Investigation on Glass Machined by Abrasive Jet Machining

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Abstract
It is very difficult to produce hole in brittle material like glass with conventional machining process; therefore the non conventional machining process such as Abrasive Jet Machining (AJM) has been used for overcome this problem. AJM process parameters were varied i.e. pressure, nozzle tip distance, and nozzle diameter. L_9 Orthogonal array of Taguchi method is used for the optimization and for calculating the optimum value for maximum material removal rate (MRR) and minimum over cut (OC). For this experiment Al_2O_3 abrasive with mesh size 150 and grit size 70µm is used. Another parameter ranges are Pressure 50psi, 55psi, 60psi, Nozzle Tip Distance 8mm,10mm,12mm, and Nozzle Diameter 1.2mm,1.5mm, 2.3mm is considered. The optimum value of air pressure for higher MRR is 55 psi, nozzle tip distance for is 10mm and nozzle diameter is 1.2mm. The optimum value of air pressure for lower over cut is 55 psi nozzle tip distance is 8mm and nozzle diameter is 1.2mm.

Keywords
AJM, Machining of Glass, Al2O3, Non conventional Machining Methods

I. Introduction

As the world is advancing forth technically in the field of space research, missile and nuclear industry; very complicated and precise components having some special requirements are demanded by these industries. The challenge is taken by the new developments taking place in the manufacturing field. Machining is any process in which a cutting tool is used to remove small chips of material from the work piece. To perform the operation, relative motion is required between the tool and the work. Hole making in workpiece is very important machining operation perform by conventional process for fastening or tightening the assembly or products. It is very difficult to produce hole in brittle material like glass with conventional machining process; therefore the non conventional machining process such as Abrasive Jet Machining (AJM) has been used for overcome this problem.

R. Haj Mohammad Jafar et al. [3] investigated the roughness and erosion rate resulting from AJM on a brittle material experimentally and modelled. It was shown that the roughness and erosion per particle were proportional to the particle kinetic energy. Decreasing the impact angle reduced the normal impact force on the target and resulted in a smother channel. Nouraeia et al. [1] resulted a better understanding of the mechanics of erosion in ASJM by comparing its performance in the micro-machining of holes and channels in borosilicate glass with that of abrasive air jet micromachining (AJM). The effect of particle velocity, particle concentration, jet traverse speed and jet impact angle were examined. Tyagi [2] discussed theoretical model of abrasive jet machining based on erosion phenomenon. The material is removed from the surface due to erosion. In abrasive jet machining process, the output parameter is achieved by controlling various input parameters. Matsumura et al. [4] discussed control of abrasive flow using the stagnation in the abrasive water jet processes for machining and polishing of micro grooves. The stagnation area under the jet nozzle is evaluated using computational fluid dynamics and associated with the surface finishing. The effect of the stagnation area is verified in the machining tests. Wang et al. [5] carried out an experimental study of particle velocities in micro-abrasive jets by using the particle image velocimetry (PIV) technique is presented. It has been found that the particle jet flow has a nearly linear expansion downstream. The particle velocities increase with air pressure, and the increasing rate increases with nozzle diameter within the range considered.

From the past literature review, few of the problems encountered during machining are like difficult to Cut a hard to machine materials, Difficult to machine brittle material such as Glass, Ceramics, Refractories etc. by conventional method. The objectives of present research are listed as to analyze the fundamental characteristics and principles underlying the material removal mechanism in abrasive jet machining of glass and Analysis of test results for investigating the influence of various parameters on material removal rate and surface roughness.

II. Experimentation

For performing the experimental work on silica glass is used as a work piece. Generation of hole in silica glass using AJM is done on the work piece. The experiments have been conducted on the Abrasive Jet Machining (AJM). Various input parameters was varied in AJM process, like Nozzle tip distance (6mm, 8mm, 10mm), nozzle diameter (1.2mm, 1.5mm, 2.3mm), pressure (55 psi, 60 psi, 65 psi). Each factor has its own effect on the output of response characteristics i.e. material removal rate (MRR) and over cut. Table 1 shows the materials used and specification of AJM machine.

