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Empirical modeling of cylindricity in turning operation of 20MNCR5 using response surface method

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Abstract

20MNCR5 is widely used material in gear manufacturing industries. Turning is the major metal removal process in gear manufacturing. Quality of turned surface is specified by many characteristics. One of them is cylindricity. Lower the value of cylindricity, higher will be the quality. The empirical model for the cylindricity is prepared in this study. Here response surface method is employed to prepare empirical model. The machining parameters are spindle speed, feed rate, depth of cut. The empirical model will help to find out the value of the quality i.e. cylindricity at different machining parameters.

***Keywords** - 20MNCR5; machining parameters; turning, empirical model; response surface method; Design Expert8.*

I. INTRODUCTION

To increase the productivity and the quality of the machined parts are the main challenges of metal-based industry. There has been increased interest in monitoring all aspects of the machining process. Quality of machining (turning) can be judged by surface roughness, cylindricity and circularity. Lower the values of surface roughness, cylindricity and circularity, higher will be the quality. Surface roughness, cylindricity and circularity depend on (1) Cutting speed (2) Depth of cut (3) Feed mostly. Speed, Feed and Depth of cut are the parameters that can be adjusted in machining operation. Most of the operators use trial and error method to find the appropriate cutting condition. The empirical model of quality is useful to predict the quality value at specified combination of machining parameters. The empirical model of surface roughness, cylindricity and circularity can be prepared using response surface method. This study focused on quality parameter “cylindricity”. Cylindricity is a surface form control. It simultaneously limits the allowed out of roundness, straightness and taper a surface may experience. The work piece material in our study is 20MNCR5 which has many applications in industries. It is generally used in gear manufacturing industries. So it is important to know the machining behavior of 20MNCR5.

II. LITERATURE REVIEW

Lin et al used an abdicative network to construct a prediction model for surface roughness and cutting force. The surface roughness and cutting force could be predicted by using cutting speed, feed rate and depth of cut by this network. The second prediction model was also prepared by using Regression analysis for surface roughness and cutting force. The adductive network was found more accurate than that by regression analysis [1]. Feng and Wang investigated for the prediction of surface roughness in finish turning operation by employing data mining techniques, nonlinear regression analysis with logarithmic data transformation. The working parameters were work piece hardness (material), feed, cutting tool point angle, depth of cut, spindle speed and cutting time [2]. Suresh et al (2002) have developed a surface roughness prediction model by using Response Surface Methodology (RSM). Genetic algorithms (GA) is used to optimize the objective function and compared with RSM results [3]. Pal and Chakraborty et al (2005) focused on development of a back propagation neural network model for prediction of surface roughness in turning operation [4]. Doniavi et al (2007) used response surface methodology (RSM) in order to develop empirical model for the prediction of surface roughness [5]. Nitin agarwal (2012) has prepared surface roughness model with machining parameter in CNC milling [6].

III. RESPONSE SURFACE METHODOLOGY (RSM)

Response surface methodology (RSM) is a collection of techniques for application where a response of interest is influenced by several variables and the objective is to optimize this response. General approach was developed in early 1950s and applied in the chemical industry has found application in settings such as semiconductor and electronics manufacturing, machining, metal cutting, and joining processes.

RSM is a sequential procedure. Often, when one is at a point on the response surface that is remote from the optimum then once the region of the optimum found, a more elaborate model, such as the second order model, may be employed, and an analysis may be performed to locate the optimum. The eventual objective of RSM is to determine the optimum operating conditions for the system or to determine a region of the factor space in which operating requirements are satisfied.

IV. CYLINDRICITY

To Cylindricity is a surface form control. It simultaneously limits the allowed out of roundness, straightness and taper a surface may experience. The tolerance given in the feature control frame is considered radial (or per side), therefore a Cylindricity tolerance of 0.007 is able to protect against any pits or bumps larger than 0.007 but may allow bumps of 0.007 to oppose one another at 180° points on a cylinder surface. Cylindricity is a geometric control similar in many ways to circularity. Both circularity and cylindricity are radial controls to be considered always regardless of feature size. For circularity checks, a probe will contact the work piece at different cross sections during separate 360° rotations. For Cylindricity, the probe will move axially during 360° rotations.

