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Investigating the optimal cutting parameters for surface roughness in turning process

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ABSTRACT: This paper presents a study of the influence of cutting parameters on the surface roughness in turningPH14-8MO nickel-chromium, AISI C1040 and AISI C1020 carbon steel and 5-35-NCI gray iron using a cemented carbide insert. The experiments were a full factorial design with three cutting parameters, namely, cutting speed, feed rate and depth of cut. The selection of optimal cutting parameters has become very important issue to control the required surface quality. The Taguchi method was used to identify the optimal cutting parameters for a desired surface roughness for turning operations. Experimental data were obtained and demonstrated that the surface roughness depended on the machining parameters and material type in terms of hardness. At low cutting speeds, the relationship between surface roughness and cutting speed is positive due to the formation of built-up edge, while at high cutting speeds, an inverse relationship occurs due to the deterioration of the built-up edge. The results also demonstrate that low cutting parameter values tend to result in better surface roughness.

KEYWORDS: Hardness, surface roughness, cutting parameters, turning processes.

I. INTRODUCTION

In machining of parts, surface quality is one of the most specified customer requirements. The product quality depends highly on surface roughness as decrease of surface roughness leads to decrease of product quality. Turning machine process is one of the most commonly operations used by which metal is removed by rotating the work piece with respect to a tool. The important parameters of turning machines are; cutting speed, feed rate, depth of cut and tool geometry e.g. rake surface, clearance angle**.** Feed rate is the distance moved by the tool in an axial direction for each revolution of the work piece. Depth of cut is the thickness of metal removed from the work piece and measured in a radial direction. A large number of theoretical and experimental studies on surface roughness of machined products have been reviewed where cutting conditions such as cutting speed, feed rate, depth of cut, tool geometry, and the material properties of both the tool and work piece have a significant influence on the machined part quality [1].Surface roughness of a turned surface depends on the selection of cutting variables, such as cutting speed, feed and depth of cut [2]. K.Suleimaninvestigated the influence of the three most important machining parameters including the of depth of cut, feed rate and cutting speed on surface roughens of work piece material and concluded that the influence of cutting speed on surface roughness of work pies is small when high cutting speeds are used [3].The quality and the integrity of the finish-machined surfaces are affected by work-piece material hardness and properties. The surface roughness decreases with increasing hardness[4].A.K. Nandi found that the relationship between cutting parameters including cutting speed and depth, cutting speed and consecutive cut, and cutting material and consecutive cut were all significant [5].The value of the cutting speed at which the built–up edge will be of maximum height and the speed beginning with which there will be no built – up edge depend upon the machining conditions. According to the study conducted by A. Rosenberg and A. Yeremin, the higher the hardness of the steel being machined the larger the cutting angle of the tool and the thicker the uncut chip i.e. the higher the cutting speed at which the built – up chip disappears [6].

Thiele et al.used a set of full factorial design to determine the effects of work piece hardness on surface roughness in finish hard turning. The surface roughness of the machined parts (Ra) was recorded in Table 1 below. This parameter is known as the arithmetic mean roughness value, A (Arithmetic Average)or CLA(Centreline Average). However, Ra is widely recognized in measuring surface roughness and the most used international parameter of roughness[7].Deng reported a positive correlation between the leakage current and the surface roughness [8]. Koenig et al. also reported that an increase in feed rate results in increasing the maximum compressive residual stress and deepens the affected zone[9]. Chang-Xue (Jack) Fen illustrated an experimental study of the impact of turning parameters on surface roughness. Their results showed that in machining steel (8620) and Al (6061T), the depth of cut does not impact the surface roughness in the studied range. They further found that the productivity of work in machining some steel parts can be improved as long as depth of cut would not worsen the surface microstructure of the material; and the dimensional, and geometric accuracy [10].In this study, the influence of various parameters including cutting speed, feed rate, and depth of cut on surface roughness of the following materials :- (101HRB hardened PH14-8MO nickel-chromium alloy steel), (115HRB hardened AISI C1040 carbon steel), (95HRB hardened AISI C1020 carbon steel), and (90HRB hardened 5-35-NCI gray cast iron) were experimentally investigated .

