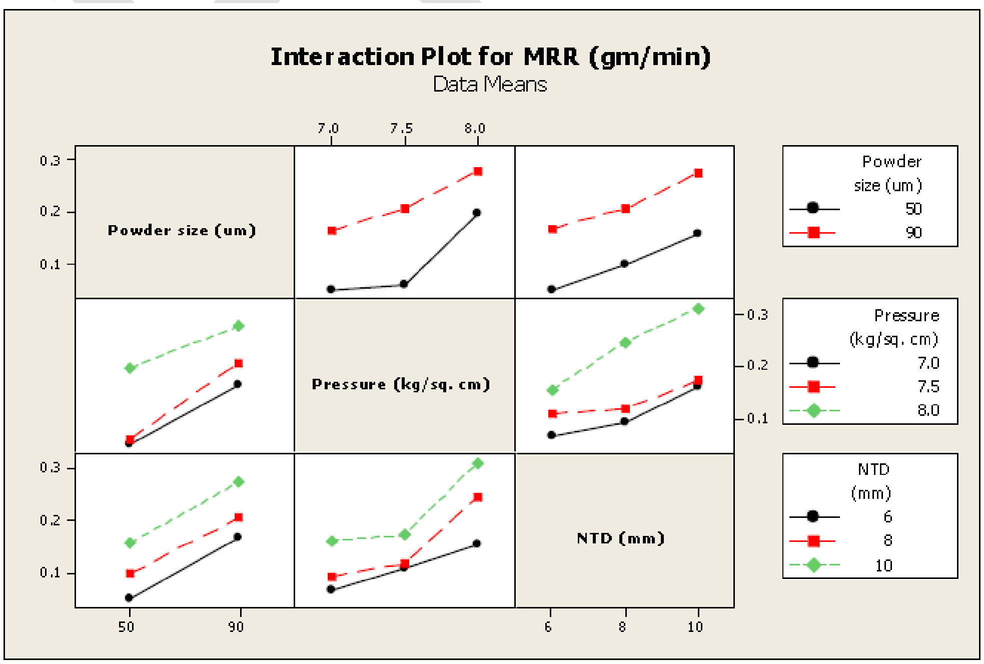

Fig. 2 Interaction Plot for MRR (gm/min)

Interaction plot for material removal rate is as shown in fig. 2.Considering abrasive size and pressure highest MRR is observed at pressure 8 bar and abrasive size of 90 µm, whereas lowest value of MRR is observed at abrasive size of 50 µm and 7 bar pressure. Considering the pressure and nozzle tip distance (NTD) maximum material removal rate (MRR) is observed at 8 bar pressure and 10 mm nozzle tip distance. Considering abrasive size and nozzle tip distance maximum material removal rate is observed at abrasive size of 90 µm and nozzle tip distance of 10 mm, whereas minimum value of MRR is observed at abrasive size of 50 µm and nozzle tip distance of 6 mm.

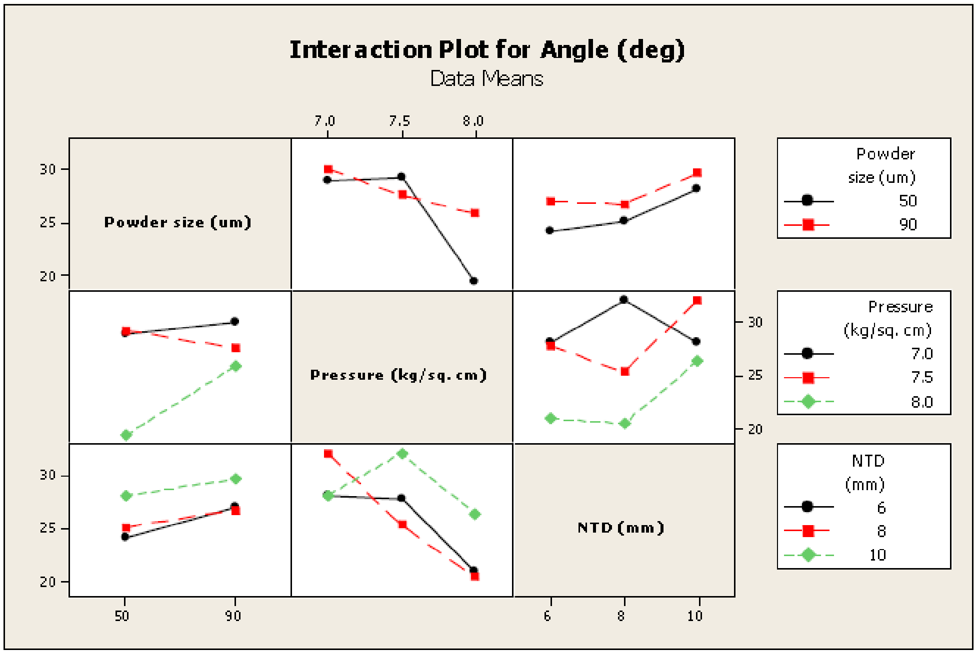

Fig. 3 Interaction Plot for Angle (Degree)