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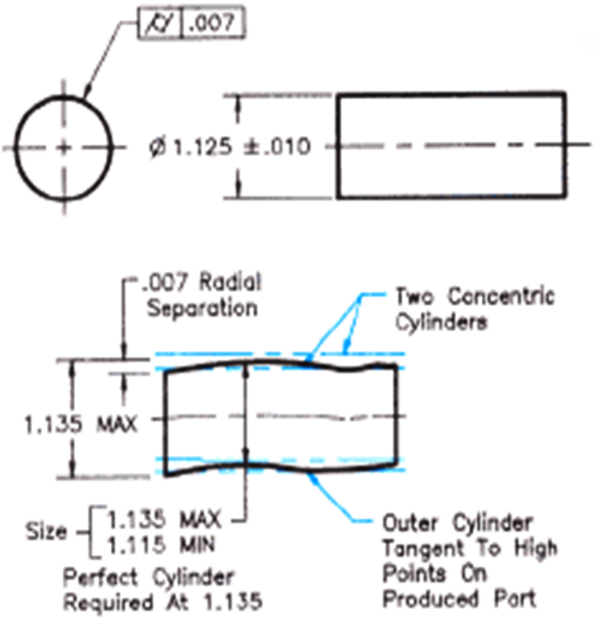

Figure 1. Cylindricity

V. PLAN OF EXPERIMENT

According to the scope and objectives the present study has been done through the Following Plan of experiment.

A) Cutting bar to the desired size by power saw and make the pieces ready for turning.

B) Checking and preparing the CNC ready for performing the machining operation.

C) Performing straight turning operation on specimens in various combinations of input parameters like: cutting speed, feed and depth of cut.

D) Measuring cylindricity with the help of CMM.

VI. EXPERIMENTAL DETAIL

- WORK PIECE MATERIAL: 20MNCR5 Φ-25 MM, L = 100 MM,
- INSERT USED: DNMG 150408 MA UE6110
- MACHINE TOOL: CNC LX-200 SUPER.
- CYLINDRICITY MEASUREMENT: CMM
- OPERATION: TURNING.

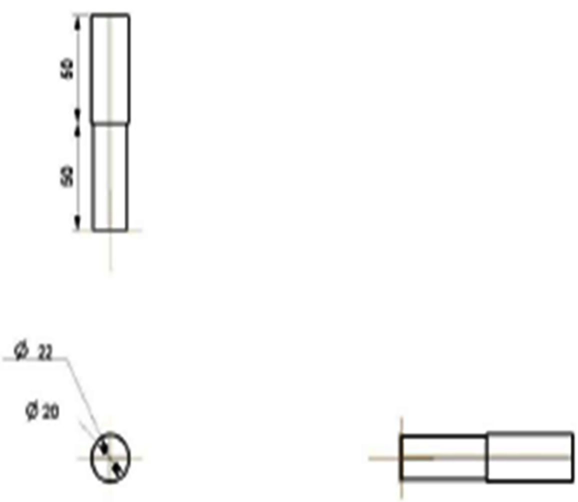

Figure 2. Dimensions of work piece

Figure 3. Actual Work piece

VII. EXPERIMENT PROCEDURE

Response surface method with central composite method is used to prepare the prediction model for cylindricity. There are 3 variables speed, feed and depth of cut and each variable are at 3 levels. Process parameters and their levels are mentioned below.

	Level		
Parameters	1	2	3
Speed (A)	800	1000	1200
Feed (B)	200	400	500
Depth of cut (C)	0.25	0.5	0.75

Table 1. Process parameters and their levels

For each combination of parameters 1 experiment is performed and cylindricity is measured with CMM. The details are presented below. The values given for cylindricity are in mm.