II. EXPERIMENTAL AND RESULTS

The experimentation was carried out considering four machining parameters: Feed rate ; cutting speed; depth of cut, and hardness as independent variables, while surface roughness as dependent variable. The dataset of Independent and dependent variable was obtained on the basis of measurement. Four different material work pieces were experimentally investigated in this study, 8MO nickel-chromium alloy steel, AISI C1040 Carbon steel, AISI C1020 Carbon steel, and 5-35-NCI gray cast iron. The diameter and length of the cylindrical bar specimen used were 25 mm, and 150 mm, respectively. However, the finish turning has been executed when the specimen diameter was 16mm. The hardness tests were performed by using Rockwell type hardness tester which revealed that the actual hardness of each specimen of alloy steel was 101HRB and each specimen of carbon steel was 115HRB. The hardness values were determined by the mean values of the measured work piece hardness. The experiments were conducted on the lathe machine model SN40C, spindle power 6.6 KW. The surface roughness was measured with a Taylor- HabsonSurtronic 3Cprofilometer and Mitutoyo SJ-digital surface analyser. The surface roughness values were recorded at six equally spaced locations around the circumference every 25 mm distance from the edge of the specimen to obtain statistically meaningful data for each factor level combination.The data obtained was analysed by SPSS software and the factors and factor levels are summarized in Table 1.

Table .1. Factor levels result in a total of 16 unique factor level combinations.

	Standard Order				**Readings R_a (μ m)**				**Mean R_a (μ m)**
No.	**Material hardness HRB**	**Feed**	**Speed**	**Depth Of cut**					
	A	B	C	D	1	2	3	4	
1	-1	-1	-1	1	0.54	0.58	0.58	0.50	0.55
2	1	-1	-1	-1	4.80	4.24	3.70	4.58	4.33
3	-1	1	-1	-1	1.32	1.42	1.36	1.46	1.39
4	1	1	-1	1	1.12	1.68	1.24	1.02	1.265
5	-1	-1	-1	-1	1.14	0.88	1.00	0.88	0.975
6	1	-1	-1	1	2.44	2.98	3.68	2.28	2.845
7	-1	1	-1	1	1.36	1.88	2.24	1.18	1.665
8	1	1	-1	-1	2.66	2.28	3.04	2.48	2.615
9	-1	-1	1	-1	0.52	0.42	0.72	0.80	0.615
10	1	-1	1	1	0.68	0.70	0.68	0.62	0.67
11	-1	1	1	1	0.94	0.92	1.02	1.00	0.97
12	1	1	1	-1	0.96	0.96	0.94	0.96	0.955
13	-1	-1	1	1	0.70	1.26	1.82	1.94	1.43
14	1	-1	1	-1	0.66	0.60	0.84	0.68	0.695
15	-1	1	1	-1	1.10	1.08	1.12	1.16	1.115
16	1	1	1	1	1.18	1.22	1.42	1.44	1.315

The effects of feet rate, cutting speed and depth of cut parameters on surface roughness for three different hardness steels and gray cast iron are shown in figures1,2,3. It is noticeable that in every case, surface roughness was found to be positively correlated with the feet rate and cutting speed and depth of cut; it means when feet rate and cutting speed and depth of cut increases, surface roughness also increases. For this reason, the metal resists the rupture more and requires larger efforts for chip removal which was in line with the finding obtained by Groover 1996, p. 634 [11].Cutting speed and feed rate are often considered as pair because of their combined effect on the cutting process in which an increase in feed rate improves machine ability

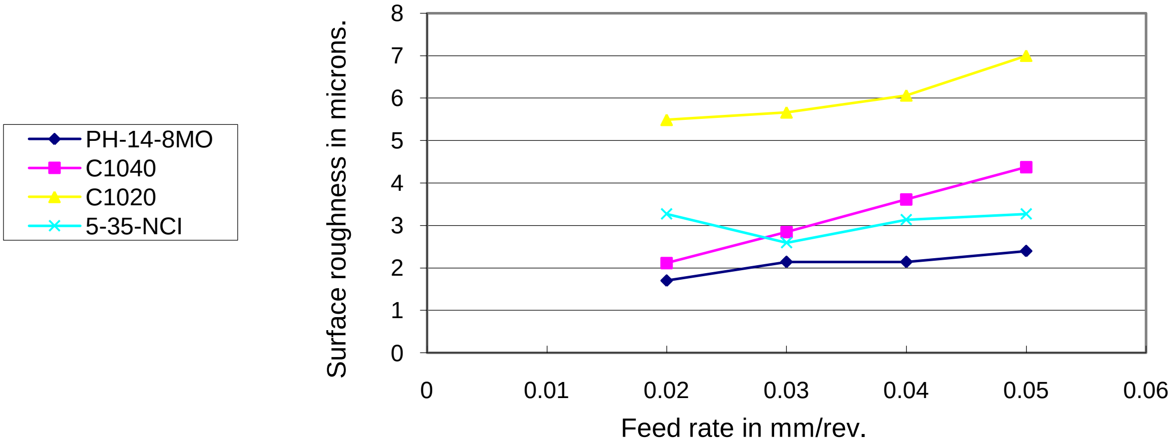

Fig.1. Effect of feed rate on surface roughness.

