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Parametric Optimization of Abrasive Jet Micromachining through Genetic Algorithm

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ABSTRACT: Abrasive jet micro machining (AJMM) is an advanced machining process for machining of hard and brittle materials. This article deals with the experimental study of process parameters of AJMM to achieve an optimized Material removal rate (MRR). Some input factors for above study are considered in the level of experiments such as Pressure, nozzle tip distance (NTD), the size of abrasives (SOA), and nozzle diameter. These parameters are varied during the experimentation. The comprehensive impact of the process parameter is examined and a Mathematical model for MRR is likewise developed by response surface methodology (RSM). In addition, a Genetic algorithm (GA) is implemented to optimize the MRR in MATLAB. Error estimation is done by comparing the Simulation result of GA with the experimental result and observed that there is no significant error in the estimation of simulation results.

KEYWORDS: RSM, GA, Abrasive jet micro machining (AJMM)

I. INTRODUCTION

Abrasive Jet Micro Machining (AJMM) is a recently developed advanced machining process, which is suitable for the cutting, grooving or drilling process. AJMM is mainly used for machining the hard and brittle materials, such as glass, silicon, ceramics, and wood. In this process, abrasive particles mixed with compressed air in an appropriate ratio. The mixture of an abrasive particle with air is accelerated through a nozzle which strikes on the workpiece surface. As a result, the material is removed by the collision of abrasive air mixture to the workpiece.

The elements of AJMM are the compressor, mixing chamber, flow control valve, nozzle, machining chamber etc. The performance of AJMM can be regulated by various parameters i.e. pressure, nozzle tip distance, types & size of abrasives, flow rate, mixing ratio and nozzle diameter. The accuracy of the process is judged by material removal rate (MRR), surface roughness, taper produced and over cut. These parameters are considered as responses. An optimum value of process parameters provides the desired performance with the lowest machining cost. To achieve the optimum values of responses various tools and techniques used for analysis or optimization.

II. CONTROLLABLE PARAMETERS AND DESIGN MATRIX

The conceivable controllable parameters of AJMM are abrasive jet pressure, nozzle tip diameter(NTD), an angle of attack, standoff distance(SOD) and size of abrasive (SOA). Table I shows the range of these factors and arranged design matrix.



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TABLE I

ACTUAL VALUES OF PROCESS PARAMETERS AND CODED LEVELS

S.N.	Process	Unit	Levels	
	Parameters		-1	1
1.	Pressure	Kgf/cm2	1	6
2.	NTD	Mm	3	35
3.	SOA	Microns	60	100

(i) Response Analysis

Material removal rate (MRR) is the ratio of the volume of material is to be removed per unit time in mm³/sec. The MRR is material removal per unit time can calculate by:

$$MRR = \frac{A^*t}{T}$$

Here A =Area of drilling of workpiece (mm2)

t = Thickness of workpiece (mm)

T = Machining time of drill (sec.)

Table II presents the experimental set as well as MRR for each run.

TABLE II						
CCD RUNS RESPONSE VALUES WITH THE INPUT PARAMETER						

	Input Variable			Response
Run	Pressure	NTD	SOA	MRR
	Kgf/cm2	mm	Microns	mm3/sec
1.	3.5	3	80	0.794182
2.	6	3	60	6.49461
3.	1	3	100	0.19968
4.	3.5	19	80	1.72258
5.	3.5	19	80	3.37362
6.	1	35	100	0.348862
7.	6	35	60	4.57233
8.	3.5	19	100	1.32377
9.	6	3	100	10.251
10.	3.5	19	80	4.90852
11.	1	3	60	0.385219
12.	3.5	19	80	5.71086
13.	1	35	60	10.2853
14.	3.5	19	80	10.6809
15.	6	35	100	6.32497
16.	3.5	35	80	2.7437
17.	3.5	19	60	5.27498
18.	6	19	80	7.18255
19.	1	19	80	1.68793
20.	3.5	19	80	5.77821



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III. GENETIC ALGORITHM (GA) METHODOLOGY

Genetic algorithm (GA) is a modified optimization tool which depends on the principles of genes and natural selection. GA can optimize difficult problem of continuous or discrete variables and it can be dealing with a large number of variables. GA is mainly suitable for solving maximization problems. Minimization problems are solved by changing into maximization.

