International Journal of Scientific Research in Science, Engineering and Technology
Print ISSN: 2395-1990 | Online ISSN : 2394-4099 (www.ijsrset.com)
doi : https://doi.org/10.32628/IJSRSET2310381

The Surface Roughness Model When Turning of 1066 Steel by TiC Insert

Do Thi Kim Lien[1], Nguyen Dinh Man[2], Phung Tran Dinh¬[1], Nguyen Duy Chien[1]
[1]Faculty of Mechanical Engineering, Viet Hung Industrial University, Vietnam
[2]Faculty of Mechanical Engineering, Thai Nguyen University of Technology, Vietnam

ARTICLEINFO

Article History:

Accepted: 10 May 2023
Published: 29 May 2023

Publication Issue
Volume 10, Issue 3
May-June-2023

Page Number
274-279

ABSTRACT

Surface roughness (SR) is a very important parameter to evaluate the quality of a machining process in mechanical production. The construction of the surface roughness
model during the machining process will be the basis for predicting the surface roughness for each specific case. The construction of a surface roughness model when turning of 1066 steel was done in this study. An experimental process was performed with a total of fifteen experiments. These fifteen experiments have been designed according to a Box-Behnken matrix. In each experiment, the values of three parameters were changed, including cutting speed (V), feed rate (S), and depth of cut (t). Surface roughness values were also measured at each experiment and then a surface rouhness model was built. This model demonstrates the mathematical relationship between surface roughness and three cutting parameters. A second surface roughness model was also established using the Box-Cox transformation. The accuracy of these two models was compared through three parameters including coefficient R2, R2(pred), and R2(adj). The results show that all three parameters of the second model are better than the first model. In other words, the accuracy of the surface roughness model has been improved through the use of Box-Cox transformation to convert the data.

Keywords: 1066 steel turning, surface roughness, Box-Cox conversion, TiC cutting tool.

I. INTRODUCTION

1066 steel is steel manufactured to United States standards. This type of steel has the advantage of high wear resistance and is used a lot to make parts with high requirements for wear resistance such as parts in the cement industry, thermoelectricity, sliding plates, etc., etc [1]. Thanks to advances in materials science, from assessing properties to improving those properties, this steel is increasingly used to make high-quality parts. Parts with high requirements for quality often need to be finished with some surfaces to be assembled with other parts. Therefore, ensuring these mounting surfaces have a small roughness is often a requirement when processing this steel. However, the number of published studies on surface roughness in particular, and on the processing processes of this steel is quite small. Searching for related articles, the authors of this article can only list some recent studies when processing this material such as research on surface roughness when surface grinding [2], study on surface roughness and machining productivity when external grinding [3], investigating the change in hardness of surface layer when grinding [4-7], evaluating cutting force when milling [8], and investigate the phenomenon of hardening of the surface layer when machining EDM (Electrical Discharge Machining) [9]. The absence of published studies on turning of this material is the primary reason why this research needs to be carried out.

To evaluate a turning process, one or more different criteria can be used. Surface roughness is the most commonly used parameter to evaluate turning processes. The reason for this is that surface roughness has a direct influence on the wear resistance, fatigue strength, and chemical corrosion resistance of the product surface [10]. In addition, measuring surface roughness during the experiment is also easier than measuring other parameters such as cutting force, cutting heat, etc. [11]. When studying surface roughness during turning process, a commonly used method is to build surface roughness models. Surface roughness modeling is the basis for predicting surface roughness under specific conditions. However, the accuracy of the prediction results depends on the accuracy of the surface roughness model.Therefore, it is necessary to improve the accuracy of the model. This is also the second reason to improve the accuracy of the surface roughness model in this study.

II. TURNING PROCESS EXPERIMENT

The steel used in the test is 1066 steel. The test steel samples have lengths and diameters of 150 mm and 25 mm respectively. Before testing, the steel samples were heat treated to a hardness of 56HRC. The percentages by mass of the major chemical elements in the steel that have been analyzed by spectrophotometer have the values shown in Table 1

Table 1. Chemical composition of 1066 steel

Element	C	Si	Mn	P	S	Cr	Ni
%	0.64	0.22	1.05	0.003	0.003	0.18	0.31

The cutting tool used during the experiment was a TiC-coated insert. This type of insert is commonly used in the turning process [12]. Some parameters of the insert such as the front angle is 14^0, the back angle is 9^0, and the nose radius is 0.2 mm.

