Analysis of Abrasive Jet Micro Machining by Taguchi Technique

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Abstract *- Abrasive jet micro-machining (AJMM) is an advanced technique in the field of micro machining. This operation is widely utilized as a part of the industry for cutting intricate shape on hard and brittle materials that usually difficult to perform. In present experimental study, the effect of process variables on the material removal rate (MRR) and shape evolution was demonstrated by Taguchi and ANOVA Method using Minitab17 which provides an acceptable simulated result. Drilling operation of glass is done at varied jet pressure, standoff distance (SOD), nozzle inclination (NI) and nozzle tip diameter (ND) as the process variable. Material removal rate and sphericity constant of drilled hole are considered as the output of whole machining process. To exhibit the solution and to validate this multi-response analysis a statistical tool, DOE has been followed under which Taguchi orthogonal array (OA) is utilized for experimental design and optimum outcome accomplished through Analysis of variance (ANOVA). It was discovered from the parametric analysis that all the process variables are impressive to evaluate the criteria of MRR whereas both machining pressure and nozzle inclination are most influencing factors for sphericity constant.*

Keyword- *AJMM, Glass, Minitab17, Taguchi OA, ANOVA*

I. INTRODUCTION

Abrasive jet micro-machining is a non-traditional machining also called as micro abrasive blasting or pencil blasting in this machining technique, high-speed stream of abrasive impinges on the target material. This high-velocity jet is developed due to a conversion of high-pressure energy of air or carrier gas into its kinetic energy. The high-velocity jet that coming out throughout nozzle is a mixture of compressed air with a hard abrasive particle. Consequently, this abrasive particle erodes the material by micro cutting activity and additionally fragile crack formation of the target material.

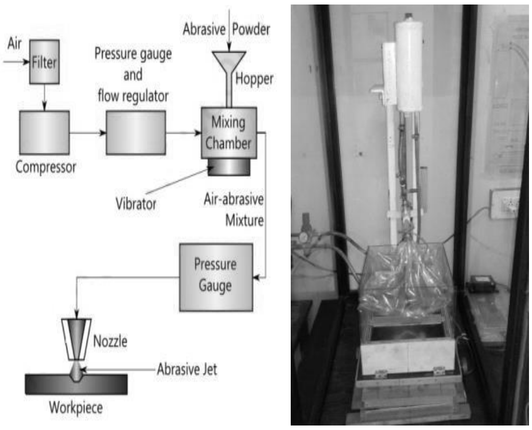

Fig 1. Abrasive Jet Micro Machining setup

In this Morden machining process property of abrasive a particle plays a vital role to remove the material on a workpiece surface. Therefore, to improve material removal rate a hard and ununiform abrasive is preferred. usually Al_2O_3, SiC has considered during machining even glass beads, sea sand is utilized as abrasive.

II. EXPERIMENTAL SETUP

Machining setup consists of following elements

1. Air compressor
2. Mixing chamber
3. Flow control valve
4. Venturi
5. Machining chamber
6. Nozzle

The abrasive jet machine consists of air compressor that generates high pressurized air, abrasive feeding system with venturi and CNC controlled moving table. The venturi used in this investigation is the progressive approach of analysis of process parameters. Generally, it added to improve the exit velocity of the jet through nozzle also the superior mixing of both abrasive and compressed air. The control valve is directed carefully with maintaining the jet flow. For evaluating the MRR workpiece is weighed before and after machining. The proportion of total weight loss to cutting time gives the volumetric material removal rate. At last the sphericity of drilled hole is measured by the digital microscope.

III. CONTROLLABLE PARAMETERS AND DESIGN MATRIX

TABLE:I Selection of Factors and Levels

CONTROL FACTOR	LEVELS				RESPONSES	
	1	2	3	4		
PRESSURE (kgf/cm^2)	3	4	5	6	Material removal rate (MRR) (gm/sec.)	Sphericity constant (S_c)
NOZZLE INCLINATION (degree)	54	66	78	90		
SOD (mm)	5	10	15	20		
NOZZLE DIAMETER (mm)	1.5	1.7	1.9	2.1		

The conceivable parameters of AJMM are abrasive jet pressure, nozzle tip diameter, an angle of attack and standoff distance. The principle points of this exploration are to complete the examinations by choosing diverse factors and their levels, applying Taguchi Orthogonal array (OA) of analysis and afterward investigating the outcomes got. The number of observation were done as proposed by the Taguchi experimental design according to a number of a process variable, their levels, and their collaborations. In view of the above quality of a study, the required least number of observation to be direct. The closest OA satisfying this condition is L16. It can accommodate a greatest three number of the control element, each at three levels. with 16 tests.

The analytical procedure through MINITAB statistical tool concentrates many process parameters at the same time and enhanced the response that generally most economically.