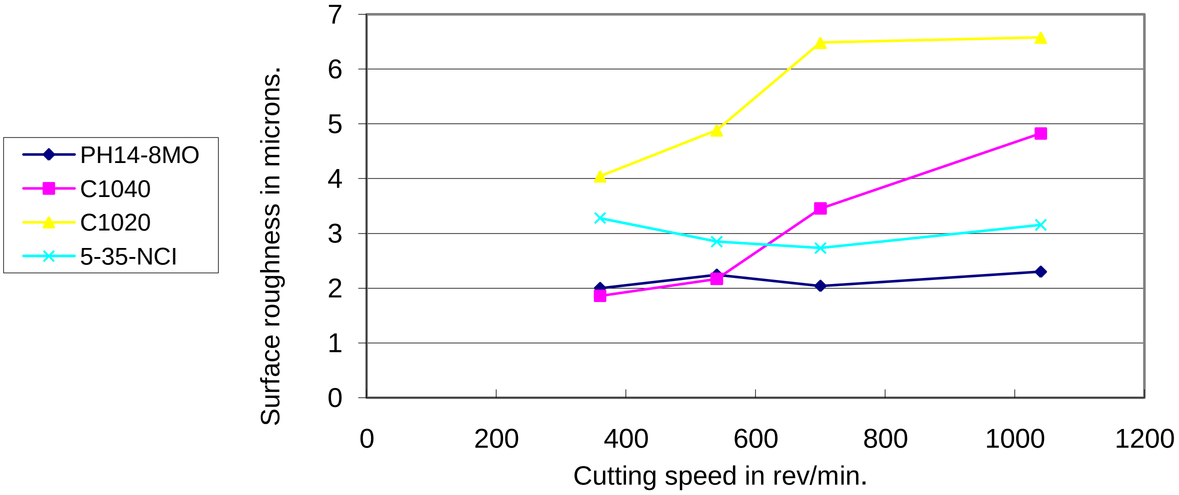

Fig.2. Effect of cutting speed (rev/min) on surface roughness.

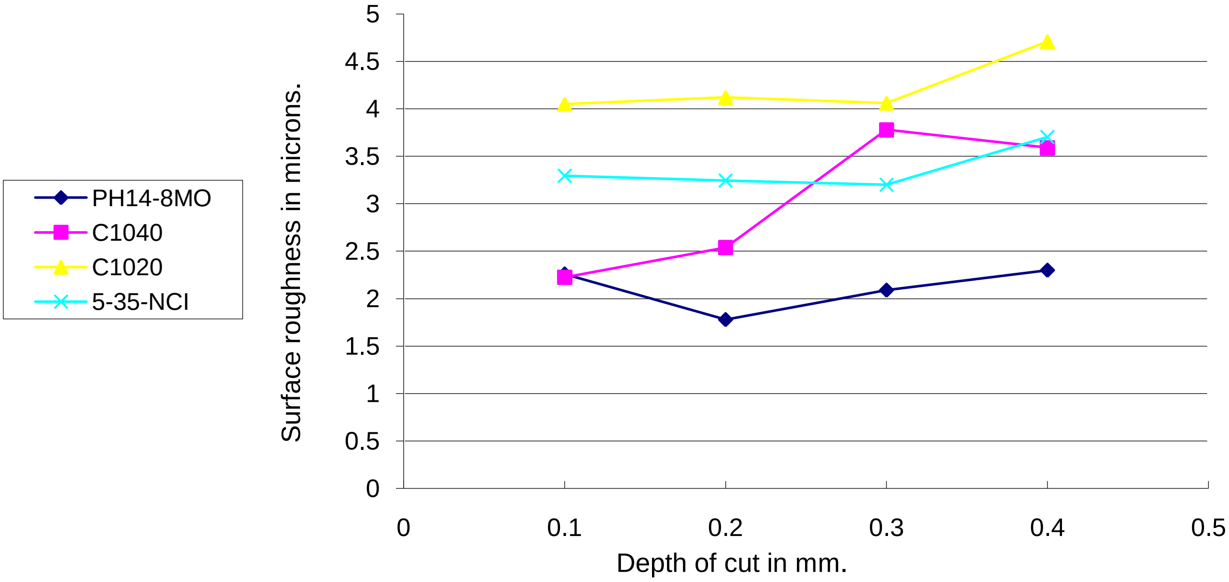

Fig.3. Effect of depth of cut (mm) on surface roughness.

