Al Mukhtar Journal of Sciences
Vol (28), No. (02), Year (2013) 12-19
Omar Al Mukhtar University, Al Bayda, Libya.
National Library No.: 280/2013/Benghazi

Statistical analysis of the effect of machining parameters on the straightness error of high carbon steel turned components

Abdulmansaf A. Bouzaid[1], Farag A. M. Alwahdi[2] and Ahmad K. B. Almajri[3]

[1]*The Higher Institute for general Vocations, Derna, Libya. Email: yasadeen@yahoo.com*
[2] *Department of Mechanical Engineering, Omar Almukhtar University ,Libya. E-mail: Faragalwahdi@hotmail.com* .
[3]*The Higher Institute for general Vocations, Derna, Libya.*

DOI: https://doi.org/10.54172/mjsc.v28i2.155

Abstract

The objective of the present work is to study the effect of machining parameters on the straightness error of cylindrical parts of high carbon steel (SAE 1095) having hardness 210 BH produced in a lathe machine. The considered turning parameters that affect the straightness error are cutting speed ,feed rate and depth of cut at three levels for each parameter with two replicates of different length by diameter ratio for instance there are 3x3x3x2= 54 specimens to be machined. The straightness error are measured for each specimen and statistical analysis are carried out .The analysis of variance performed on the measured data shows that the cutting speed is the most significant factor affecting straightness error, secondly the feed rate and lastly the depth of cut. Also, the interaction cutting speed-depth of cut and cutting speed-feed rate-depth of cut affect the straightness error of the machined work piece too. The present work is provided with three dimensional surface graphs which show low straightness error at high cutting speed for each considered level of feed rate and depth of cut.

الملخص العربي

الأشكال الهندسية للقطع الميكانيكية المنتجة بواسطة عمليات التشغيل تنحرف عن الشكل الهندسي الموصوف.الشكل الهندسي للقطع المنتجة يلعب دور مهم في تلبية احتياجات المستهلك التي تتطلب الجودة وقلة التكلف وقلة الاحتكاك و

Received, April 30, 2012; accepted, Feb 24, 2013

العمر الأطول. هذا الاحتياج هو الذي يدفع الباحثين لدراسة تأثير متغيرات التشغيل مثل سرعة القطع و معدل التغذية وعمق القطع ونصف قطر حافة سكينة القطع علي أخطاء الشكل الهندسي للمنتج. يهدف هذا العمل إلي دراسة تأثير متغيرات التشغيل من سرعة القطع ومعدل التغذية وعمق القطع علي خطأ الاستقامة لعينات مصممة اسطوانية الشكل من الصلب العالي الكربون (SAE 1095) صلابته 210BH مشغولة علي المخرطة.أجريت الدراسة علي ثلاث مستويات من متغيرات القطع وكررت القياسات مرتين لتشمل نسبتين مختلفتين من طول العينة إلي قطرها ,بمعني انه هناك $3 \times 3 \times 3 \times 2 = 54$ عينة اختبار شغلت وأخذت قياساتها. تم قياس خطأ الاستقامة لكل عينة و اجري تحليل التباين لجميع القياسات المأخوذة. لقد تبين من التحليل الذي اجري علي البيانات المقاسة أن سرعة القطع لها تأثير مهم علي خطأ الاستقامة حيث ينخفض الخطأ عند التشغيل عند السرعات العالية ويأتي بعدها في الترتيب من حيث التأثير والأهمية معدل التغذية و أخيرا يأتي عمق القطع من حيث التأثير. أيضا شمل التحليل دراسة تأثير تفاعل متغيرين و ثلاثة متغيرات من متغيرات التشغيل علي خطأ الاستقامة حيث تبين أن تفاعل كل من سرعة القطع–معدل التغذية وسرعة القطع–معدل التغذية–وعمق القطع لها تأثير علي خطأ الاستقامة. زود هذا العمل برسومات سطحية ثلاثية الأبعاد تبين تأثير تفاعل متغيرات التشغيل علي خطأ الاستقامة التي يلاحظ منها انخفاض خطأ الاستقامة عند سرعة القطع العالية وانخفاض كل من معدل التغذية و/ أو عمق القطع و في الختام طرحت عناوين بحث إضافية.

