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Influence of Machining Parameter on Concentricity of the Hole on VMC Machining using RSM (Central Composite Design)

Dileep Panchal
Asst. Professor, Department Of Mechanical Engineering, St' Martins Engineering College, Hyderabad

Abstract: ***In machining operation, work piece geometric dimensions and tolerance (GD&T) requirements is an important requirement for many applications. Thus, the choice of optimized cutting parameters is very important for controlling the required for concentricity of the hole requirements.***

The focus of present experimental study is to optimize the cutting parameters through work piece geometric dimensions and tolerance (GD&T) requirements as concentricity of the hole. This is an experiment carried out by employing a central composite design to develop a mathematical model in order to predict concentricity of the hole. After that the design of experiments (DOE) methodology by central composite design was used for optimizations (using Minitab 16, software) to find the optimum cutting parameters conditions for concentricity of the hole.

The dissertation work is an experimental study of concentricity of the hole which was performed on VMC machine of EN8 and EN31 materials using carbide tool by varying the cutting parameters such as cutting speed and feed to determine optimum cutting parameters conditions for concentricity of the hole. After that work piece is testing on trimos instrument and getting the results those results analyzed in Minitab 16 software. Analysis of variance (ANOVA) was carried out for concentricity of the hole on EN8 and EN31 materials and their contribution rates were determined. Finally experimental observation shows the optimum parameters for concentricity of the hole and helps in saving the time along with required dimensional accuracy.

Key words: - Concentricity of the hole, CCD, VMC and parameters.

I. INTRODUCTION

Concentricity is controlling a common datum axis between two or more holes on the work piece and which controls the tolerance zone. Concentricity resilience could be situations during which the axes of all cross-section components of an element's surface of revolution are remain common to the axis of a datum plane. A concentricity tolerance identifies a cylinder-shaped resilience zone whose axis overlaps with a datum axis and inside which all cross-sectional axes of the characteristics being controlled lie. The resistance zone is similarly arranged about the datum axis for concentricity. The Concentricity necessitates that the middle purposes of the controlled component, no matter its size, be inside the tolerance zone.

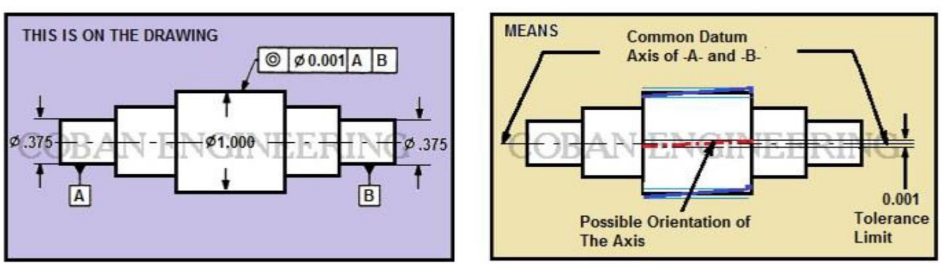

Fig-1:- Concentricity of the Holes

A. *Objectives*

To investigate the influence of different machining parameters or variables of VMC on EN8 and EN31 materials through RSM approach, To check machine characteristics of roundness of EN8 and EN31 material on CMM or trimos measuring equipment's and to examine the effect of process factors on dimensional accurateness and getting results. To advise best input factors for a given best output in form of dimensional accurateness.

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II. METHODOLOGY

"Methodology is the systematic, theoretical analysis of the methods applied to field of the study"