Interaction plot for angle is as shown in fig. 3 Considering abrasive size and pressure highest angle is observed at pressure 7 bar and abrasive size of 90 µm, whereas lowest value of angle is observed at abrasive size of 50 µm and 8 bar pressure. Considering the pressure and nozzle tip distance (NTD) maximum angle is observed at 7.5bar pressure and 10 mm nozzle tip distance. Considering abrasive size and nozzle tip distance angle is observed at abrasive size of 90 µm and nozzle tip distance of 10 mm, whereas minimum value of angle is observed at abrasive size of 50µm and nozzle tip distance of 6 mm.

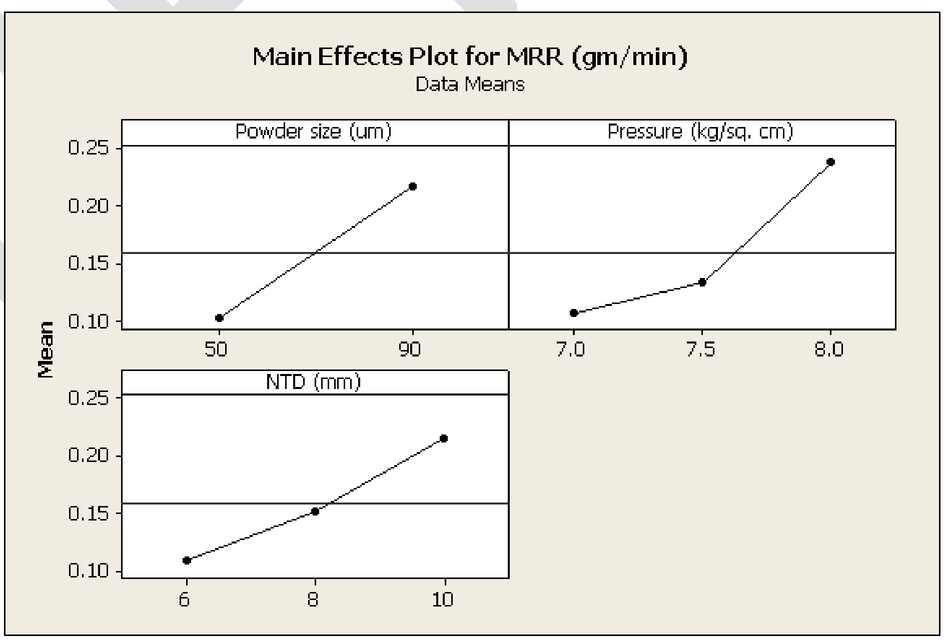

Fig. 4 Main effect of Material Removal Rate(gm/min)

The main effects plots shown in fig 4 shows the effect of process parameters on the MRR .With a increase in the abrasive particle size there is an increase in the MRR .The similar characteristic were observed by Jukti Prasadan Padhy[7] and F. Anand Raju et al.[12].The increase in pressure causes an increase in the MRR .This is because with an increase in the pressure there is an increase in the kinetic energy of the abrasive particles projecting out of the nozzle .The increase in NTD causes an increase in the MRR.

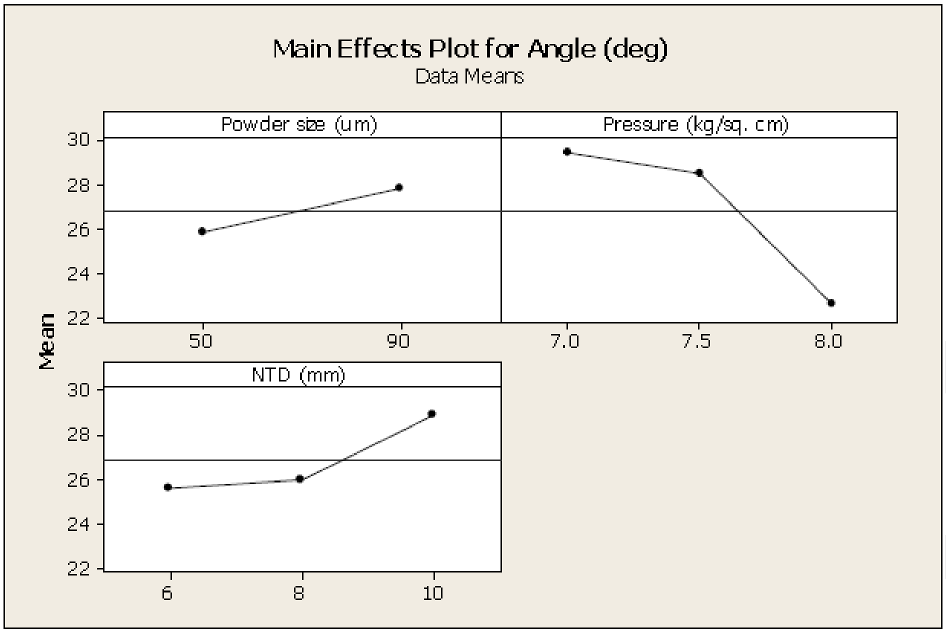

Fig. 5 Main effect of Taper Angle (Degree)

