OPTIMIZATION OF MATERIAL REMOVAL RATE (MRR) IN MILLING OF ZIRCONIA CERAMIC MATERIAL USING TAGUCHI AND RESPONSE SURFACE METHODOLOGY (RSM) TECHNIQUE

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ABSTRACT **-**The paper presents experimental investigation into optimization of MRR during milling of zirconia ceramic material. Experiments were conducted using three input machining parameters cutting speed, feed and depth of cut at three different levels. Taguchi orthogonal array (OA) L9 was used for performing the experiments. MRR optimization was performed using Taguchi and RSM technique. After optimizing, confirmation test were performed and results of both the test were compared to find better technique. The results led to a conclusion that RSM technique provides better results as compared to Taguchi technique.

Keywords: **MRR, RSM, cutting speed, feed, depth of cut.**

1. INTRODUCTION

Milling is one of the most important metal removing processes which are widely used for purpose of machining. In machining MRR is of greater concern as it controls the surface finish and cost associated with machining. If MRR increases the surface finish reduces and it increases with reduction in MRR. As the MRR decreases the time required for machining also increases, thus increasing cost of production. Hence the MRR should be at such a level which would provide better surface finish at minimum cost. A lot of researchers had optimized MRR using various techniques some of which are discussed. Sumit Raj and Kaushik Kumar [1] optimized MRR during Electro Discharge Machining (EDM) of EN45 tool steel using Taguchi method. Balbir Singh et al. [2] analysed the influence of machining parameters on MRR improvement during EDM process. S. Banerjee et al. [3] improved the MRR by 26% during machining of EN47 spring steel using Taguchi technique. Gurwinder Singh and Shalom Akhai [4] optimized MRR during CNC plasma arc cutting using design of experiment (DOE). M. S. Reza et al.[5] optimized MRR for EDM process and concluded that higher discharge voltage was responsible for MRR. S. Doruk Merdol and Yusuf Altintas [6] optimized the MRR during simulation of milling process by varying the feed rate. S.L. Campanelli et al. [7] performed multi objective optimization of laser milling of 5754 aluminium alloy for improving machining productivity and surface quality. Vikas et al. [8] optimized and compared the MRR for EN19 and EN41 material and concluded that discharge current was most significant factor. Jinka Ranganayakulu et al. [9] optimized MRR during electrochemical discharge machining. Sayak Mukherjee et al.[10] optimized MRR during turning opeartaion and concluded that depth of cut was the most influential factor influencing MRR. Arvind Kumar [11] optimized MRR during turning of 1018 mild steel using taguchi technique. Bikram Jit Singh and Harsimran Singh Sodhi [12] optimized turning parameters using RSM technique.

In this paper effect of input parameters on MRR was investigated using taguchi L9 OA. Taguchi and RSM technique was then applied to optimize MRR and to find which technique performs better.

2. EXPERIMENT PROCEDURE

2.1. CNC Milling Machine

The CNC milling machine on which experiments were performed is shown in Fig. 1. with details of machine given in Table 1.

Table 1. CNC Details

Machine Name	CNC HAAS Vf-1
Spindle Speed	10000 rpm
Motor	14.9 kW

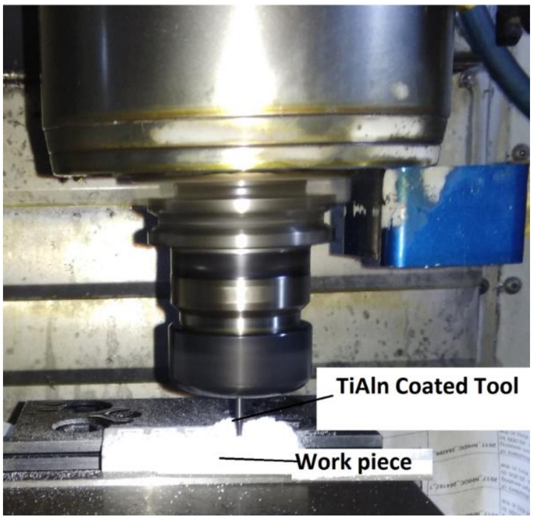

Fig. 1: Milling setup

Fig. 2: TiAln Coated tool

2.2. Work Material & Tool material

Zirconia ceramic work piece material was machined using TiAln coated tool details of which are given in Table 2.