A 10% emulsion solution was used for cooling during the experiment. This solution is introduced into the cutting zone at a flow rate of 12 l/min.

Surface roughness was measured with the SJ201 gauge. The experimental matrix was designed in the Box-Behnken form. This is the most commonly used matrix form to build the relationship between input parameters and output parameters [13]. The values of the three cutting parameters were changed in each experiment. Three cutting parameters were mentioned in this study including cutting speed, feed rate, and depth of cut. These are three parameters that can be adjusted quickly by the operator of the machine [14]. Each parameter has been selected with three levels of values corresponding to the three encoding levels -1, 0, and 1. The values of the parameters have been selected at each level as shown in Table 2.

Table 2. Values of cutting parameters at levels

Parameter	Unit	Code symbol	Actual symbol	Value at levels		
				–1	0	1
Cutting speed	m/min	A	V	160	200	240
Feed rate	mm/rev	B	S	0.2	0.4	0.6
Depth of cut	mm	C	t	0.2	0.3	0.4

The experimental matrix was built according to the Box-Behnken method with fifteen experiments as shown in Table 3.

Table 3. Matrix of experiments

Trial.	Code value			Actual value			SR (μm)
	A	B	C	V (m/min)	S (mm/rev)	t (mm)	
1	-1	0	-1	160	0.4	0.2	1.400
2	1	0	-1	240	0.4	0.2	2.329
3	-1	1	0	160	0.6	0.3	0.966
4	1	1	0	240	0.6	0.3	1.554
5	0	1	1	200	0.6	0.4	1.171
6	0	0	0	200	0.4	0.3	0.887
7	-1	0	1	160	0.4	0.4	0.871
8	1	0	1	240	0.4	0.4	1.378
9	0	0	0	200	0.4	0.3	0.885
10	0	-1	1	200	0.2	0.4	0.788
11	0	0	0	200	0.4	0.3	0.883
12	0	-1	-1	200	0.2	0.2	1.097
13	0	1	-1	200	0.6	0.2	1.503
14	-1	-1	0	160	0.2	0.3	0.798
15	1	-1	0	240	0.2	0.3	1.097

The experimental process was carried out according to the sequence of experiments as shown in Table 3. Surface roughness (SR) in each experiment was also summarized in Table 3.

Minitab 16 software is used to analyze experimental data in Table 3. The surface roughness model is built in Eq. (1).

$$SR = 0.8850 + 0.2903A + 0.1767B - 0.2651C + 0.2867A^2 - 0.0680B^2 + 0.3227C^2 - 0.0722AB - 0.1055AC - 0.0057BC \quad (1)$$

The three coefficients used to evaluate the accuracy of the regression model are R^2, R^2(pred), and R^2(adj). The closer these coefficients are to 1, the more accurate the regression model is claimed to be [13]. Eq. (1) has the coefficients R^2, R^2(pred) and R^2(adj) of 94.55%, 12.79%, and 84.74%, respectively. Thus, it can be seen that the coefficient R^2 has a rather high value, but the other two coefficients have a small value, especially the coefficient R^2(pred) has a very small value. This shows that if Eq. (1) is used to predict surface roughness, the predicted results will be much different from the experimental results. Therefore, to improve the accuracy of using the regression model to predict the surface roughness, it is necessary to improve its accuracy. This content will be implemented shortly.

III. IMPROVE THE ACCURACY OF THE SURFACE ROUGHNESS MODEL

In this study, the Box-Cox transformation method will be used to improve the accuracy of the surface roughness model. The condition to perform the Box-

Cox transformation is the set of surface roughness values when the experiment is not distributed according to the normal distribution [13]. Therefore, checking the distribution rules of the set of surface roughness values when testing is necessary. Figure 2 shows the distribution of surface roughness values when testing.