The observed values of taper angle are shown in Table 2. During the process of AJM, the influence of machining parameter like abrasive size, pressure and nozzle tip distance has significant effect taper angle as shown in main effect plot for taper angle in Fig 5. The pressure is directly proportional to the taper angle. This is because higher pressure leads to higher velocity. Therefore the abrasive particles have very less time to impinge on the work piece .This causes a decrease in taper angle with increase in pressure. The NTD is directly proportional to taper angle It is observed because higher NTD causes the abrasive particles to expand in air before impinging on the glass work piece. This leads to higher top surface diameter and a consequent increase in the taper angle.

1) The experimental results indicate that material removal rate is directly proportional to pressure and increases up to 10 mm nozzle tip distance (NTD).
2) With higher abrasive size of 90 μm, pressure 8 bar and nozzle tip distance of 10 mm higher material removal rate (0.3720gm/min) is obtained.
3) The experimental results indicate that taper angle is inversely proportional to pressure.
4) With smaller abrasive size of 50 μm, pressure 8 bar and nozzle tip distance of 8 mm lower taper angle (14.31˚) is obtained.

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CONCLUSION

This paper presents the experimentation work carried by changing different process parameters affecting the performance of AJM. The experiments were designed according to Taguchi method. Experimental work was done by considering abrasive size, nozzle tip distance and pressure as machining parameter to study MRR and taper angle. The result was analyzed using ANOVA. From analysis it was concluded that the pressure and abrasive size both are significant for MRR and only pressure for taper angle.Individual optimal settings of parameters are carried out to minimize taper angle and maximize MRR. More number of experiments can be carried out to study the effect on different performance characteristics.

REFERENCES:

[1] Ray P K, Paul A. K. (1987), “Some Studies on Abrasive Jet Machining”, Journal of the Institutions of Engineers, (India), Vol. 68, PP.27-30
[2] R. Balasubramaniam, J. Krishnan and N. Ramakrishnan , “An experimental study on the abrasive jet deburring of cross drilled

holes", Journal of Materials Processing Technology, Volume 91, Issues 1-3, 30 June 1999, Pages 178-182
[3] Manabu Wakuda, Yukihiko Yamauchi, Shuzo Kanzaki. ''Material response to particle impact.'' Journal of Materials Processing Technology 132,pp. 177–183,2003
[4] A. El-Domiaty, H. M. Abd El-Hafez and M.A. Shaker. ''Drilling of Glass Sheets by Abrasive Jet Machining.'' World Academy of science, Engineering and Technology, vol.3, pp.57-63,Aug.2009
[5] Alireza Moridi, Jun Wang, Yasser M. Ali, Philip Mathew and Xiaoping Li. ''Drilling of Glass Sheets by Abrasive Jet Machining.'' Key Engineering Materials, vol. 443, pp. 645-651,June 2010
[6] Mr. Bhaskar Chandra. ''A Study of effects of Process Parameters of Abrasive jet machining." International Journal of Engineering Science and Technology, vol.3, pp.504-513, Jan. 2011.
[7] Jukti Prasadn Padhy, "Optimization and effect of controlling parameters on AJM using Taguchi technique" International Journal of Engineering Research and Applications ISSN : 2248-9622, Vol. 4, Issue 3(Version 1), pp.598-604, March 2014.
[8] Park, D-S., M-W. Cho, H. Lee, and W-S. Cho (2004). "Micro-grooving of Glass Using Micro Abrasive Jet Machining." Journal of Materials Processing Technology, Vol. 146, pp. 234-240
[9] J.M. Fan, C.Y.Wang, J. Wang," Modelling the erosion rate in micro abrasive air jet machining of glasses" Wear 266 (2009) 968–974
[10] U.D.Gulhani,P.P.Patkar,S.P.Patel,A.A.Patel et al ,Analysis of AJM Parameters on MRR, Kerf width of Hard and Brittle Materials like ceramics,--IJDMT April- 2013
[11] Massimiliano Barletta, Stefano Guarino, Gianluca Rubino, Vincenzo Tagliaferri," Progress in fluidized bed assisted abrasive jet machining (FB-AJM):Internal polishing of aluminium tubes" International Journal of Machine Tools & Manufacture 47 (2007) 483–495
[12] F.. Anand Raju, V Gnana Prakash, Dr, M. L. S. Deva Kumar," Fiber Glass Cutting by using Abrasive Jet Machining and Analysis of process parameters," International Journal of Computer Trends and Technology (IJCTT) – volume 4 Issue 7–July 2013