Effect of spindle speed and feed rate on surface roughness of Carbon Steels in CNC turning

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Abstract

This paper investigates the effect of process parameters in turning of Carbon Alloy Steels in a CNC lathe. The parameters namely the spindle speed and feed rate are varied to study their effect on surface roughness. The experiments are conducted using one factor at a time approach. The five different carbon alloy steels used for turning are SAE8620, EN8, EN19, EN24 and EN47. The study reveals that the surface roughness is directly influenced by the spindle speed and feed rate. It is observed that the surface roughness increases with increased feed rate and is higher at lower speeds and vice versa for all feed rates.

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1. Introduction

In metal cutting and manufacturing industries, surface finish of a product is very crucial in determining the quality. Good surface finish not only assures quality, but also reduces manufacturing cost. Surface finish is important in terms of tolerances, it reduces assembly time and avoids the need for secondary operation, thus reduces operation time and leads to overall cost reduction. Besides, good-quality turned surface is significant in improving fatigue strength, corrosion resistance, and creep life.

Due to the increasing demand of higher precision components for its functional aspect, surface roughness of a machined part plays an important role in the modern manufacturing process. Turning is a machining operation, which is carried out on lathe. The quality of the surface plays a very important role in the performance of turning as a good quality turned surface significantly improves fatigue strength, corrosion resistance, or creep life. Surface roughness also affects several functional attributes of parts, such as contact causing surface friction, wearing, light reflection, heat transmission, ability of distributing and holding a lubricant, load bearing capacity, coating or resisting fatigue. Therefore, the desired surface finish is usually specified and the appropriate processes are selected to reach the required quality [1].

Surface roughness plays an important role in affecting friction, wear and lubrication of contacting bodies [2]. Surface roughness is one of the parameters that greatly influence the friction under certain running conditions [3]. Surface roughness of the contacting surfaces influences the frictional properties of those surfaces during the forming processes [4]. It is clear now that surface roughness geometry strongly influences the manner in which the contacting surfaces...
are interacting. Furthermore, it is well known that the final geometry of surface roughness is influenced by various machining conditions such as spindle speed, feed rate and depth of cut [5].

2. Literature Review:

A.B. Abdullah et al developed analytical based surface prediction technique which can be more accurate, flexible, reliable and non-destructive and then evaluate its prediction ability. The sensitivity analysis program proposed a useful computational tool to help analysis of the relation between the cutting parameter and surface roughness of machined surfaces without embarking on laborious time consuming and often expensive machining trials. The sensitivity results showed that the feed rate is the most important cutting parameter for determining the machined surface roughness Ra, when end milling aluminum platen [6].

C. Natarajan et al worked on a number of brass specimen C26000 material which were machined in a CNC turning machine in dry cutting condition and then a TIME TR 100 surface roughness tester was used to measure the roughness average (Ra) values of all the specimens. They concluded that considering the individual parameters, feed rate had been found to be the most influencing parameter on surface roughness, followed by spindle speed and depth of cut [7]. Mohammed T. Hayajneh et al performed a set of experiments on aluminium samples to study the effects of machining parameters on the surface roughness in the end milling process. The study developed a better understanding of the effects of spindle speed, cutting feed rate and depth of cut on the surface roughness. The machining parameters investigated influenced the surface finish of the machined workpiece significantly. The study showed that the cutting feed is the most dominant factor of those studied [8].

Deepak Mittal et al investigated the effect of process parameters in turning of Titanium grade 2 on conventional lathe. Three parameters namely spindle speed, depth of cut and feed rate were varied to study their effect on material removal rate and tool failure. The study reveals that material removal rate is directly influenced by all the three process parameters. However the effect of spindle speed and feed rate is more as compared to depth of cut [9]. D. I. Lalwani et al carried out an experimental investigation of cutting parameters influence on cutting forces and surface roughness in finish hard turning of MDN250 steel using coated ceramic tool. The cutting parameters chosen were cutting speed, feed rate and depth of cut. The results showed that the cutting speed has no significant effect on cutting forces and surface roughness [10].