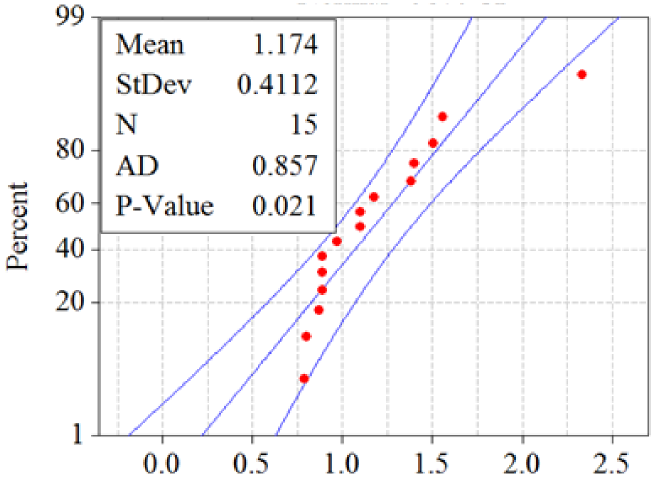

Figure 2. Probability plot of surface roughness

In Figure 2, the red dots represent the surface roughness values, the straight line represents the center of the normal distribution, and the two side curves represent the limits of the normal distribution. We see that there are red dots located far away from the line, even red dots are outside the limits of the normal distribution. It proves that the set of surface roughness values is not distributed according to the normal rule. On the other hand, a probability P-value of 0.021 is smaller than the significance level (normally the significance level is chosen to be 0.05). This also confirms that the set of surface roughness values is not normally distributed. That is, the surface roughness dataset is eligible to perform the Box-Cox transformation.

Figure 3 is a diagram of the Box-Cox transformation. We find that the lambda conversion coefficient (λ) is equal to -1.00, which means that the relationship between the surface roughness before and after the transformation is represented by Eq. (2).

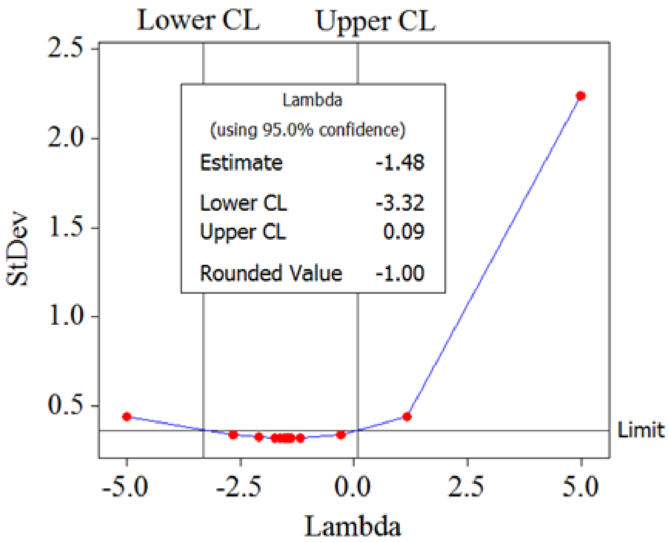

Figure 3. Box-Cox transformation model of surface roughness

$$SR' = (SR)^{\lambda} = \frac{1}{SR} \quad (2)$$

Where: SR and SR' are the values of surface roughness before and after Box-Cox conversion, respectively. In Table 3, surface roughness values are summarized before and after the Box-Cox conversion.

Table 3. Surface roughness values before and after Box-Cox conversion

Trial.	SR (μm)	SR' (dimensionless)
1	1.400	0.714
2	2.329	0.429
3	0.966	1.035
4	1.554	0.644
5	1.171	0.854
6	0.887	1.127
7	0.871	1.148
8	1.378	0.726
9	0.885	1.130
10	0.788	1.269
11	0.883	1.133
12	1.097	0.912
13	1.503	0.665
14	0.798	1.253
15	1.097	0.912

The surface roughness data set after the Box-Cox transformation is checked again for its distribution rule. The test results are shown in the chart in Figure 4.

