Experimental Investigation of Abrasive Jet Machining

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Abstract- *The research examined the effects of the process parameters, namely applied pressure (Pr), standoff distance (SOD), nozzle diameter (dn) on the accuracy of the machined surface in terms of generated taper of the produced holes. The Taguchi method was used to determine the significant factor in the machining process. The results have revealed that the diameter difference was proportional to the integration part of the machined holes, the nozzle diameter, standoff distance and applied pressure. Moreover, although, a proportional relationship was detected between the hole diameter and applied standoff distance. To obtain lower diameter difference of top and bottom diameter of the holes produced on the surface of the glass, the optimum parameter combination was investigated.*

This paper summarizes various techniques investigated by different researchers to perform different operations like cutting, drilling etc.

Keywords- AJM, abrasive, kinetic energy, stand-off distance, grain size

I. INTRODUCTION

As per the research and development for the last forty years several new methods were developed for machining. Among the new methods we have dealt with the Abrasive Jet Machining. The conventional techniques which are like turning, drilling, milling etc., are mostly used and involves the use of mechanical energy between workpiece and the tool whereas in this method no need of such arrangement with non-conventional on modern machining techniques.

Abrasive jet machining (AJM) removes material through the action of a focused stream of abrasive-Jet [3] Abrasive particles are propelled by compressed air at certain velocities of up to 300 m/sec. When this stream is directed at a workpiece, the result of this action can be used for cutting, etching, cleaning, deburring, polishing, and drilling.
Material removal occurs due to a chipping action, which is especially effective on hard, brittle materials such as glass, silicon, tungsten, and ceramics. Soft materials, such as rubber and some plastics resist the chipping action and thus are not effectively processed by AJM [5]. In addition to heat carried away by the abrasive propellant gas, workpieces experience no thermal damage [1].

Analysis of Variance (ANOVA) is technique which is used for making best decisions. It is a statistical method. It checks the impact of different factors by comparing the means of different samples. We can use ANOVA to prove if all the factors are equally effective or not.

Design of Experiment (DoE) is technique developed by Taguchi. It is set of experiments which are well planned. DoE is a better approach to get the systematic data of any parameters. In this level raise to factor gives exact number of experiments to be carried out. In our experiments we used 3 levels of experiments and 3 levels of 2 factors as pressure and SoD. For 2 different nozzle diameter.

Minitab 18 is software which statistical tool and concepts are used to improve the quality of process or product. We used Minitab 18 version to find out the most significant parameter combination in our experiments. The ANOVA gave us the statistical model of the results using Minitab.

II. FABRICATION OF SETUP

The basic experimental setup was developed for the concerned experimentation that was carried out for the research. The setup includes nozzle, which can be changed according to requirement, mixing chamber, pressure gauge, SoD varying system, piping system, ball valve and compressor.

III. EXPERIMENT PROCEDURE

Experiments were carried out to study the most effective parameter of tempered glass (toughened glass) at different parameters of AJM and these parameters are pressure, stand of distance, and nozzle diameter. The parameters and levels were selected primarily based on the literature review of some of the previous studies from reputed journals. Nine experiments were conducted with different parameters. For this experimentation Taguchi L9 orthogonal array was used, which has nine rows corresponding to the number of tests, with three columns at three levels.

Parameter	Level		
	1	2	3
Pressure (kg/cm^2)	3	4	5
Standoff Distance (mm)	4	8	12

Table.1: AJM Process Parameters

Sr. No.	Tank air pressure (p) (kg/cm^2)	Stand-off Distance (mm)	Diameter of holes		
			Top Diameter	Bottom Diameter	Diameter Difference
1	3	4	6.0234	3.1987	2.8247
2	3	8	5.5023	2.5421	2.9602
3	3	12	6.0123	4.2341	1.7782
4	4	4	6.0954	3.0123	3.0831
5	4	8	6.5632	3.5462	3.0170
6	4	12	6.5432	3.5692	2.9740
7	5	4	5.7632	4.5231	1.2401
8	5	8	6.0123	3.4689	2.5434
9	5	12	7.7532	4.7834	2.9758

Table.2: For Nozzle Diameter 3mm

Sr. No.	Tank air pressure (p) (kg/cm^2)	Stand-off Distance (mm)	Diameter of holes		
			Top Diameter	Bottom Diameter	Diameter Difference
1	3	4	6.5623	3.5462	2.0161
2	3	8	7.0123	5.8762	3.1361
3	3	12	9.5023	5.5482	3.9541
4	4	4	7.3169	4.5872	2.7297
5	4	8	9.8764	6.4210	3.4554
6	4	12	8.5321	4.5023	4.0298
7	5	4	8.5241	6.7654	1.7587
8	5	8	9.0243	7.7624	2.2619
9	5	12	7.5086	5.2629	2.5457

Table.3: For Nozzle Diameter 4mm

IV. RESULTS AND ANALYSIS OFEXPERIMENTS

By choosing the optimum parameter and their best combination diameter difference of throughout hole will be reduced. Experiments were carried out on the 3mm thickness of glass.