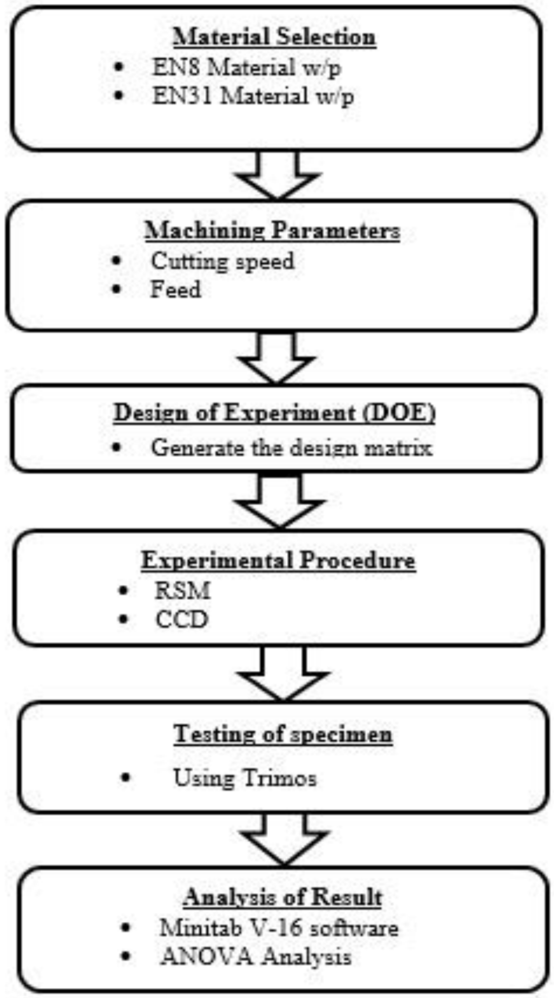

Fig-2.0:-Flow chart of methodology

A. *Material Selection for Machining*

Materials like EN8 and EN31 are selected because EN material has good properties like good mechanical properties, corrosion resistance and low carbon.

Table-2.1.1: EN8 Material Chemical Composition:

Chemical composition	
Carbon	0.36-0.44%
Silicon	0.10-0.40%
Manganese	0.60-1.00%
Sulphur	0.050%
Phosphorus	0.050%

Fig-2.1.1:- EN8 material

EN 31 is an outstanding high carbon mixture steel that provides a high measure of hardness with compressive strength and scraped area resistance.

Table-2.1.2:EN31 Material chemical composition

Chemical composition	
Carbon	0.95/1.10
Silicon	0.10/0.35
Manganese	0.40/0.70
Sulphur	0.050max
Phosphorus	0.040max
Chromium	1.20/1.60

Fig-2.1.2 EN31 material

B. Machining Parameters On Concentricity Of Hole

Here we consider only two factors. They are

1) *Cutting Speed:* Cutting speed is characterized as the speed at which the cutting edge of the device passes above the material. It is expressed in the meter per minutes.

$$V= \frac{\pi \cdot D \cdot N}{1000} \ (m/min)$$

Where,

V= Cutting Speed, D= Diameter and N=Spindle Speed

2) *Feed:* It is the distance that the tool travels on the work or work goes to be away the tool finally at each rotation of the cutter. Feed is represented in mm/rev. Different feed for various machine are stable within ranges and typically depend on the depth of cut and the derived quality of the work.

III. DESIGN OF EXPERIMENTS

A. Generating the Design Matrix with DOE (Minitab V16)

Design of experiments is used to identify out the relationship between varied variables which fits into the product and also helps to find the response of those variables on the standards and demonstration of the product.

Experimental design additionally helps in enhancing efficiency. Within the experimentation, changes in variables are deliberately presented into the organization, so as to check the activities of the organization on the performance features i.e. output. The most productive method for enhancing the adjustments in variable is by statistical methodology.

Testing can also be done by other techniques but statistical technique is the best route of experimentation.

B. Selection of Parameters and their Levels

Various different input parameters throughout the experiments are cutting speed and feed.

The table below reveals domain of experiments containing the machining parameters selected and their particular levels. The experimental data has also been provided.

Table: 3.2 Domain of Experiment

Machining parameters	Notation	Unit	Levels of parameters		
			Level 1	Level 2	Level 3
Cutting speed	V	m/min	350	400	450
Feed	F	mm/rev	0.1	0.2	0.3

Design matrix gained by using a running order of 13 numbers of tests considering above stated machining parameters shown below for different materials. Here two materials EN8 and EN31 materials are out lined in design matrix. It's obtained from the Minitab V16 software with help of parameters.