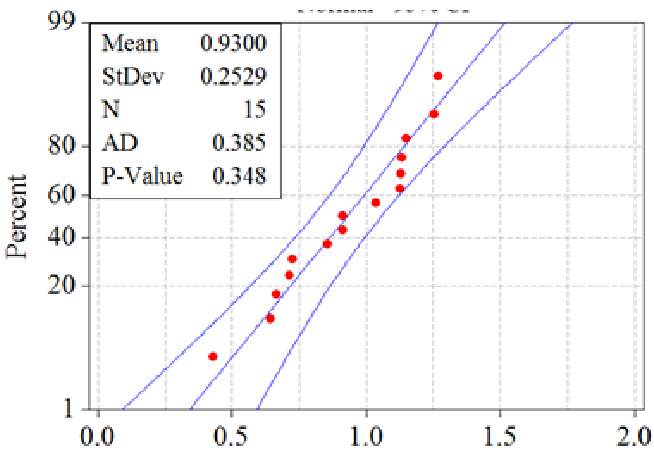

Figure 4. Box-Cox transformation model of surface roughness after Box-Cox transformation

Looking at Figure 4, we see that all the red dots are within the limits of the distribution law. In other words, the data set after the Box-Cox transformation is distributed according to normal rules. The probability P-value of 0.348 is much larger than the significance level. This also confirms that this data set has a normal distribution.

From the data set of surface roughness after Box-Cox transformation, an equation like in Eq. (3) has been built.

$$SR' = 1.1299 - 0.1800A - 0.1434B + 0.1595C - 0.1698A^2 + 0.0007B^2 - 0.2057C^2 - 0.0125AB - 0.0343AC - 0.0422BC \quad (3)$$

Combining (2) and (3) we get the surface roughness model as Eq. (4):

$$SR = \begin{bmatrix} 1.1299 - 0.1800A - 0.1434B + 0.1595C - 0.1698A^2 \\ +0.0007B^2 - 0.2057C^2 - 0.0125AB \\ -0.0343AC - 0.0422BC \end{bmatrix}^{-1} \quad (4)$$

Eq. (4) has the coefficients R2, R2(pred) and R2(adj) of 99.09%, 85.42%, and 97.44%, respectively. These values are all very close to 1, which proves that Using Eq. (4)to predict surface roughness will ensure high accuracy. The quantities R^2, R^2(pred), and R^2(Adj) of two models (1) and (4) have been summarized in Table 4

Table 4. Some parameters of surface roughness models

Model	R^2	R^2(pred)	R^2(Adj)
Without transformation	94.55%	12.79%	84.74%
Using Box-Cox transformation	99.09%	85.42%	97.44%.

According to the data in Table 4, all three coefficients R2, R^2(pred), and R^2(Adj) of the model using Box-Cox transformation are larger than those of the model without data transformation. That proves that the model using the Box-Cox transformation has higher accuracy than the other model. In other words, improving the accuracy of the surface roughness model has been successfully implemented in this study.

IV. CONCLUSION

Building a regression model showing the relationship between input parameters and output parameters is a commonly used method in experimental research in general and in the field of machine building in particular. These regression models are often used to predict output parameters for certain values of input parameters. However, the accuracy of the prediction results depends a lot on the accuracy of the built regression model. Therefore, in order to improve the accuracy of the prediction results, it is imperative to improve the accuracy of the regression model. This work was carried out in this study when building a regression model of surface roughness in the 1066 steel hardening test. Box-Cox data transformation was used to perform this task. Accordingly, the surface roughness model when using the Box-Cox transformation has higher accuracy than the model not using the data transformation. This success makes the surface roughness prediction more accurate.