Sr No	S	F	D	Y (mm)
1	0	1.6817928	0	0.039
2	-1	-1	1	0.022
3	-1.6817928	0	0	0.021
4	0	0	0	0.035
5	0	0	0	0.036
6	0	0	0	0.033
7	1	1	1	0.047
8	0	0	0	0.037
9	0	0	-1.6817928	0.031
10	1	1	-1	0.035
11	1.6817928	0	0	0.041
12	-1	-1	-1	0.021
13	1	-1	-1	0.023
14	-1	1	-1	0.031
15	0	0	0	0.035
16	0	-1.6817928	0	0.021
17	1	-1	1	0.037
18	-1	1	1	0.034
19	0	0	0	0.034
20	0	0	1.6817928	0.037

Table 2. CCD for Cylindricity

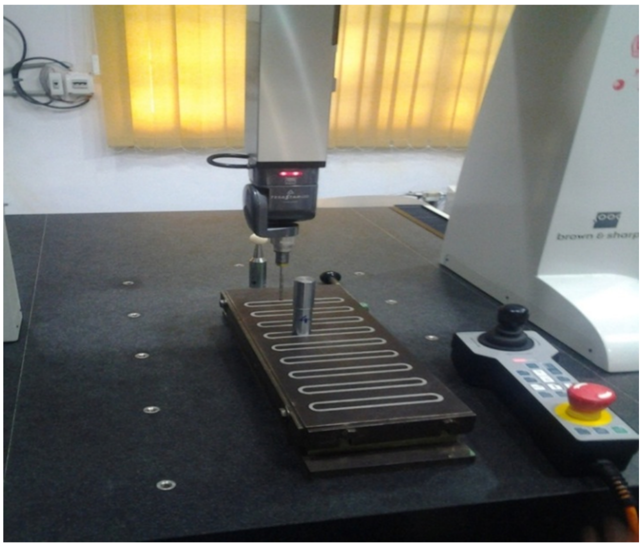

Figure 3. Arrangement of cylindricity measurement using CMM

After performing experiments prediction model is prepared using Design Expert software. Here Design Expert8 is used to prepare prediction model of cylindricity for turning operation.

VIII. RESULTS AND DISCUSSION

The Model F-value of 31.78 implies the model is significant. There is only 0.01% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.05 indicate model terms are significant. In this case speed, feed, depth of cut, speed*depth of cut, speed* speed, feed* feed are significant model terms. Values greater than 0.1 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

The "Lack of Fit F-value" of 2.46 implies the Lack of Fit is not significant relative to the pure error. There is a 17.32% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good and we want the model to fit.

- Std. Dev. 1.859E-003
- R-Squared 0.9662
- Mean 0.033
- Adj R-Squared 0.9358
- C.V. % 5.72
- Pred R-Squared 0.8005
- PRESS 2.041E-004
- Adeq Precision 20.295

The "Pred R-Squared" of 0.8005 is in reasonable agreement with the "Adj R-Squared" of 0.9358. "Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 20.295 indicates an adequate signal. This model can be used to navigate the design space.

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	0.000988437	9	0.000109826	31.77616002	< 0.0001	significant
A-A	0.000334968	1	0.000334968	96.91656867	< 0.0001	
B-B	0.000403927	1	0.000403927	116.8684936	< 0.0001	
C-C	0.00011769	1	0.00011769	34.05121032	0.0002	
AB	0	1	0	0	1.0000	
AC	0.0000605	1	0.0000605	17.50451528	0.0019	
BC	0	1	0	0	1.0000	
A^2	3.06969E-05	1	3.06969E-05	8.881546031	0.0138	
B^2	4.73707E-05	1	4.73707E-05	13.70581662	0.0041	
C^2	2.29212E-06	1	2.29212E-06	0.663180308	0.4344	
Residual	3.45625E-05	10	3.45625E-06			
Lack of Fit	2.45625E-05	5	4.9125E-06	2.456251089	0.1732	not significant
Pure Error	0.00001	5	0.000002			
Cor Total	0.001023	19				

Table 3. ANOVA for Cylindricity

IX. CONCLUSIONS

Response surface method is suitable to prepare the prediction model for cylindricity.

Final Equation in Terms of Coded Factors:

R1 =	+0.035	
	+4.953E-003	* A
	+5.438E-003	* B
	+2.936E-003	* C
	+0.000	* A * B
	+2.750E-003	* A * C
	+0.000	* B * C
	-1.459E-003	* A^2
	-1.813E-003	* B^2
	-3.988E-004	* C^2

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