The GA technique is the natural process of evolution to solve optimization and search problems towards better solutions. GA has three main operators" reproduction, crossover, and mutation. For implementing GA in an optimization of the machining parameters, the process parameters are encoded as genes by using binary string encoding.

For a researcher, it is important to choose suitable GA parameters which differ from factors and constraints in order to the algorithm to perform circumspective solutions. The main idea of selection is to prefer better solutions. Many selection procedures have been proposed to accomplish this idea, including stochastic universal selection, roulette wheel selection, ranking selection and tournament selection etc.

(i) Problem Formulation

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The optimization problem for maximization of MRR is formulated as:

Max. MRR

Sub. to: MRR>0

Where:

MRR=+4.78758-1.30555*Pressure+0.57965*NTD-0.092351*SOA -0.049680* Pressure*NTD+0.039078*

Pressure*

SOA -4.59167E -003* NTD * SOA

and

Pressure \in [1-6] Kgf/cm2

NTD \in [3-35] mm

SOA \in [60-100] Microns
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The parameter of Genetic Algorithm was used with a population size of 100 and SBX parameter value of 2 and polynomial mutation parameter value of 10. Variation in population is the best value of MRR and population average with generation as shown in Figure 1. It can be seen that convergence is achieved by end of 100 generations and the population Average and population best values match closely after100 generation. GA was run 20 times and the best value in each run was observed.



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Fig. 2. Best Individual Input Parameters at Optimum MRR

Fig. 2 exhibit the best values of input parameters individually to optimize the MRR. The range of MRR values varies with the generation as shown in Figure 3.



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It demonstrates the maximum, minimum and mean values of MRR in the form of a range. The variation of MRR changes at each individual run, maximum MRR Obtained from the curve is 0.73208 mm3/sec. The plot for the genealogy of individuals is shown in figure 4. This plot shows that the account of descents from ancestors so it gives the complete history of optimization of MRR.

The lines from one generation to next generation are color coded as follows:

1. Mutation children are indicated by red line.

2. Crossover children are indicated by a blue line.

3. Elite individuals indicated by the black line.



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(ii) Model Checking for Single Objective Optimization

TABLE III					
Input Variables					
Pressure	1.0 kgf/cm2				
NTD	3.0 mm				
SOA	93.82698789703296				
	Microns				
Response Parameter					
GA Predicted MRR	0.73208mm3/sec.				
Experimental MRR	0.6222 mm3/sec				
% Prediction Error	15				

Validation of GA predicted results is required to know the variation from the actual experimental results. The difference in results is measured by the factor percentage of prediction results. The percentage of the prediction error is determined as:

 $\frac{Prediction \ Error = GA \ Pridicted - Experimental \times 100}{GA \ Pridicted}$



Fig. 5. Hole image for validity for MRR model

(iii) Effect of Parameters on MRR

It has been found from above investigation that the average change in MRR is linear with increase in pressure. Results obtained clearly show that high pressure results in high MRR. Whereas increases with NTD and will decrease after reaching its maximum value because abrasive particles lose their velocity so that the KE of particles decrease which affects the MRR. It can be seen with increasing the abrasive size MRR is diminished. At higher mesh size, the larger number of abrasive particles associated in machining process which give good finishing with low MRR.



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IV. CONCLUSION

In present work, the optimal process parameters for glass material in AJMM is developed by GA approach. Therefore, single objective optimization is being done. The whole experimental study emphasizes on the formulation of the regression model for MRR and further optimize by GA that gives a most favourable result. The optimum values of an input parameter for MRR are 1 kgf/cm2 pressure, 3 mm NTD, 93.85 microns SOA. Error estimation is done by comparing the Simulation result of GA with the experimental result. It is observed that 11% error in the estimation of simulation results which does not consider an as significant error. The formulated result of single objective optimization demonstrates suitable area in the design region of the process variable that can be preferred to augmentation of desired output during machining. The optimized process variable at which material removal rate obtain maximum is almost equivalent to experimental results.

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