C. EN8 and EN31 Material design matrix sheet

VMC-EN8-COH-CCD					
StdOrder	RunOrder	PtType	Blocks	Cutting speed	Feed
10	1	0	1	400	0.2
7	2	-1	1	400	0.1
11	3	0	1	400	0.2
12	4	0	1	400	0.2
13	5	0	1	400	0.2
4	6	1	1	450	0.3
8	7	-1	1	400	0.3
9	8	0	1	400	0.2
5	9	-1	1	350	0.2
3	10	1	1	350	0.3
1	11	1	1	350	0.1
2	12	1	1	450	0.1
6	13	-1	1	450	0.2

VMC-EN31-COH-CCD					
StdOrder	RunOrder	PtType	Blocks	Cutting speed	Feed
10	1	0	1	400	0.2
7	2	-1	1	400	0.1
11	3	0	1	400	0.2
12	4	0	1	400	0.2
13	5	0	1	400	0.2
4	6	1	1	450	0.3
8	7	-1	1	400	0.3
9	8	0	1	400	0.2
5	9	-1	1	350	0.2
3	10	1	1	350	0.3
1	11	1	1	350	0.1
2	12	1	1	450	0.1
6	13	-1	1	450	0.2

IV. EXPERIMENTATION

This experiment was conducted on the vertical machining center (VMC) and machining additionally performed on the vertical machining center (VMC). Every experiment on the work piece was conducted as per input factors as like cutting speed and feed.

Fig-4.0.1:-Experimental Setup on VMC machine

Fig-4.0.2:- After Experiment on VMC machine

In this experiment we selected two materials like EN8 and EN31 medium carbon steel and high carbon steel. Contour holes on the both work piece materials were made as per the design matrix.

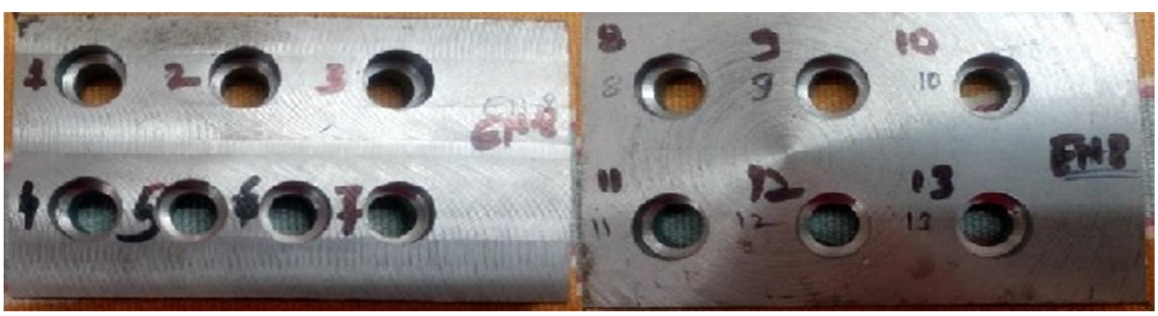

Fig-4.0.3:- EN8 work piece material with contour holes

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Fig-4.0.4:- EN31 work piece material with contour holes

A. Response Surface Methodology

Response surface methodology (RSM) may be a collection of statistical methods and mathematical replicas that are suitable for modeling and enhancing the problems during which the maximum response is influenced by the freelance variables on dependent variables. The final aim of RSM in to enhance the correct relation between the variables and also the response.

The RSM includes two approaches, they are

1) Central Composite Design (CCD)
2) Box Behnken Design (BBD)
a) *Central Composite Design (CCD):* A central composite design is that the more generally utilized response surface designed test. Central composite designs are factorial or fractional factorial design with center points, which increase with a group of axial points (also called star points) and let you estimate curvature. You can use a central composite design to:
i) Efficiently determine first- and second-order terms.
ii) Model a response variable with curvature by additional center and axial points to a previously-done factorial design.

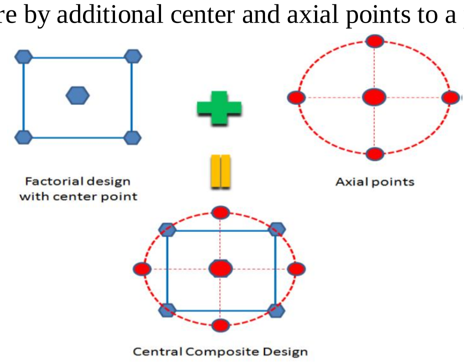

Fig-4.1:- Central Composite Design

B. Trimos

Trimos is the measuring instrument. Using this instrument we conducted experiments for getting exact results in the dimensional measurement and its dimensional accuracy. This instrument has a number of probes and that the appropriate selected diameter probe was selected and set to the instrument. Its measures inner diameter and outer diameter of the work piece and also finding the shift between the two holes and getting the results on display in this instruments.