Keywords *Cutting speed; Straightness error; Feed rate.*

1. Introduction

The forms obtained by machining processes deviate from the specified geometry Form geometry is important due to consumer demands for quality ,less costly product, minimum friction, minimum wear and extended operating part life. This demands condition is pushing researchers to study the effect of machining parameters such as cutting speed, feed rate, depth of cut and tool geometry among the several factors that affect machined parts geometry. The literature survey indicates that there are significant amount of research have been carried out regarding surface roughness studies and few work give significance to the form errors produced on the machined part specially which connected with the machining parameters of cutting speed, feed rate and depth of cut. Table 1. shows the general factors that affecting surface roughness. Rico et al. (2010) reported that the cutting speed and feed rate significantly affect the roundness of cylindrical component. Shouman and Bouzaid (2000) have been developed empirical formula for the evaluation of straightness and roundness errors of high carbon steel turned component as function of machining parameters and length by diameter ratio of specimen.

Table 1. Factors affecting surface roughness.

Author	Control Parameters	Significant Parameters	Operation
Risa (2011)	cutting speed, feed rate and depth	cutting speed, feed rate	turning
Asilturk (2011)	cutting speed, feed rate, depth of cut and nose radius of tool	cutting speed, feed rate, depth of cut and nose radius	turning
Rafai and Islam (2010)	cutting speed, feed rate and depth of cut	cutting speed, feed rate and depth of cut	turning
Kuzinovski et al. (2009)	cutting speed, feed rate and cutting depth	cutting speed, feed rate, force and cutting depth.	turning
Salles and Gonçalves (2003)	cutting speed, feed rate and depth of cut	feed rate	turning
Hayajneh et al. (2007)	spindle speed, feed rate and depth of cut	feed rate, interaction between feed rate and depth of cut and interaction between feed rate and spindle speed	milling

2. Machining conditions

In order to analyze the effect of the considered cutting parameters on the straightness error a three variables, three levels with two replicates of different (L/D) ratios factorial design were performed to include 54 machined specimens. All the specimens were machined on a lathe machine with one end gripped in a three jaw chuck while the other end was kept free. Table 2 shows the levels of the machining variables used in the experiment whereas Table 3. demonstrates the machining conditions used in turning the desired number of work pieces and the corresponding straightness error.

Table 2. The levels of machining parameters.

Machining parameter	Unit	Low	Medium	High
Cutting speed (v)	m/min	12	21	30
Feed rate (F)	mm/rev	0.05	0.1	0.2
Depth of cut (d)	mm	0.1	0.3	0.5

3.Straightness measurement

Straightness error is measured using Talyrond 200 System Annon (1984), where straightness graph measurement is an essential part of the system operation. The straightness of the machined surface is measured by the minimum separation of two parallel plans which just contain the surface Fig 1. Table 3. demonstrates the measured straightness error of each replicate and the corresponding machining condition.

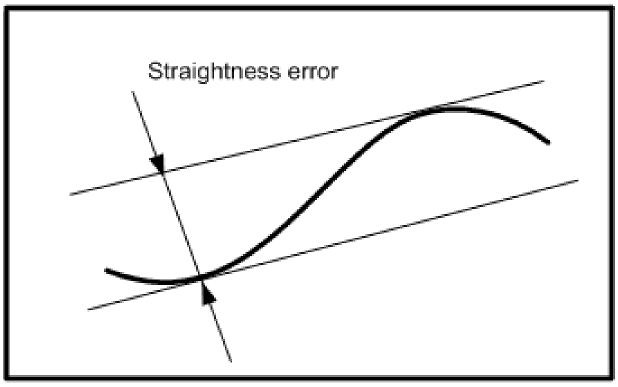

Figure 1. Assessment of straightness Error

Table 3. Machining conditions and the corresponding measured straightness error

Feed rate (mm/rev)	Cutting speed (m/min)	Depth of cut (mm)	Replicate 1	Replicate 1
0.05	12	0.1	10.06	11
0.05	21	0.1	6.47	19.19
0.05	30	0.1	3.68	3.87
0.05	12	0.3	18.86	25.65
0.05	21	0.3	3.62	3.77
0.05	30	0.3	2.75	4.03
0.05	12	0.5	6	6.84
0.05	21	0.5	4.09	5.53
0.05	30	0.5	1.87	3.68
0.10	12	0.1	10.5	11.69
0.10	21	0.1	5.03	5.53
0.10	30	0.1	2.87	3.5
0.10	12	0.3	5.12	7.12
0.10	21	0.3	4.12	5.65

