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Flatness Optimization of Zirconia Ceramic Material employing Response Surface Methodology

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Abstract: **In this paper, the effect of input parameters using titanium aluminum nitride coated tool is analyzed for milling of zirconia ceramic material. Zirconia ceramic is widely used in aerospace, dental, etc. industries. Taguchi L9 OA is selected to perform the experiments while flatness is selected as the output response. Flatness is one of the important surface features which ensure that the surface created by machining is parallel to that of the tool. Flatness of the surface is measured using a CMM machine. Minitab software was employed for finding the optimum level of parameters. It is concluded that flatness has improved by employing the RSM technique.**

Keywords —CMM, Depth of cut, Feed, Flatness, Optimiztion, RSM, Speed.

I. INTRODUCTION

The surface texture of a workpiece governs the functioning of the part. While machining it is difficult to produce a perfectly flat surface every time due to various errors during machining. This hampers the aesthetics as well as the working of the product. If the surface produced while machining has good surface features, further investment to create a smooth surface reduces. Hossein Cheraghi et. al [1] evaluated an optimized process to calculate the error in flatness and straightness for manufactured parts that converts the non-linear issues to linear issues. Bruce L. Tai et al [2] improved the flatness of the workpiece while machining by using two different methods of optimization. Saurin Sheth et al [3] optimized the flatness and surface roughness by employing taguchi orthogonal array and regression model. Subhas Chandra et al [4] optimized surface roughness in centreless grinding operation by combining particle swarm and response surface optimization techniques. Soleymani Yazdi and Khorram [5] optimization of surface roughness and material removal rate were performed by employing response surface method and artificial neural network methods. Mukesh Kumar Barua et al [6] studied the effect of machining parameters on the surface roughness and had developed a response surface regression model. Bikram Jit Singh and Harsimran Singh Sodhi [7] had simultaneously optimized the surface roughness and material removal rate using response surface methodology on Minitab 16 software. Bhuvnesh Bhardwaj et al [8] improved the surface roughness for milling of EN 353 material using response surface methodology. Nilrudra Mandal et al [9] developed a model to forecast flank wear of cutting tool using response surface methodology. K. Palanikumar et al [10] successfully modeled the surface roughness in machining of composites using response surface methodology. Kompan Chomsamutr and Somkiat Jongprasithporn [11] optimized the life of cutting tools using taguchi approach and response surface methodology.

II. EXPERIMENTATION

1.1. EQUIPMENT/MATERIALS USED

Tests were performed on CNC HAAS -3 Axis VMC machine depicted in Fig.1 machining rectangular shape zirconia ceramic workpiece depicted in Fig.2. Flat shape titanium aluminum nitride coated tool depicted in Fig.3 with 3 mm diameter and 300 helix angle was loaded on the machine spindle rotating at a maximum speed of 10000 rpm equipped with 14.9 KW drive motor.

Fig.1 CNC HAAS Machine

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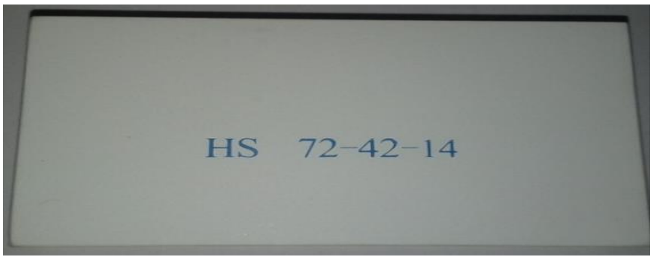

Fig.2 Rectangular workpiece

Fig.3 TiAln Coated Tool

1.2. FLATNESS MEASUREMENT

Global Performance Coordinate Measuring Machine depicted in Fig.4 was utilized for measuring flatness of the slot. The virtual plane was created by a probe at 4/5 different points within the slot. The flatness of the created plane was measured to measure the flatness of the slot. Fig.5 depicts the reading recorded by the software for the flatness.