Fig-4.2:- Trimos instrument using for our project

EN8 and EN31 dimension of work piece

StdOrder	RunOrder	PtType	Blocks	Cutting speed	Feed	Concentricity of hole
10	1	0	1	400	0.2	0.05
7	2	-1	1	400	0.1	0.04
11	3	0	1	400	0.2	0.051
12	4	0	1	400	0.2	0.049
13	5	0	1	400	0.2	0.049
4	6	1	1	450	0.3	0.033
8	7	-1	1	400	0.3	0.032
9	8	0	1	400	0.2	0.05
5	9	-1	1	350	0.2	0.053
3	10	1	1	350	0.3	0.045
1	11	1	1	350	0.1	0.035
2	12	1	1	450	0.1	0.046
6	13	-1	1	450	0.2	0.047

StdOrder	RunOrder	PtType	Blocks	Cutting speed	Feed	Concentricity of hole
10	1	0	1	400	0.2	0.025
7	2	-1	1	400	0.1	0.017
11	3	0	1	400	0.2	0.021
12	4	0	1	400	0.2	0.024
13	5	0	1	400	0.2	0.028
4	6	1	1	450	0.3	0.043
8	7	-1	1	400	0.3	0.043
9	8	0	1	400	0.2	0.027
5	9	-1	1	350	0.2	0.019
3	10	1	1	350	0.3	0.023
1	11	1	1	350	0.1	0.016
2	12	1	1	450	0.1	0.014
6	13	-1	1	450	0.2	0.018

V. RESULTS AND DISCUSSIONS

In this machining operation having two necessary parameters like cutting speed and feed with facilitate of “response surface methodology” (RSM) and “central composite design” (CCD). ANOVA is utilized for capability of the model for response during this experimentation. ANOVA is arithmetical choice technique utilized for finding any variance average performance of experimented parameters. ANOVA analysis is completed by the Minitab version 16 software. In this chapter results gained from ANOVA using Minitab version 16 software is out lined by utilizing the software to getting the graphs and tables.

A. *Central Composite Design*

In this experiment, 2 factors are used for central composite design (CCD).
The specifications are:-
Factors: 2, Replicates: 1, Base run: 13, Total run: 13, Base block: 1 and Total block: 1

B. *Response Surface Regression*

The model relationship between a response variable and one or more predictors, using the regression investigation.
A numerous regression analysis was shown on the verified information. Minitab delivers smallest square, incomplete minimum square then logistic regression process.

Table-5.2:- Estimated regression coefficients for concentricity of hole for EN8 and EN31material:

Terms	Coeff.	SE coeff.	T test	P value
Constant	0.04445	0.086818	0.512	0.624
Cutting speed	-0.00041	0.000437	-0.928	0.384
Feed	0.92511	0.105765	8.747	0.000*
Cutting speed*cutting speed	0.00000	0.000001	1.409	0.202
Feed*feed	-1.20862	0.135808	-8.899	0.000*
Cutting speed*feed	-0.00115	0.000226	-5.095	0.001*

S = 0.00225699

PRESS = 0.000309382

R-Sq. = 94.28%

R-Sq.(pred) = 50.53%

R-Sq.(adj) = 90.19%

Terms	Coeff.	SE coeff.	T test	P value
Constant	-0.309989	0.133914	-2.315	0.054*
Cutting speed	0.001839	0.000675	2.727	0.029*
Feed	-0.546322	0.163141	-3.349	0.012*
Cutting speed*cutting speed	-0.000003	0.000001	-2.988	0.020*
Feed*feed	0.524138	0.209481	2.502	0.041*
Cutting speed*feed	0.001100	0.000348	3.160	0.016*

S = 0.00348136

PRESS = 0.000601569

R-Sq. = 91.76%

R-Sq.(pred) = 41.55%

R-Sq.(adj) = 85.87%

Using Minitab software the response superficial design may be investigated. Its gives a number of coefficients determined by regression coefficients along with SE coefficient and value for T test and also p value. The SE coefficient is considered as standard error of coefficient, which is utilized to build confidence intermission and execution hypothesis experimentation. T is the test static with student circulation and P-value is related with this test in statistics. P-values is chance to getting in test statistic results.