Feed rate (mm/rev)	Cutting speed (m/min)	Depth of cut (mm)	Replicate 1	Replicate 1
0.10	30	0.3	2.12	4.56
0.10	12	0.5	6.69	5.18
0.10	21	0.5	4	4.12
0.10	30	0.5	2.43	5.53
0.20	12	0.1	6.62	10.28
0.20	21	0.1	4.9	5.34
0.20	30	0.1	3.75	4.15
0.20	12	0.3	13.31	6.43
0.20	21	0.3	4.35	4.31
0.20	30	0.3	3.9	4
0.20	12	0.5	7.81	6.56
0.20	21	0.5	5.59	5.78
0.20	30	0.5	2.24	4.25

4. Analysis of data

The data was analyzed using multifactor experiment analysis (Miller and Frennd 1985). Decision: For replications, since F=4.49 table 4 does not exceed 7.686, the value of $F_{0.01}$ for 2 and 27 degrees of freedom, we can reject the null hypothesis for instance the test for replications is not significant at this level, but it cannot be rejected at 0.05 level of significance since F=4.49 table 4. exceed 4.212 the value of $F_{0.05}$ at the same degrees of freedom. For the main effect of factor A (cutting speed) since F=36.38 table 4. exceeds 5.498 and also for the main effect of factor B (feed rate) since F=7.696 table 4. exceeds 5.498 the value of $F_{0.01}$ for 2 and 27 degrees of freedom the null hypothesis must be rejected for instance the tests for the effect of each main factors A and B on straightness error are significant. For the main effect of factor C (depth of cut) F=5.372 table 4. exceeds 3.362 the value of $F_{0.05}$ for 2 and 27 degrees of freedom, we can reject the hypothesis for instance the test for the main effect C is significant at 0.05 level of significance. For the interaction of main factors AB and BC since F=2.18 and F=2.619 table 4. respectively do not exceed 4.116 or 2.732 the values of $F_{0.01}$ and $F_{0.05}$ for 4 and 2 degrees of freedom, we cannot reject the null hypothesis for instance the test for interaction of AB and BC have no effect on specimens straightness. For the interaction of factors AC, since F=11.35 table 4. exceeds 4.116, the value of $F_{0.01}$ for 4 and 27 degrees of freedom, we can reject the null hypothesis for instance the test for interaction of AC are significant. For three factors interaction ABC since F=6.4 table 4. exceeds the value of $F_{0.01}$ for 8 and 27 degrees of freedom, we can reject the hypothesis for instance the test for interaction of ABC on specimens straightness is significant.

Table 4. The analysis of variance for straightness error.

Source of Variation	Degrees of freedom	Sum of squares	Mean Squares	F
Replication	1	22.471	22.471	4.49
Main effects:				
A (cutting speed m/s)	2	363.89	181.94	36.38
B (feed rate mm/rev)	2	76.97	38.48	7.696
C (depth of cut mm)	2	53.72	26.86	5.372
Two factors interaction				
AB	4	43.61	10.9	2.18
AC	4	227.06	56.765	11.35
BC	4	52.38	13.095	2.619
Three factors interaction				
ABC	8	257.86	32.235	6.4
Error	27	132.294	5	
Total	53	1055.64	-	-

The following three dimensional surface graphs were generated using Lab View 6.1 software. Fig 2.and 3 demonstrate the effect of cutting speed-feed rate and cutting speed-depth of cut respectively. These figures clearly show that low straightness error can be achieved for any level of feed rate and /or depth of cut when the cutting speed is high. On the other hand Fig 4. out lines the effect of depth of cut-feed rate on the straightness error ,according to the graph there is a slight increase in straightness error at the considered levels of depth cut and high feed rate whereas almost medium level of depth cut and low level of feed rate produce high straightness error. Also Fig 4. shows that low straightness error can be achieved at considered levels of depth of cut and high feed rate.

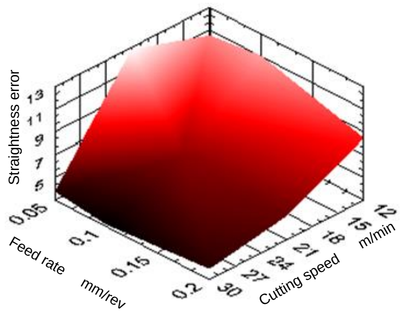

Figure 2. Surface plot of straightness error versus cutting speed and feed rate for depth of cut = 0.1.