TABLE II: Taguchi Design Matrix and Response

	PROCESS VARIABLE					OUTCOME	
Exp. No.	Pressure (Kgf/cm^2)	NI (degree)	SOD (mm)	ND (mm)	W1-W2 (gm)	MRR (gm/sec)	S_c
1	3	54	5	1.5	0.06	0.0075	0.725
2	3	66	10	1.7	0.0699	0.02083	0.827
3	3	78	15	1.9	0.1658	0.04253	0.901
4	3	90	20	2.1	0.1248	0.046259	1
5	4	54	10	1.9	0.1243	0.02833	0.697
6	4	66	5	2.1	0.0566	0.017018	0.789
7	4	78	20	1.5	0.1599	0.0246	0.849
8	4	90	15	1.7	0.1124	0.04517	1
9	5	54	15	2.1	0.1250	0.04328	0.645
10	5	66	20	1.9	0.1921	0.047808	0.804
11	5	78	5	1.7	0.0667	0.01975	0.84
12	5	90	10	1.5	0.1125	0.031718	1
13	6	54	20	1.7	0.1500	0.0366	0.669
14	6	66	15	1.5	0.0924	0.03514	0.774
15	6	78	10	2.1	0.09	0.042056	0.828
16	6	90	5	1.9	0.1746	0.05048	1

Fig. 2: Glass piece after micro drilling

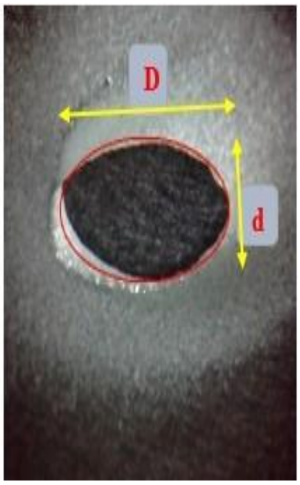

Fig. 3: Hole sphericity

IV. RESULT AND DISCUSSION

Material wear rate and sphericity constant (Sc) of Sample is calculated through these formulas:

$$\text{MWR (gm/sec)} = \frac{\text{(Basic weight- Final weight)}}{\text{Time}}$$

Sphericity constant =Shorter dia. (d) /longer dia. (D)

S/N ratio Analyse - Taguchi approach emphasis on the importance of analyzing the experimental response deviation applying a signal to noise ratio, that responsible for the decrement in the variation of process characteristic due to uncontrollable factors. The material removal rate was treated on "large-the-better" concept. MRR is computed using the formula.

Taguchi Analysis: MRR (gm/sec) versus Pressure (Kgf/cm2), NI (degree), SOD (mm), ND (mm)

TABLE III: Response Table for Signal to Noise Ratio (Larger is better)

Level	Pressure (Kgf/cm^2)	NI (degree)	SOD (mm)	ND (mm)
1	-32.56	-32.36	-34.48	-33.43
2	-31.36	-31.13	-30.52	-30.84
3	-29.44	-30.30	-27.67	-27.68
4	-27.82	-27.38	-28.50	-29.22
Delta	4.74	4.99	6.80	5.75
Rank	**4**	**3**	**1**	**2**

Ranks at a table of S/N ratio that will help quickly determine, which factors have the greatest impact on results. The larger delta value of factor given rank 1. The stand of distance is higher contribution factor for MRR.

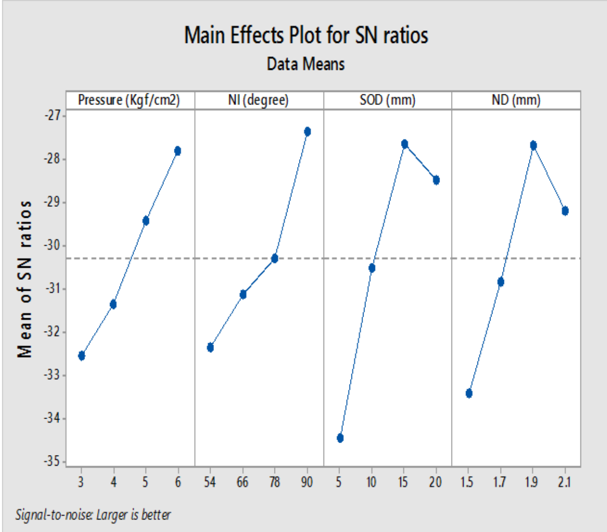

Fig. 4: Parametric effect on MRR

TABLE IV: Analysis of Variance for MRR

Source	Contribution	Adj. SS	Adj. MS	F-Value	P-Value
Pressure	16.55%	0.000407	0.000136	10.48	0.043
NI	21.36%	0.000526	0.000175	13.52	0.030
SOD	31.95%	0.000786	0.000262	20.23	0.017
ND	28.55%	0.000703	0.000234	18.08	0.020
Error	1.58%	0.000039	0.000013		
Total	100%				

Analysis of variance with R-sq. is 98.42% and R-sq.(adj) is 92.10%

During the process of abrasive jet micro machining, the influence of varied input factors like machining pressure, nozzle inclination nozzle diameter and stand of distance has significant on material wear rate as a display in main consequence plot of S/N ratio in fig.4. Nozzle stand-off distance is the most significant factor affecting the MRR.