In this research, the main objective is to study the effect of spindle speed and feed rate with constant depth of cut on surface roughness of carbon alloy steel in CNC turning operation.

3. Experimental Details:

Five different carbon alloy steels with varying composition of carbon and other alloying elements are turned in Econo CNC 26 lathe (Fig. 1). The compositions of the five different materials selected for experimentation are given in Table: 1.

| CARBON STEEL | %C | %Si | %Mn | %P | %S | %Cr | %Mo | %Ni | %V | %Al |
|--------------|----|-----|-----|----|----|-----|-----|-----|----|-----|
| SAE8620      | 0.21 | 0.29 | 0.72 | 0.026 | 0.023 | 0.59 | 0.19 | 0.46 | _  | 0.30 |
| EN19         | 0.41 | 0.21 | 0.13 | 0.013 | 0.020 | 1.10 | 0.25 | 0.03 | _  | _   |
| EN8          | 0.43 | 0.20 | 0.79 | 0.024 | 0.020 | _    | _    | _    | _  | 0.56 |
| EN24         | 0.45 | 0.22 | 0.57 | 0.040 | 0.040 | 1.5  | 0.30 | 1.55 | _  | _   |
| EN47         | 0.49 | 0.24 | 0.66 | 0.040 | 0.033 | 0.93 | _    | _    | 0.193 | _   |

The materials were turned using a carbide tip tool in wet condition using Triponol B (33) coolant, with a constant depth of cut of 0.5mm. Each category of material was turned at 5 different spindle speeds and 5 different feed rates. The spindle speeds were 339, 430, 576, 730 and 980rpm and the feed rates were 0.05, 0.075, 0.1, 0.125 and 0.15 mm per revolution. The spindle speeds and feed rates were selected from the standard tables given for the safe operation of the materials to avoid excessive tool wear and tool failure. The surface roughness of all the 125 sample pieces were measured using a surface roughness tester, Mitutoyo Surftest SJ-301 (Fig. 2), which is a stylus type surface roughness measuring instrument developed for shop floor use. The SJ-301 is capable of evaluating surface texture with a variety of parameters according to various national and international standards. The measurement results are displayed...
digitally/graphically on the touch panel, and output to the built-in printer. The stylus of the SJ-301 detector unit traces the minute irregularities of the workpiece surface. Surface roughness is determined from the vertical stylus displacement produced during the detector traversing over the surface irregularities. The Arithmetic Mean Deviation of the profile, Ra of the each sample piece is noted down as a surface roughness measure.

Few samples of the surface roughness profile generated by the surface roughness tester are shown in Fig. 4 below.

**Surface Roughness Profile of EN8 at 339 rpm and 0.05 mm/rev:**

**Surface Roughness Profile of EN19 at 730 rpm and 0.125 mm/rev:**

**Surface Roughness Profile of EN24 at 430 rpm and 0.125 mm/rev:**

**Surface Roughness Profile of EN47 at 980 rpm and 0.15 mm/rev:**
Surface Roughness Profile of SAE8620 at 730 rpm and 0.1 mm/rev:

Fig. 4 – Samples of surface roughness profile generated.

4. Results and discussion:

The graphs of surface roughness v/s spindle speed and surface roughness v/s feed rate is plotted for 5 different types of carbon alloy steels (Graph: 1 to graph: 10).