Table 2. TiAln tool details

Diameter	3 mm
Flank Length	12 mm
Helix Angle	300
Hardness	2000 HV
Coating thickness	5 µm

2.3. Material removal rate

The material removal rate for machining was calculated by ratio of the volume of material removed to the time taken during machining.

3. EXPERIMENT DESIGN

The experiments conducted were based on Taguchi orthogonal array (OA) design. The input parameters selected were cutting speed, feed and depth of cut at three different levels. For 3 input parameters at three different levels L9 OA was selected. The selected input and their levels are given in Table 3. The details of experiments performed and the measured responses are given in Table 4.

Table 3. Input parameters and their levels

Parameters	**Units**	**Level 1**	**Level 2**	**Level 3**
Cutting Speed (A)	rpm	7500	8500	9500
Feed (B)	mm/min	75	105	135
Depth of Cut (C)	mm	0.4	0.8	1.2

Table 4. Details of experiments performed with measured response MRR

Expt No.	**Cutting Speed**	**Feed**	**Depth of Cut**	**MRR**
	rpm	mm/min	mm	mm3/min
1	7500	75	0.4	31.746
2	7500	105	0.8	73.394
3	7500	135	1.2	240.000
4	8500	75	0.8	64.000
5	8500	105	1.2	115.385
6	8500	135	0.4	78.431
7	9500	75	1.2	95.238
8	9500	105	0.4	39.216
9	9500	135	0.8	156.863

4. TAGUCHI TECHNIQUE

Taguchi recommends analyzing the means and S/N ratio using conceptual approach that involves graphing the effects and visually identifying the factors that appear to be significant, thus making the analysis simple [13]. The response table for average S/N ratio for Larger the better MRR is shown in Table 5 and is shown in form of graph in Fig. 3 which was directly obtained from Minitab Software.

Table 5. Response Table for Signal to Noise Ratio for MRR

Level	Speed	Feed	Depth of Cut
1	38.32	35.24	33.26
2	38.42	36.81	39.12
3	38.45	43.13	42.81
Delta	0.13	7.89	9.54
Rank	3	2	1

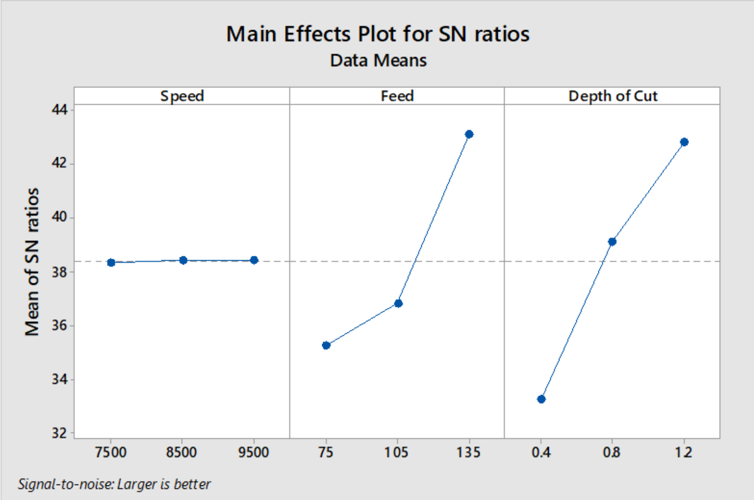

Fig.3: Larger the better graph for MRR

The optimal machining factors for MRR can be seen in Fig.3 and Table 5. The levels and S/N ratios for the factors giving larger MRR value were specified as factor A (Level 3, cutting speed =9500 rpm), factor B (Level 3, feed = 135 mm/min) and factor C (Level 3, depth of cut = 1.2 mm).