Table-5.3:- Analysis of variance for concentricity of hole for EN8 and EN31 material

Source	DOF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	0.000587	0.00587	0.000117	23.06	0.000
Linear	2	0.000028	0.000390	0.000195	38.25	0.000
Cutting speed	1	0.000008	0.000004	0.000004	0.86	0.384
Feed	1	0.000020	0.000390	0.000390	76.51	0.000
Square	2	0.000427	0.000427	0.000213	41.90	0.000
Cutting speed*cutting speed	1	0.000023	0.000010	0.000010	1.99	0.202
Feed*feed	1	0.000403	0.000403	0.000403	79.20	0.000
Interaction	1	0.000132	0.000132	0.000132	25.96	0.001
Cutting speed*feed	1	0.000132	0.000132	0.000132	25.96	0.001
Residual error	7	0.000036	0.000036	0.000005		
Lack of fit	3	0.000033	0.000033	0.000011	15.65	0.011
Pure error	4	0.000003	0.000003	0.000001		
Total	12	0.00623				

Source	DOF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	0.000944	0.000944	0.000189	15.58	0.001
Linear	2	0.000689	0.000205	0.000102	8.45	0.014
Cutting speed	1	0.000048	0.000090	0.000090	7.44	0.029
Feed	1	0.000641	0.000136	0.000136	11.21	0.012
Square	2	0.000135	0.0004135	0.000067	5.55	0.036
Cutting speed*cutting speed	1	0.000059	0.000108	0.000108	8.93	0.020
Feed*feed	1	0.000076	0.000076	0.000076	6.26	0.041
Interaction	1	0.000121	0.000121	0.000121	9.98	0.016
Cutting speed*feed	1	0.000121	0.000121	0.000121	9.98	0.016
Residual error	7	0.000085	0.000085	0.000012		
Lack of fit	3	0.000055	0.000055	0.000018	2.44	0.205
Pure error	4	0.000030	0.000030	0.000007		
Total	12	0.001029				

DOF = Degree of freedom.
Seq SS = Sequential sum of square.
Adj SS = Adjusted sum of square.
Adj MS = Adjusted mean square.
F = the value of fisher test.
P = the probability value.

ANOVA examines some process factors which are necessary to cause effect on the performance characteristics. This analysis gives necessary parameters and its performance in controlling the response of machining in dimensional accurateness.

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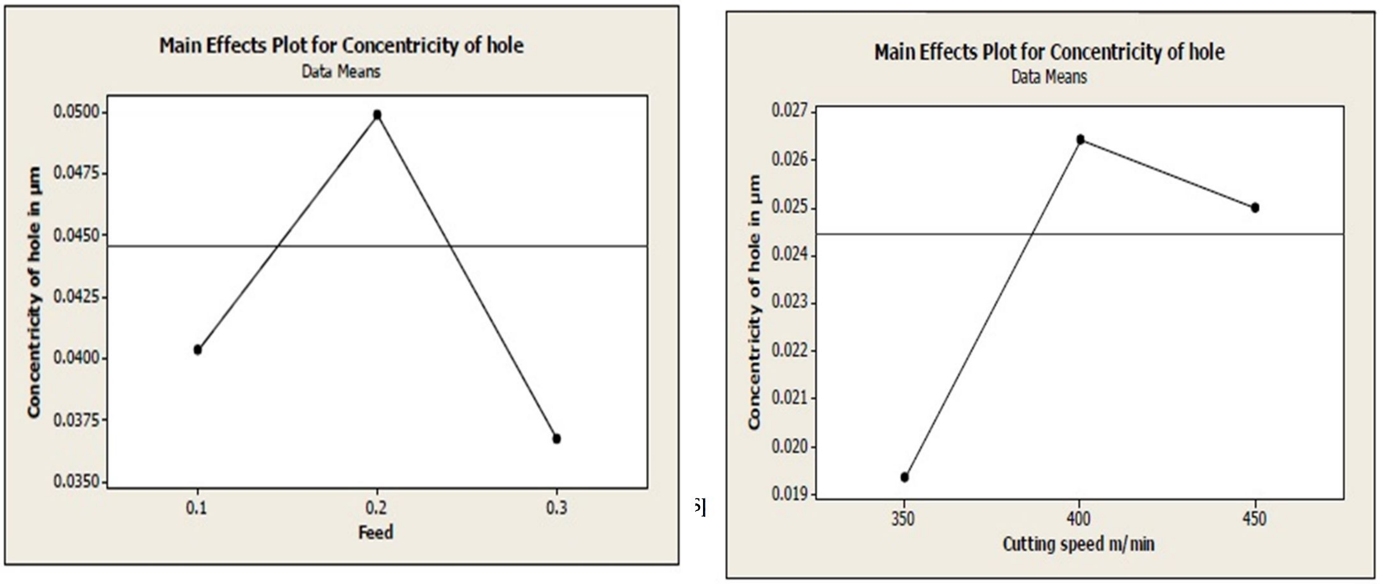
C. Plot