Graph for material EN8:

Graph: 1. Surface roughness v/s Feed rate for EN8

Graph: 2. Surface roughness v/s Spindle speed for EN8

Graph for material EN19:

Graph: 3. Surface roughness v/s Feed rate for EN19

Graph: 4. Surface roughness v/s Spindle speed for EN19
Graph for material EN24:

Graph: 5. Surface roughness v/s Feed rate for EN24

Graph for material EN47:

Graph: 7. Surface roughness v/s Feed rate for EN47

Graph for material SAE8620:

Graph: 9. Surface roughness v/s Feed rate for SAE8620

Graph: 6. Surface roughness v/s Spindle speed for EN24

Graph: 8. Surface roughness v/s Spindle speed for EN47

Graph: 10. Surface roughness v/s Spindle speed for SAE8620
4.1 Effect of spindle speed
Spindle speed refers to the rotating speed of the work piece. It was increased from 339 rpm to 980 rpm. The depth of cut was kept at 0.5mm throughout, but feed rate was varied from 0.05mm/rev to 0.15mm/rev in steps of 0.025mm/rev, with single turning operation for each feed rate. The surface roughness decreased with increased spindle speed.

4.2 Effect of feed rate
Feed rate is the rate at which the tool advances along its cutting path. It was increased from 0.05mm/rev to 0.15mm/rev in steps of 0.025mm/rev, by keeping the depth of cut constant at 0.5mm throughout and varying speed from 339rpm to 980rpm with single turning operation for each speed. The surface roughness increased with increased feed rate.

5. Conclusion:
From this study of effect of spindle speed and feed rate on surface roughness of carbon alloy steels it may be concluded that the better surface finish may be achieved by turning carbon alloy steels at low feed rate and high spindle speeds. The outlying points in the Graph: 1 to Graph: 10 can be attributed to factors such as vibration of machine, obliqueness in workpiece, tool wear, temperature of workpiece and variation in material composition. It should also be noted that the turning operation for all work pieces carried out sequentially. This also adds to tool wear.

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References:
[1] Mike SL, Joseph C, Chen, Li M (1998), "Surface roughness prediction for CNC End milling", Materials and processes quality control manufacturing, J. Ind. Technol., 15(1): (1999).

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[2] Lee and Ren, S.C. Lee and N. Ren, “Behaviour of elastic-plastic rough surface contacts as affected by surface topography, load and material hardness”, Tribol. Trans. 39 (1) 1996, pp. 67-74.

[3] B. Xiao Li, G. Rosen, Naser Amimi and H. Nilsson Per, “A study on the effect of surface topography on rough friction in roller contact”, J. Wear 254. 2003, pp. 1162-1169.

[4] O. Mahrenholtz, N. Bontcheva and R. Iankov, “Influence of surface roughness on friction during metal forming processes”, J. Mater. Process. Technol. 159, 2005, pp. 9-16.

[5] A. I. Selmy, I. El-Sonbaty, F. Shehata and U. A. Khashaba, “Some factors affecting the accuracy of turned parts”, Scientific Bulletin of the Faculty of Engineering vol. 24 (2), Ain Shams University, Egypt, 1989, pp. 356-368.

[6] A.B. Abdullah, L.Y. Chia and Z. Samad, ‘The Effect of Feed Rate and Cutting Speed to Surface Roughness.’ Asian Journal of Scientific Research 1(1): 12-21, 2008.

[7] C. Natarajan, S. Muthu and P. Karuppuswamy, “Investigation of cutting parameters of surface roughness for a non-ferrous material using artificial neural network in CNC turning”, Journal of Mechanical Engineering Research Vol. 5(1), pp. 1-14, January 2011.

[8] Mohammed T. Hayajneh, Montasser S. Tahat, Joachim Bluhm, “A Study of the Effects of Machining Parameters on the Surface Roughness in the End-Milling Process.” Vol.1, Number 1, ISSN 1995-6665, 2007.

[9] Deepak Mittal, M.P. Garg and Rajesh Khanna, “An investigation of the effect of process parameters on MRR in turning of pure titanium (Grade-2)”, International Journal of Engineering Science and Technology, Vol. 3 No. 8 August 2011.

[10] D.I. Lalwani, N.K. Mehta, P.K. Jain, “Experimental investigations of cutting parameters influence on cutting forces and surface roughness in finish hard turning of MDN250 steel”, Journal of materials processing technology 206 (2008), 167-179.