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Study of Aluminum Oxide Abrasive on Tempered Glass in Abrasive Jet Machining Using Taguchi Method

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ABSTRACT

The abrasive jet machining (AJM) is a non-conventional machining process in which a abrasive particles are made to impinge on the work material at a high velocity. The jet of abrasive particles is carried by carrier gas or air. The high velocity stream of abrasive is generated by converting the pressure energy of the carrier gas or air to its kinetic energy . The high velocity abrasive particles remove the material by micro-cutting action as well as brittle fracture of the work material . Abrasive jet machining is generally good for cutting hard or brittle materials and is usually performed to furnish machining or finishing operation such as cutting, deburring, etching, etc. This project deals with the fabrication of the Abrasive Jet Machine and machining on tempered glass, calculating the material removal varying various performance parameters like pressure, angle & abrasive grit size so on. Before performing the experiment ,fabrication done on AJM which are also discussed.. The different problem faced while machining on tempered glass are also discussed.Taguchi method and ANOVA is used for analysis of material removal rate .

Keywords: *Aluminum Oxide; Tempered Glass; Abrasive Jet Machining; Taguchi Method*.

1.0 Introduction

AJM unit with vortex type mixing chamber and it was restricted to abrasive jet drilling only [1]. Magnetic abrasive jet machining is a new concept in AJM used for in finishing processes for internal surfaces, in this method working fluid mixed with magnetic abrasives, which is jetted into the internal surface of the tube, with magnetic poles being provided on the external surface of the tube. In this study, the new-concept finishing process or the magnetic abrasive jet machining system was developed [2].For studied the Effect of work piece properties on mach inability in abrasive jet machining of ceramic materials. Abrasive jet machining (AJM), a specialized form of shot blasting using fine-grained abrasives was used; it is an attractive micro-machining method for ceramic materials. In this paper, the mach inability during the AJM process is compared to that given by the established models of in AJM is a technique in which a particle jet is directed towards a target for mechanical material solid particle erosion, in which the material removal is assumed to originate in the ideal crack formation system [3]. The specialized form of shot blasting in Abrasive jet machining (AJM) and is beneficial for hard, brittle materials such as structural ceramics [4]. For investigated Micro-grooving of glass by using micro-abrasive jet machining, Micro abrasive jet machining (AJM) is similar to sand blasting, and effectively removes hard and brittle materials [5].In the machining of small holes by the conventional micro abrasive jet machining, the colliding abrasives accumulate in the bottom of the hole, preventing the direct impact of successive abrasives onto the work piece. As a result, the machining efficiency decreases as the machining progresses. Hence introduces a new method of micro abrasive jet machining, called micro abrasive intermittent jet machining (MAIJM), in which there exists a period of time during which no abrasive is injected into the gas stream from the nozzle so that the continuous flow of gas without abrasives from the nozzle could blow away any abrasives that have accumulated in the hole. [6].

High Resolution Powder Blast Micromachining technique removal.

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It is a fast, cheap and accurate directional etch technique for brittle materials like glass, silicon and ceramics [13]. Some other methods in which the wax-coated abrasive particles are used and in this method polishing time reduces and achieves an improved surface finish.[14].

2.0 Experiment Procedure

Experiment was conducted to study the MRR (material removal rate) of tempered glass (toughened glass) at different parameters of AJM and these parameters are pressure, angle and abrasive mesh size. The parameters and levels were selected primarily based on the literature review of some of the studies.

Initially weight the glass work piece which is rectangle in shape (dimensions are 7*3 cm *5mm) with the help of digital balance and weight after machining is measured by using digital balance for calculating the MRR. Time of machining was 4 seconds. Thus MRR is calculated using the formula:

$$MRR = \frac{\text{(intial weight- final weight)}}{\text{machining time}}$$

Nine experiments were conducted with different parameters. For this Taguchi L9 orthogonal array was used, which has nine rows corresponding to the number of tests, with three columns at three levels.