5. RESPONSE SURFACE METHODOLOGY

Response surface methodology (RSM) is a collection of mathematical and statistical techniques for empirical model building. The objective is to optimize a response (output variable) which is influenced by several independent variables (input variables). RSM comprises a body of methods for exploring for optimum operating conditions through experimental methods [12]. The RSM is a dynamic and foremost important tool of Design of Experiment (DOE) where in the relationship between process output(s) and its input decision variables, it is mapped to achieve the objective of maximization or minimization of the output properties [14].

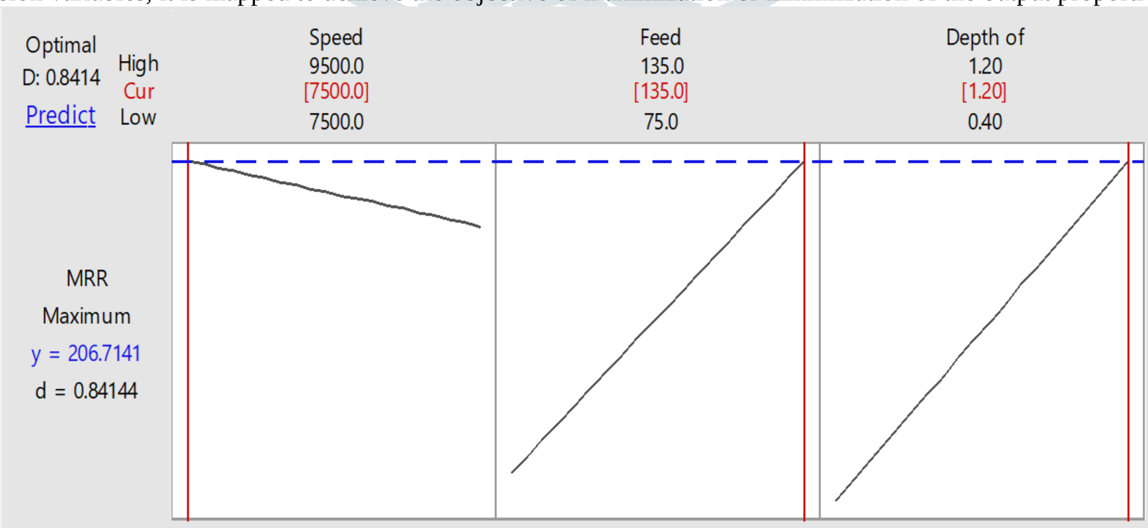

Fig. 4: Optimized result for RSM technique

The optimization result generated by Minitab software using response surface optimiser is shown in Fig. 4 optimal value were specified as factor A (Level 1, cutting speed =7500 rpm), factor B (Level 3, feed = 135 mm/min) and factor C (Level 3, depth of cut = 1.2 mm).

6. VALIDATION OF OPTIMAL RESULTS

Based on the optimization results obtained by the optimization technique validation experiments were again conducted by setting the machine on the optimal factors results of which are given in Table 6. Three experiments were conducted on the optimized factors and average of the three is given in the Table 6. Based on the validation results obtained it can be concluded that RSM optimization technique provided better results than taguchi technique as MRR given by RSM technique is more as compared to taguchi technique.

Table 6. Results for validation experiments

Technique	Cutting Speed	Feed	Depth of Cut	Observed MRR
Taguchi	9500	135	1.2	196.72
RSM	7500	135	1.2	214.29

7. CONCLUSION

On the basis of the conducted experiments and results of validation it can be concluded that

- Taguchi and RSM technique can effectively be used for the purpose of single parameter optimization.
- Optimal factors as cutting speed at 9500 rpm, feed at 135 mm/min and depth of cut at 1.2 mm was found by application of taguchi technique.
- Optimal factors as cutting speed at 7500 rpm, feed at 135 mm/min and depth of cut at 1.2 mm was found by application of taguchi technique.
- Among the two techniques of optimization applied RSM technique provided better result of 214.29 mm3/min as compared to taguchi technique of 196.72 mm3/min.

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