Table 1: Nomenclature of Machining Unit and Their Specifications

Nomenclature	Dimensions and specifications
Work piece material	Silica Glass
Size of work piece material	150x150
Thickness (mm)	2.8
Nozzle diameter sizes (mm)	1.2,1.5,2.3
Material of nozzle	Tungsten Carbide
No of experiment	9
Pressure (psi)	50,55,60
Abrasive	Al_2O_3
Mesh size & Grit size	150 and 70µm

Fig. 1: Machining of Glass Using AJM

When the machining finishes then close all the valves one by one and checked the piece and weight taken. 9 readings each by using three different nozzles at different condition have been taken on the work piece for the more accuracy in the experiment.

Fig. 2: Machined Work Piece With Variable Nozzle

III. Results and Discussion

The effect of machining parameters pressure, nozzle tip distance, and nozzle diameter is evaluated using ANOVA. Three repetitions for each of 3 trials were completed in the case of variable nozzle diameter so as to measure MRR and also later Signal to Noise ratio (S/N ratio) is evaluated using the Minitab software. The results of MRR for solid electrode of the 9 experiments with repetition are given in Table 2 below.

Table 2: Results after AJM at Various Input Parameters

S. No	Pressure	NTD	Nozzle dia	Weight before machining (gm)	Weight after machining (gm)	Weight loss (gm)	Time (sec)	MRR Mg/s	Over cut mm
1	50	8	1.2	24.9	24.8	0.1	10	10	0.2
2	50	10	1.5	25	24.8	0.2	10	20	2.78
3	50	12	2.3	24.9	24.7	0.2	15	13	1.24
4	55	8	1.5	24.9	24.7	0.2	8	25	0.14
5	55	10	2.3	27.3	27.2	0.1	10	10	0.8
6	55	12	1.2	24.8	24.5	0.3	11	27	3.44
7	60	8	2.3	24.8	24.7	0.1	10	10	1.6
8	60	10	1.2	25.1	24.8	0.3	8	37	1.26
9	60	12	1.5	25	24.8	0.2	12	16	2.7

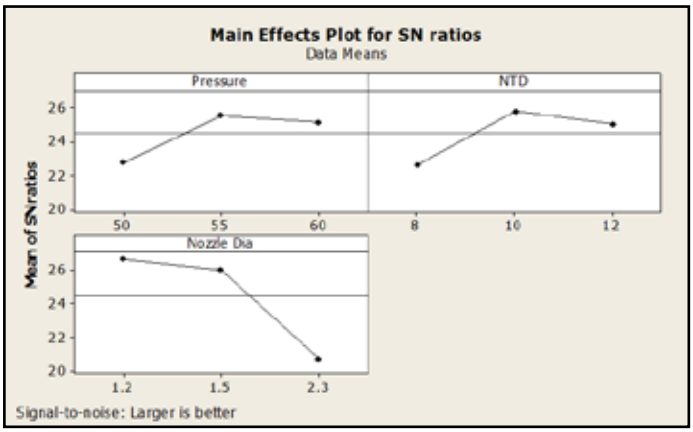

Fig. 3: Effect of the Process Parameters on S/N ratio of MRR

It is noted that the maximum material removal rate i.e. MRR 37.5 is obtained using Al_2O_3 abrasive particle and other conditions are air pressure 60 psi, nozzle dia 1.2 mm, and nozzle tip distance 10 mm.

After compiling the data in Minitab software, the mean of S/N ratio of MRR are plotted on the graphs.

In Figure 3.1 the graph is plotted between mean of S/N ratio of MRR and air pressure. From figure it is clear that of S/N ratio of MRR is increase by increasing pressure from 50 psi to 55 psi and the S/N ratio of MRR decrease by increasing pressure from 55 psi to 60 psi. The optimum value of air pressure for higher MRR is 55 psi.

The graph is plotted between mean of S/N ratio of MRR and nozzle tip distance (NTD). Here the mean value of S/N ratio of MRR is increase by increasing nozzle tip distance from 8 to 10mm. Further mean value of S/N ratio of MRR is decrease by increasing nozzle tip distance from 10 to 12 mm. The optimum value of nozzle tip distance for higher MRR is 10mm.

The graph is plotted between mean of S/N ratio of MRR and nozzle dia. Here the mean value of S/N ratio of MRR is decrease

by increasing the nozzle diameter from 1.2 to 1.5 mm. By further increasing the nozzle diameter from 1.5 to 2.3 mm the value of S/N ratio of MRR is again decrease. The optimum value of nozzle diameter for higher MRR is 1.2mm.