V. REFERENCES

[1]. R. A. Vorob'ev, V. N. Dubinskii, Comparison of the Influence of Heat Treatment and Magnetic-Pulse Treatment on the Mechanical Characteristics of 65G Steel upon Instrumental Indentation , The Physics of Metals and Metallography, 2015, Vol. 116, No. 11, pp. 1159–1164

[2]. D. D. Trung, Influence of Cutting Parameters on Surface Roughness in Grinding of 65G Steel, Tribology in Industry, Vol. 43, No. 1 (2021) 167-176, DOI: 10.24874/ti.1009.11.20.01

[3]. D. D. Trung, The combination of TAGUCHI – ENTROPY – WASPAS - PIV methods for multi-criteria decision making when external cylindrical grinding oF 65G steeL, Journal of Machine Engineering, 2021, Vol. 21, No. 4, 90–105, https://doi.org/10.36897/jme/144260

[4]. J. D. Liu, G. C. Wang, B. L. Wang, K. M. Chen, Study on the Formation of Grind-hardening of Steel AISI 1066, Key Engineering Materials, vol. 329, pp. 57-62, 2017, doi: 10.4028/www.scientific.net/KEM.329.57

[5]. L. Judong, Y. Wei, H. Songwei, X. Zhilong, Experimental Study on Grinding-hardening of 1060 Steel, Energy Procedia, vol. 16, pp. 103 – 108, 2012, doi: 10.1016/j.egypro.2012.01.019

[6]. J. Z. Zhuang, J. D. Liu, Y. Z. Zhang, Study on Depth and its Uniformity of 65Mn Steel Grind-Hardened Layer, Key Engineering Materials, vol. 487, pp. 94-98, 2011, doi: 10.4028/www.scientific.net/KEM.487.94

[7]. J. D. Liu, G. C. Wang, Z. Wang, S. T. Fan, Experimental Research on Grind-Hardening of 65Mn Steel, Materials Science Forum, vol. 505-507, pp. 787-792, 2006, doi: 10.4028/www.scientific.net/MSF.505-507.787

[8]. J. Liu, J. Zhuang, J. Xiong, Study on Grinding Force of Grind-Hardening Based on Orthogonal Experimental Method, International Conference on Mechanic Automation and Control Engineering (MACE), pp. 1676-2678, 2011, doi: 10.1109/MACE.2011.5987277

[9]. S. N. Sharifullin, I. A. Fayzrakhmanov, N. R. Adigamov, R. R. Akhmetzyanov, R. R. Shaykhutdinov, R. M. Lyadov, V. A. Shustov, A. T. Bayniyazova, Some characteristics of surface hardening of steel 65G in the electric-spark method, IOP Conf. Series: Journal of Physics: Conf. Series 1328 (012100), 2019, doi:10.1088/1742-6596/1328/1/012100

[10]. M. H. El-Axir, M. M. Elkhabeery, M. M. Okasha, Modeling and Parameter Optimization for Surface Roughness and Residual Stress in Dry Turning Process, Technology & Applied Science Research, 7(5), 2017, 2047-2055, https://doi.org/10.48084/etasr.1560

[11]. S. N. Hong, U. V. T. Nhu, Multi-objective Optimization in Turning Operation of AISI 1055 Steel Using DEAR Method, Tribology in Industry, Vol. 43, No. 1 (2021) 57-65, DOI: 10.24874/ti.1006.11.20.01

[12]. D. D. Trung, Application of TOPSIS and PIV methods for multi-criteria decision making in hard turning process, Journal of Machine Engineering, 2021, Vol. 21, No. 4, 57–71, https://doi.org/10.36897/jme/142599

[13]. A. Dean, D. Voss, D. Draguljić, Design and Analysis of Experiments - Second Edition, Springer, 2007.

[14]. D. D. Trung, Effect of cutting parameters on the surface roughness and roundness error when turning the interrupted surface of 40X steel using HSS-TiN insert, Applied Engineering Letters Vol.7, No.1, 1-9 (2022), https://doi.org/10.18485/aeletters.2022.7.1.1

Cite this Article

Do Thi Kim Lien, Nguyen Dinh Man, Phung Tran Dinh, Nguyen Duy Chien, "The Surface Roughness Model When Turning of 1066 Steel by TiC Insert", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Online ISSN : 2394-4099, Print ISSN : 2395-1990, Volume 10 Issue 3, pp. 274-279, May-June 2023. Available at doi : https://doi.org/10.32628/IJSRSET2310381

Journal URL : https://ijsrset.com/IJSRSET2310381