Table 1: AJM Process Parameters

Parameter	code	Levels		
		1	2	3
Pressure (kg/cm^2)	A	4	6	8
Angle between the workpiece and nozzle jet (degree)	B	40^0	20^0	0^0
Abrasive(mesh size)	C	1000	500	320

Table: 2. MRR of Taguchi L9 Orthogonal Array

Expt. No.	A	B	C	MRR (g/sec.)
1	1	1	1	0.0034
2	1	2	2	0.0049
3	1	3	3	0.0084
4	2	1	2	0.0086
5	2	2	3	0.0102
6	2	3	1	0.0096
7	3	1	3	0.0126
8	3	2	1	0.0113
9	3	3	2	0.0148

The L_9 orthogonal arrays table with 9 rows (corresponding to the number of experiments).

3.0 Results and Analysis of Experiments

3.1 Analysis of the S/N ratio

Taguchi method stresses the importance of studying the response variation using the signal – to – noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The metal removal rate was considered as the quality characteristic with the concept of "the larger-the-better" [27].

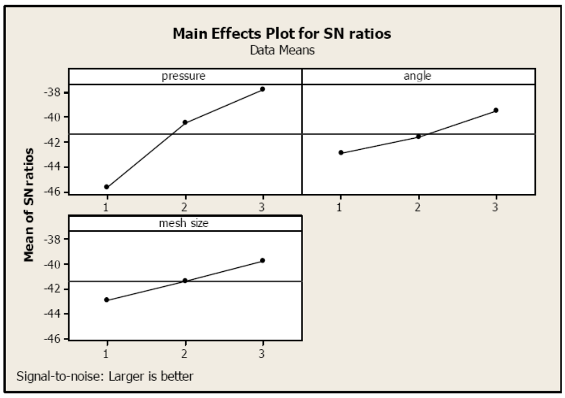
The S/N ratio values are calculated by using this equation. S/N = -10*log (mean square deviation) Where n is the number of measurements in a trial/row, in this case, n=1 and y is the measured value in a run/row. The S/N ratio values are calculated by taking into consideration above equation.

Table 3: Taguchi Analysis Response Table for Signal to Noise Ratios Larger is Better

Level	Pressure	Angle	Grit size
1	-45.69	-42.89	-42.89
2	-40.50	-41.65	-41.37
3	-37.84[a]	-39.49[a]	-39.78[a]
Delta	7.85	3.40	3.11
Rank	1	2	3

Optimum level (Level 3 is optimum level)

Fig 1: Graph Showing S-N Ratio, Larger is Better



The MRR increases with increasing in Pressure and decreasing in angle and abrasive size in mesh of abrasive. MRR is proportional to the pressure. With the increase in pressure the kinetic energy of the abrasive particle also increases. The kinetic energy of the abrasive particle is responsible for material removal by erosion process. Hence increase in pressure enhancement the MRR. With the decrease in angle between the workpiece and nozzle jet and abrasive mesh size the MRR increase because the abrasive mixture impinge on the workpiece more directly without deflecting, with a larger force, thus results in greater removal rate. And as the abrasive meshsize decreases, abrasive particle size increases, thus smaller mesh abrasives removes more metal as compared to the particle of larger mesh.

4.0 Analysis of Variance (ANOVA)

ANOVA is a statistically based, objective decision making tool for detecting any differences in the average performance of groups of items tested. 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. First, the total sum of squared deviations SST from the total mean S/N ratio nm can be calculated as [27]

$$SS_T = \sum_{i=1}^{n} (n_i - n_m)^2$$

Where n is the number of experiments in the orthogonal array and n_i is the mean S/N ratio for the i_{th} experiment.