Plot refers to the sequence of events inside a story which affected other events through the principle of cause and effect

They are two types of plot

1) *Main Effect Plot:* In the style of experiments and analysis of variance, a main impact is that the impact of associate variable on a variable quantity averaging across the amount of the other freelance variables. The term is often utilized in the context of factorial design and regression models to differentiate main effects from interaction effects.

EN8 and EN31 material



2) Interaction Plot

Interaction could be a reasonable action that happens as two or more objects have an impact upon each other. The idea of a two-way impact is important within the concept of interaction, as against unidirectional causative impact. A closely connected term is interconnectivity, which deals with the interactions among system combinations of many straightforward interactions that cause surprising emergent phenomena. Interaction is totally different tailored meanings innumerous sciences.

EN8 and EN31 material

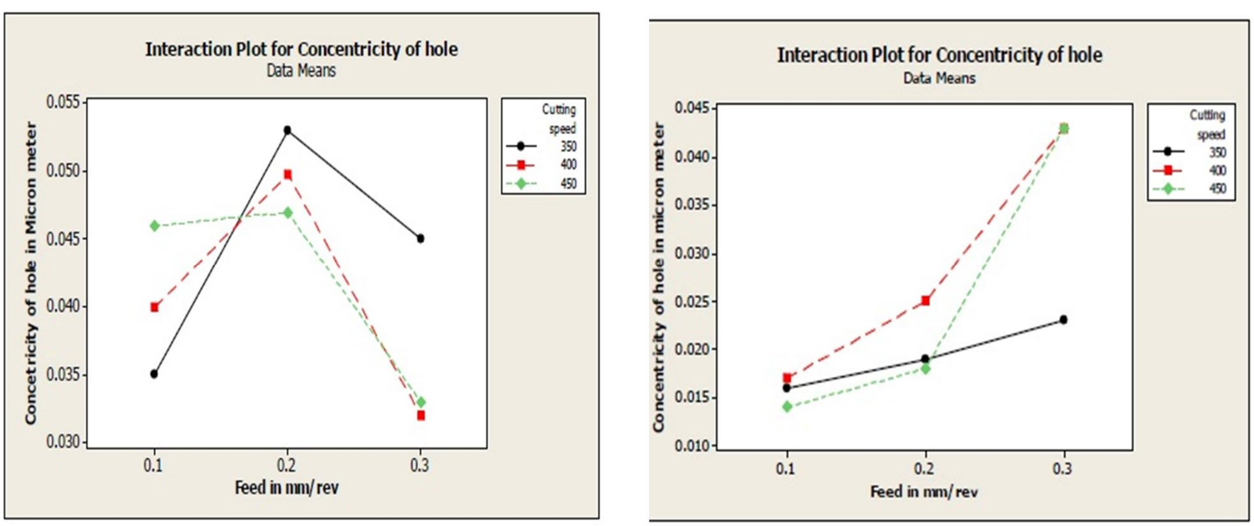


Fig-5.4.2:- Interaction plot for concentricity of hole v/s cutting speed and feed

VI. CONCLUSION

A. By this experiment observation it gives the best parameter for the concentricity of hole for EN8 material when cutting speed is 400m/min and feed rate is 0.3mm/rev respectively.

B. EN31 material also shows better parameters for cutting speed 450m/min and feed rate 0.1mm/rev. This material is harder compared to EN8 materials.

C. Here referring the design matrix and obtaining best input parameters and it's effects on the dimensional accuracy, it also gives best dimensional accuracy.

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