The regression analysis considers all four main effects and their two-factor interaction terms. Its purpose is to determine which factors and factor interactions are statistically significant in affecting the surface roughness. It was observed that all the main factors and two-factors interactions were statistically significant apart from feed B, and three two-factor interactions AC (material X nose radius), BE (feed X d.o.c), and CD (nose radius X speed) as their standardized coefficients beta are less than 10%, when standardized coefficient is equal to correlation coefficient in this case. So, for further simplifying, second round regression is conducted after removing the mentioned. The adjusted R^2 of this regression model is only slightly reduced to 98.6% from 100% of the full model, and the ANOVA result for the regression model is satisfactory.

III - DISCUSSION

The experiments conducted in study investigated the impact of the following parameters; feed rate, depth of cut, cutting speed and hardness on surface roughness in finish turning.For all materials including PH14-8MO, AISI C1040, AISI C1020 and 5-35-NCI gray cast iron, the increase in cutting speed leads to increase in surface roughness (a positive relationship)due to the formation of built-up edge. This outcome is in line with the finding reported by V. Arshinov and G. Alekseev [6]. The effect of depth of cut on surface roughness in machining three tested materials PH14-8MO, 5-35-NCI, and AISI C1020 was not significant which in agreement with finding obtained by Chang-Xue[10]. When the depth of cut does not impact the roughness in some studied rang, such outcome could be used to improve productivity. However, in the case of machining AISI C1040 carbon steel, the effect of depth of cut is significant as the increase of depth of cut leads to correspondent increase in surface roughness. In addition, carbon steel recodes the best correlation coefficients with all the turning parameters among all the tested materials, which makes it the best choose and the easier in prediction.

The depth of cut has a positive effect on surface roughness in the case of machining PH14-8MO 101HRB nickel-chromium alloy steel, but it has a negative effect on surface roughness in the case of machining AISI C1040 115HRB carbon steel (see Fig.3.). These results are in line with results reported by Chang-Xue (Jack) Feng in relation to machining steel (8620) HRB86, and Al (6061T) HRB52 [10]. The effect of depth of cut on finish turning of both materials (95HRB hardened AISI C1020 mild steel, and 90HRB hardened 5-35-NCI gray Cast iron) is negative, but its effect on (95HRB hardened AISI C1020 mild steel (see Fig.3). Decreasing the feed rate results in better surface roughness but slightly faster tool wear development [9].The use of higher surface hardness with lower depth of cut produces a better surface finish. The effect of depth of cut on surface roughness in machining carbon steel is comparatively high, this makes it easier in prediction, and better choice, particularly when it shows good surface quality.

IV -CONCLUSION

Surface roughness has received great attention for many years. It has formulated an important design feature in many situations such as parts subject to fatigue loads, precision fits, fastener holes and aesthetic requirements. In addition to tolerances, surface roughness imposes one of the most critical constraints for the selection of machines and cutting parameters in process planning. The effect of feed rate is very high on the surface roughness. It is clearly observed from the graphics that surface roughness increases as feed rate increases, and this is generally considered to be a function of square of the feed rate. Decreasing the surface roughness will usually increase exponentially its manufacturing costs. In this study, the surface roughness resulted from finish turning of ferrous metals depended on machining parameters and material type in terms of hardness. The cutting speed and material type greatly influence the surface roughness. At low cutting speeds, the relationship between surface roughness and cutting speed is positive due to the formation of built-up edge, while at high cutting speeds, a contrary relationship occurs due to deterioration of a built-up edge. The effects of two factor-interactions of the work piece hardness and cutting speed on surface roughness are statistically significant in all types of material except the cast iron which shows very low correlation. High surface hardness and low cutting speed result in a better surface roughness (i.e. lower roughness) in machining carbon steel and cast iron in speed variation. The relationship between cutting speed and surface roughness in machining carbon steel is more significant than the case of alloy steel; this also makes it easier in prediction and better choice, particularly when it shows good surface quality.

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