The jet pressure is shown proportionality behavior with MRR. This is predicted due to the fact a growth in jet pressure produce high kinetic energy, causing more material erode from the workpiece. brittle materials, like glass, have a higher erosion rate especially at an angle of 90 degrees as shown in response plot. Furthermore, it can see that as nozzle tip diameter and standoff distance is increased, material wear rate also raised up to a certain region after that it will begin diminishing because of velocity loss of abrasive particles. Analysis of variance is statistically Tool for the identification of influencing factors Performance measures in a given set of data. The Minitab is used to explore the Effect of Process Parameters. ANOVA validate the analysis with R-sq. 98.42% and R-sq.(adj) 92.10%. SOD found to be a most viable parameter.

TABLE V: Response Table for Signal to Noise Ratios (Larger is better)

Level	**Pressure (Kgf/cm^2)**	**NI (degree)**	**SOD (mm)**	**ND (mm)**
1	-1.33716	-3.30722	-1.59153	-1.61007
2	-1.65391	-1.95710	-1.60616	-1.66395
3	-1.80452	-1.37029	-1.73487	-1.48393
4	-1.83901	0.00000	-1.70205	-1.87666
Delta	0.50185	3.30722	0.14334	0.39273
Rank	**2**	**1**	**4**	**3**

Nozzle inclination has been ranked 1. Hence, in order to attain a circular crater, a nozzle inclination recommended.

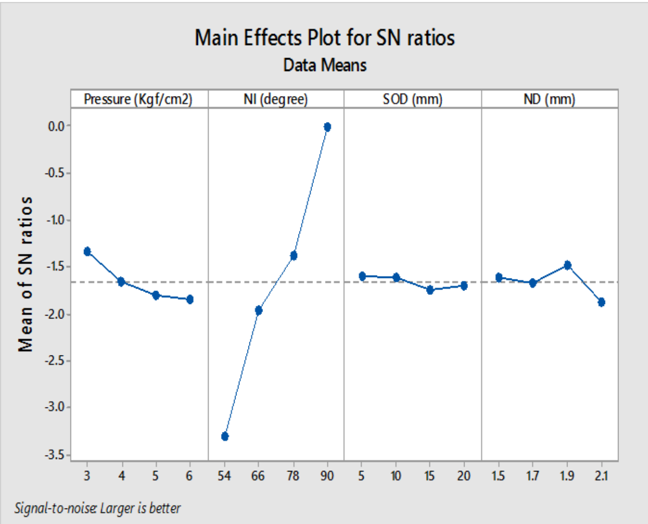

Fig. 5: Parametric effect on sphericity constant

TABLE VI: Analysis of Variance for S_c

Source	**Contribution**	**Adj. SS**	**Adj. MS**	**F-Value**	**P-Value**
Pressure	2.34%	0.005030	0.001677	11.08	0.039
NI	96.17%	0.206945	0.068982	455.83	0.000
SOD	0.12%	0.000257	0.000086	0.57	0.674
ND	1.16%	0.002493	0.000831	5.49	0.098
Error	0.21%	0.000454	0.000151		
Total	100%				

Analysis of variance with R-sq. 99.79% and R- sq.(adj) 98.95%

In fig.5 each plot presents the correlation between four distinctive processes and sphericity constant. The inclination of nozzle and machining pressure plays an essential function on influencing sphericity of hole. Besides, it is sincerely obtrusive that the other process variable does not impact very much in comparison to nozzle inclination and pressure.

Table VI represents that p value of pressure and nozzle inclination is below 0.05 that implies these factors are the most recommended factor for sphericity constant (S_c) that validate the effectiveness of ANOVA model in experimental investigation. Also, the Contribution of process parameters on sphericity of hole was determined by ANOVA and the NI is found to be the most important factor for Sphericity constant with contribution 96.17%.

V. CONCLUSION

Here are the results for calculating glass MRR –

1. It is observed that maximum erosion rate 0.5048 gram per second is obtained at a pressure of 6 kgf/cm2, inclination angle 90, nozzle tip distance 5mm and a nozzle diameter of 1.9mm.
2. It also observed that maximum value of sphericity constant (1) is obtained whenever workpiece is normally placed to nozzle (90º)
3. In addition, the significance and convenience of the developed model were determined and validate by ANOVA. The results show that the parameters pressure, ND, and SOD Considered being the most important factors for MRR while Nozzle inclination and machining pressure is higher contribution factor for sphericity constant

VI. ACKNOWLEDGMENT

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