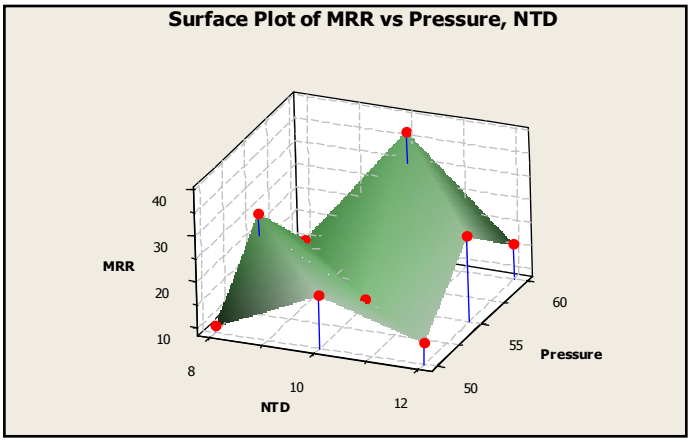

Fig. 4: Surface Plot Between Pressure and Nozzle Tip Distance

The fig. 4 shows the surface plot between of air pressure with nozzle tip distance for MRR of machining of glass. The MRR is increase and decrease by varying nozzle tip distance and air pressure. The minimum MRR is observed at minimum 50 air pressure and minimum nozzle tip distance 8mm. The maximum MRR is obtained at 55 air pressure and 10mm nozzle tip distance.

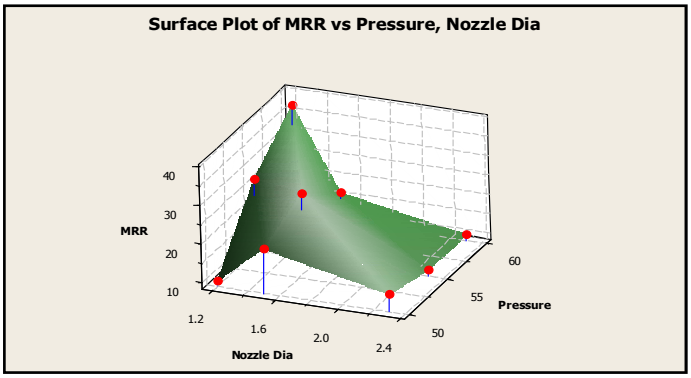

Fig. 5: Surface Plot Between Pressure and Nozzle Diameter

The fig. 5 shows the surface plot between of air pressure with nozzle diameter for MRR of machining of glass. The MRR is increase and decrease by varying nozzle diameter and air pressure. The minimum MRR is observed at minimum 50 air pressure and minimum nozzle diameter 1.2mm. The maximum MRR is obtained at 60 air pressure and 1.2mm nozzle diameter.

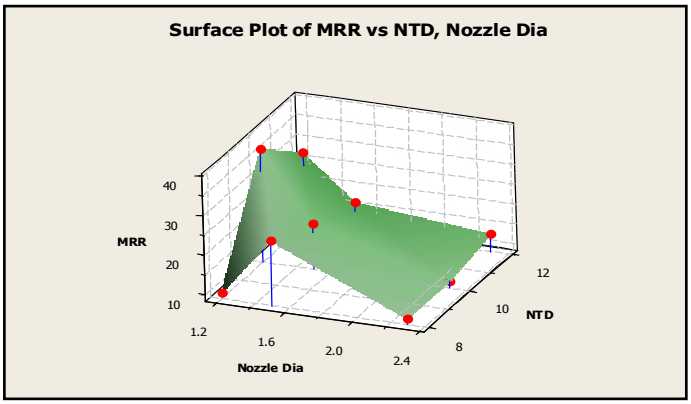

Fig. 6: Surface Plot Between Nozzle Tip Distance and Nozzle Diameter

The fig. 6 shows the surface plot between of nozzle tip distance with nozzle diameter for MRR of machining of glass. The MRR is increase and decrease by varying nozzle diameter and air pressure. The minimum MRR is observed at minimum nozzle tip distance 8mm and minimum nozzle diameter 1.2mm. The maximum MRR is obtained at 10mm nozzle tip distance and 1.2mm nozzle diameter.