Table 4: ANOVA Results for Metal Removal Rate

Source of variation	Degrees of freedom (DOF)	Sum of squares (S)	Variance (V)	F-ratio (F)	P-value (P)	Percentage (%)
Model	6	1.012E-004	1.686E-005	96.65	0.0103	
A	2	8.078E-005	4.039E-005	231.52	0.0043	79.82%
B	2	1.238E-005	6.191E-006	35.49	0.0274	12.23%
C	2	8.002E-006	4.001E-006	22.94	0.0418	7.91%
Error	2	3.489E-007	1.744E-007			0.04%
Total	8	1.015E-004				

{*1.012E-004 means 1.012 times 10 to the -4th power (.0001). It should be 0.0001012}

The percentage contribution P can be calculated as.

$$P = \frac{SS_D}{SS_T}$$

Where SS_D is the sum of the squared deviations

Statistically, there is a tool called an F test, named after Fisher , to see which design parameters have a Statistically, there is a tool called an F test, named after Fisher , to see which design parameters have a significant effect on the quality characteristic. In the analysis, the F-ratio is a ratio of the mean square error to the residual error, and is traditionally used to determine the significance of a factor. The P-value reports the significance level (suitable and unsuitable) in Table.4. If P-value < 0.05 level is significant and if P value> 0.05 level is insignificant. In Table.4 model P-value is 0.0103 which is less than 0.05 hence model is significant. Percent (%) is defined as the significance rate of the process parameters on the metal removal rate. The percent numbers depict that the pressure, angle and abrasive grit size have significant effects on the metal removal rate. It can observed from Table.4 that the pressure (A), angle (B) and abrasive (C) affect the metal removal rate by 79.82%, 12.23% and 7.91% in the abrasive jet machining(AJM) of tempered glass, respectively. A confirmation of the experimental design was necessary in order to verify the optimum cutting conditions.

5.0 Regression Analysis

The correlation between factors (Pressure, Angle and Abrasive mesh size) and metal removal rate on the Tempered (Toughened) glass were obtained by multiple linear regressions.

The standard commercial statistical software package MINITAB was used to derive the models of the form:

The regression equation is

MRR = - 0.00331 + 0.00366 pressure + 0.00120 mesh size + 0.00146 angle

R^2=0.981

In multiple linear regression analysis, R^2 is the regression coefficient (R^2 >0.90) for the models, which indicate that the fit of the experimental data is satisfactory.

$$R^2 = \frac{SS[Between]}{SS[Total]} = \frac{SSG}{SST}$$

6.0 Confirmation Test

The experimental confirmation test is the final step in verifying the results drawn based on Taguchi's design approach. The optimal conditions are set for the significant factors (the insignificant factors are set at economic levels) and a selected number of experiments are run under specified cutting conditions. The average of the results from the confirmation experiment is compared with the predicted average based on the parameters and levels tested. The confirmation experiment is a crucial step and is highly recommended by Taguchi to verify the experimental results . In this study, a confirmation experiment was conducted by utilizing the levels of the optimal process parameters (A3B3C3) for metal removal rate value in the abrasive jet machining of tempered glass and obtained as 0.0158 g/min.

7.0 Conclusions

This study has discussed an application of the Taguchi method for investigating the effects of process parameters on the metal removal rate value in the abrasive jet machining (AJM) of tempered glass. In the AJM process, the parameters were selected taking into consideration of manufacturer and industrial requirements.

From the analysis of the results in the AJM process using the conceptual signal-to-noise (S/N) ratio approach, regression analysis, analysis of variance (ANOVA), and Taguchi's optimization method, the following can be concluded from the present study:

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- Statistically designed experiments based on Taguchi methods were performed using L9 orthogonal arrays to analyze the metal removal rate as response variable. Conceptual S/N ratio and ANOVA approaches for data analysis drew similar conclusions.
- Statistical results (at a 95% confidence level) show that the pressure(A), angle (B), and abrasive grit size (C) affects the metal removal rate by 79.82%, 12.23% and 7.91% in the abrasive jet machining of tempered glass , respectively.
- The maximum metal removal rate is calculated as 0.00158 g/sec. by Taguchi's optimization method.
- In this study, the analysis of the confirmation experiment for metal removal rate has shown that Taguchi parameter design can successfully verify the optimum cutting parameters (A3B3C3), which are pressure=8 kg/cm2 (A3) angle= 00 (B3) and abrasive = 320 mesh size (C3).
- Metal removal rate increases with increase in pressure and abrasive size (microns) in abrasive jet machining of tempered glass.
- Metal removal rate increases with the decrease in angle and abrasive mesh size in abrasive jet machining of tempered glass.

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