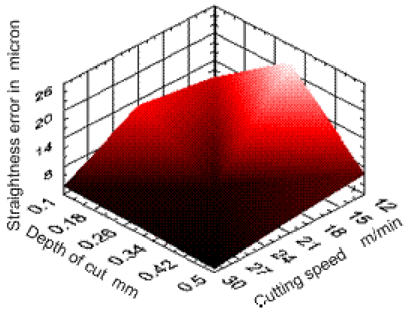

Figure 3. Surface plot of straightness error versus cutting speed and depth of cut for feed rate=0.05 mm/rev.

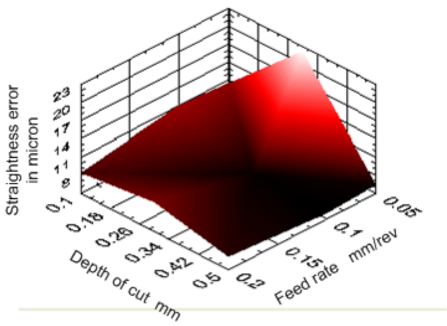

Figure 4. Surface plot of straightness error versus feed rate and depth of cut for cutting speed=12 m/min

5. Conclusions

Based on the conducted experiments and accomplished analysis the following conclusions and recommendations are obtained.

- The cutting speed is the most significant factor affecting straightness error.
- The feed rate significantly affect the straightness error.
- The interaction cutting speed- depth of cut significantly affects straightness error.
- The interaction cutting speed, feed rate, depth of cut significantly affect the straightness error.
- The effect of length by diameter ratio is significant at 0.05 level of significance.

For further work the same experiment can be conducted using different materials and different chucking method of specimen i.e. the work pieces gripped from one end and centered from the other end.

References

Asilturk, I. (2011) On-line Surface Roughness Recognition System by Vibration Monitoring in CNC Turning Using Adaptive Neuro-fuzzy Inference System (ANFIS). *International Journal of the Physical Sciences,* 6, 22, 5353-5360.

Hayajneh, T., Montasser, M., Tahat, S. and Bluhm, T.B. (2007) A Study of the Effects of Machining Parameters on Surface Roughness in the End-Milling Process. *Jordan Journal of mechanical and Industrial Engineering,* 1, 1-5.

Kuzinovski, M., Trajčevski, N. and Cichosz, P. (2009) Investigation of Cutting Forces During Machining Process by High Speed Turning. *Journal of Production Engineering*, 12, 1, 29-32.

Miller, I. and Frennd, J.E. (1985) Probability and Statistics for Engineering. *Probability_Hall inc. Englewood cliffs, 3rd Edition*.

National Instruments (1999-2001) *LabView 6.1 software*.

Rafai, N.H. and Islam, M.N. (2010) Comparison of Dry and Flood Turning in Terms of Quality of Turned Parts. *Proceedings of the World Congress on Engineering London,U.K,* 3, 2044-2049.

Rico, I., Naranjo, A., Noriega, S., Martínez, E. and Vidal, L. (2010) Effect of Cutting Parameters on the Roundness of Cylindrical Bars Turned of 1018 Steel. *International Conference on Industrial Engineering Theory, Applications and Practice, Mexico City, Mexico,* 131-136.

Risa, A. (2011) Tool Life Performances, Wear Mechanisms and Surface Roughness Characteristics When Turning Austenised and Quenched AISI 5200 Bearing Steel With Ceramics and CBN/TiC Cutting Tools. *Indian Journal of Engineering and Materials Sciences*, 18, 2, 137-146.

Salles, J.L.C. and Gonçalves, M.T.T. (2003) Effects of Machining Parameters on Surface Quality of the Ultra High Molecular Weight Polyethylene (UHMWPE). *Matéria,* 8, 1, 1-10.

Shouman, M.A. and Bouzaeid, M. (2000) Design of an Experimental Approach for the Optimization of Some Form Errors. *Alexandria Engineering journal,* 39, 1, 51-63.

Talyrond 200, Annon (1984) Operators Handbook. *Rank Taylor Hobson Ltd, 2nd edition*.