Fig 4.1Nozzle Diameter of 3mm

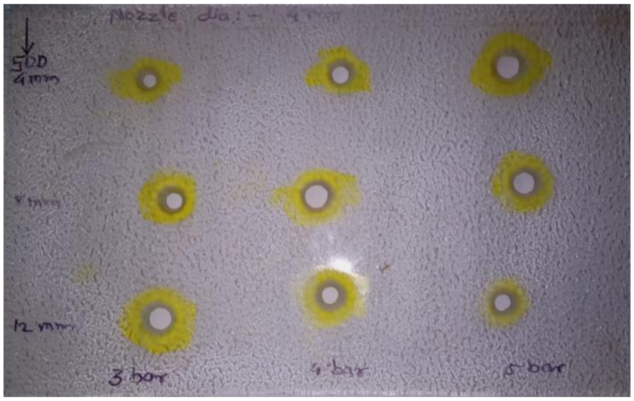

Fig.4.2 Nozzle Diameter of 4 mm

Source	DF	Adj. SS	Adj. MS	F-value	P-value
Pressure	2	1.7542	0.87712	70.51	0.000
Standoff Distance	2	0.6670	0.33351	26.81	0.000
Pressure* Standoff Distance	4	4.3141	1.07854	86.70	0.000
Error	9	0.1120	0.00124	-	-
Total	17	6.8474	-	-	-

Table 4. ANOVA for 3mm Nozzle Diameter

As, All the P- Values < 0.05, All three factors are significant in determining Diameter difference.

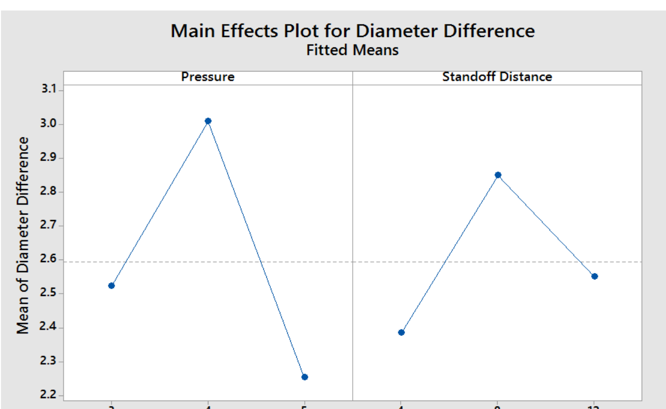

fig. 4.3 Plot for Diameter Difference for 3mm

ANALYSIS OF VARIANCE

Source	DF	Adj SS	Adj. MS	F-Value	P-value
Pressure	2	10.55	5.274	2.66	0.124
Standoff Distance	2	17.09	8.543	4.31	0.049
Pressure*Standoff Distance	4	12.12	3.031	1.53	0.274
Error	9	17.85	1.983	-	-
Total	17	57.60	-	-	-

Table 5. ANOVA for 4mm Nozzle Diameter

As, The P- Value of Standoff Distance < 0.05, Standoff Distance factor is significant in determining Diameter difference.

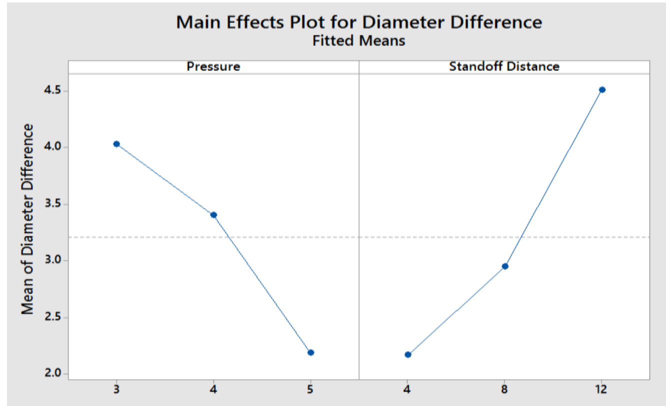

Fig.4.4Plot for diameter difference for 4mm

V. ANALYSIS OF VARIANCES

ANOVA is a statistically based on the objective of decision making tool for the detecting of any differences in the average performance of groups of items tested [8]. ANOVA helps in formally testing the significance of all main factors and their interactions by comparing the mean square against an estimate of the experimental errors at specific confidence levels. For our experimental model the statistical model of results show that for nozzle diameter 3 mm all three factors are significant. But from statistical model for 4 mm nozzle diameter we can say that standoff distance has more significance than others.

VI. CONFIRMATION TEST

The experimental confirmation test is the end step of experimentation after verifying the results based on Taguchi's design approach. The final conditions are set for the significant factors and a selected number of experiments are run under specified drilling conditions. The results after the confirmation of our experiment is compared with the predicted average based on the parameters and levels tested. Taguchi recommended the confirmation of the experiment as a crucial step and is highly suggested. In this study, a confirmation experiment was conducted by utilizing the levels of the optimal process parameters for glass. The levels were 5 bar pressure and 4 mm Sod for both the nozzle diameter.

VII. CONCLUSION

This Study has discussed is focused on investigating the effects of process parameters on the taper formation on the workpiece of AJM Process.

From the analysis of the result in the AJM process using Analysis of Variance (ANOVA), the following can be concluded from the present study, from the ANOVA, we can say that we get optimized output of diameter difference at the combination of high pressure (5 Bar) and low standoff (4 mm) distance for both the nozzle diameter.

VIII. FUTURE SCOPE

As, we fabricated the machine only for drilling operation, it can also be further developed for cutting operation using proper motion arrangement. Automation in X-Y table and automatic standoff distance adjuster can bring the ease in operation. Parameters can be more optimized by controlling the factors and environment around the machine.

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