Fig.4 CMM Machine

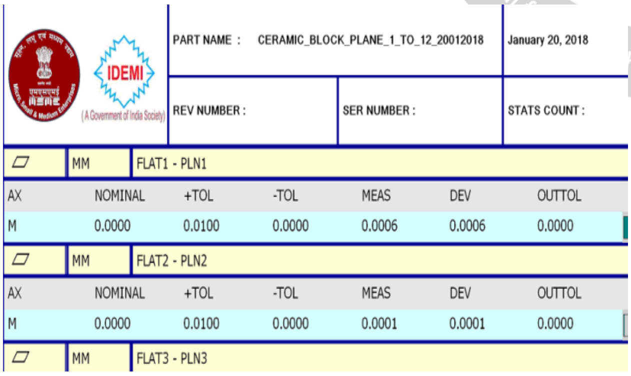

Fig.5 Flatness recording by CMM

III. TAGUCHI L9 OA

Cutting speed, feed, and depth of cut were the machining parameters selected at three different levels. Taguchi L9 OA was selected as 3 parameters at 3 levels were to be investigated. Table 1 depicts the levels of the selected parameters whereas Table 2 depicts the configuration at which the experiments were performed and the measurement of flatness recorded.

Table 1. Input parameters and their levels

No	Parameters	Units	Level 1	Level 2	Level 3
1	Cutting Speed (V)	rpm	7500	8500	9500
2	Feed (f)	mm/min	75	105	135
3	Depth of cut (d)	mm	0.4	0.8	1.2

Table 2. Output obtained at different levels of input combination

Exp No	V rpm	f mm/min	d mm	F
1	7500	75	0.400	0.0016
2	7500	105	0.800	0.0008
3	7500	135	1.200	0.0014
4	8500	75	0.800	0.0009
5	8500	105	1.200	0.0024
6	8500	135	0.400	0.0026
7	9500	75	1.200	0.0005
8	9500	105	0.400	0.0008
9	9500	135	0.800	0.0014

IV. RESPONSE SURFACE METHODOLOGY

Response Surface Methodology (RSM) explores the relationships between many informative variables and one or a lot of response variables. The strategy was introduced by George E. P. Box and K. B. Wilson in 1951. The most plan of RSM is to use a sequence of designed experiments to get an optimum response. Box and Wilson recommend employing a second-degree polynomial model to try to do this. They acknowledge that this model is barely an approximation, however they use it as the model is simple to estimate and apply.

V. FLATNESS OPTIMIZATION & VALIDATION

For optimization of flatness response optimizer of Minitab software was used. The optimized values of the input parameters are depicted in Fig. 6. Experiments were then conducted using this combination of input parameters and flatness obtained by the experiment was also recorded. The flatness measured by the machine was 0.0002 which is the optimum value as can be seen from the Table 3.

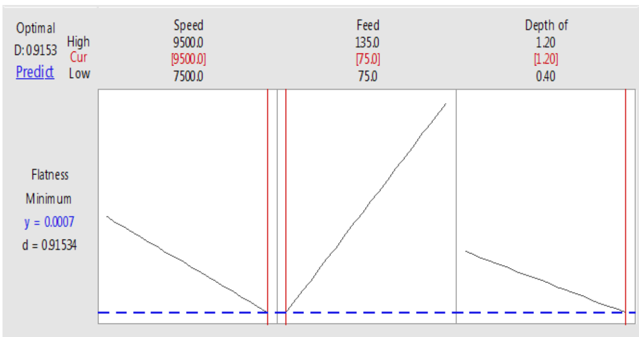

Fig.6. Optimized value by Minitab Software

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Table 3. Input parameters and their levels

Technique	V	f	d	F (Actual)
RSM	9500	75	1.2	0.0002

VI. CONCLUSION

In this work response surface optimizer of Minitab was utilized for optimizing the flatness during machining zirconia ceramic. Based on the analysis enlisted conclusions can be made.

- The response surface optimizer can be successfully utilized for optimization.
- Minimum flatness could be achieved by employing response surface optimizer.

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