During the conduction of all the experiments with different set of input parameters, observations were made for the calculation of average diameters of machined hole of work piece in each experiment. It is noted that the maximum overcut i.e. 3.44 is obtained at air pressure 55 psi, nozzle dia 1.2 mm, and nozzle tip distance 12 mm.

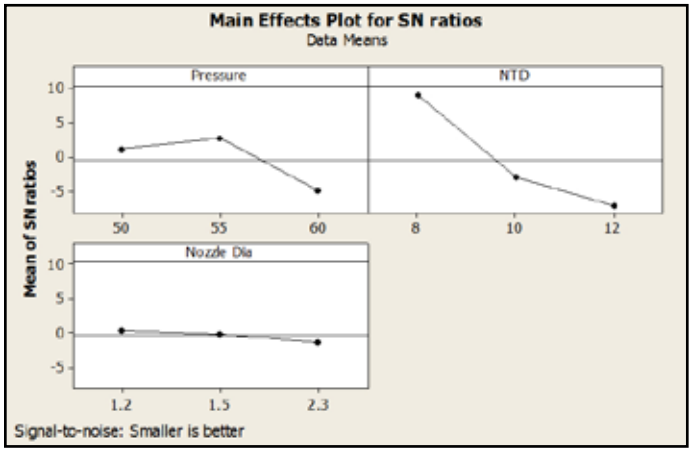

Fig. 7: Effect of the Process Parameters on S/N ratio of over cut

After compiling the data in Minitab software, the mean of S/N ratio of over cut are plotted on the graphs.

In fig. 7 the graph is plotted between mean of S/N ratio of over cut and air pressure. From figure it is clear that of S/N ratio of over cut is increase by increasing pressure from 50 psi to 55 psi and the S/N ratio of over cut decrease by increasing pressure from 55 psi to 60 psi. The optimum value of air pressure for lower over cut is 55 psi.

The graph is plotted between mean of S/N ratio of over cut and nozzle tip distance (NTD). Here the mean value of S/N ratio of over cut is decrease by increasing nozzle tip distance from 8 to 10mm. Further mean value of S/N ratio of over cut is again decrease by increasing nozzle tip distance from 10 to 12 mm. The optimum value of nozzle tip distance for lower over cut is 8mm.

The graph is plotted between mean of S/N ratio of over cut and nozzle dia. Here the mean value of S/N ratio of over cut is decrease by increasing the nozzle diameter from 1.2 to 1.5 mm. By further increasing the nozzle diameter from 1.5 to 2.3 mm the value of S/N ratio of over cut is again decrease. The optimum value of nozzle diameter for lower over cut is 1.2mm.

IV. Conclusion

1. It is noted that the maximum material removal rate i.e. MRR 37.5 is obtained using Al_2O_3 abrasive particle and other conditions are air pressure 60 psi, nozzle dia 1.2 mm, and nozzle tip distance 10 mm.
2. The optimum value of air pressure for higher MRR is 55 psi, nozzle tip distance for is 10mm and nozzle diameter is 1.2mm.
3. It is noted that the minimum overcut i.e. 0.14 is obtained using Al_2O_3 abrasive particle and other conditions are air pressure

55 psi, nozzle dia 1.5 mm, and nozzle tip distance 8 mm.

4. The optimum value of air pressure for lower over cut is 55 psi nozzle tip distance is 8mm and nozzle diameter is 1.2mm.

References

[1] H. Nouraeia, A. Wodoslawskya, M.Papinib, J.K.Spelta, "Characteristics of abrasive slurry jet micro-machining: A comparison with abrasive air jet micro-machining", Journal of Materials Processing Technology 213, pp. 1711-1724, 2013.

[2] R.K. Tyagi,"Abrasive jet machining by means of velocity shear instability in plasma", Journal of Manufacturing Processes 14, pp. 323–327, 2012.

[3] R. Haj Mohammad Jafar, J. K. Spelt, M. Papini,"Overcut and erosion rate of abrasive jet micro-machined channels: Experiments and analytical model", Wear, 303, pp. 138–145, 2013.

[4] T. Matsumura, T. Muramatsu, S. Fueki, "Abrasive water jet machining of glass with stagnation effect", CIRP Annals - Manufacturing Technology 60, pp. 355–358, 2011.

[5] Li, H. Wang, J., Fan,"Analysis and modeling of particle velocities in micro abrasive air jet", International Journal of Machine Tools and Manufacture 49, pp. 850-858, 2009.