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An Experimental Study on Hard Turning Performance of DIN 17350 Tool Steel

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ABSTRACT: The main objective is to investigate the effects of cutting speed, feed rate and depth of cut on surface roughness R_z in hard turning process of DIN 17350-tool steel (60÷62HRC) under dry condition. The full factorial experimental planning design with the help of Minitab 19 software was applied to evaluate the main effects and interaction effects of input machining parameters. The experimental results indicate that feed rate and depth of cut cause the stronger impact on the objective function R_z than cutting speed. In addition, the interaction effects of cutting speed and feed rate as well as the cutting speed and depth of cut have significant influences on the output, but the interaction effect between the feed rate and depth of cut has little impact. Furthermore, cutting speed of 1400 rpm, feed rate of 0.05 mm/rev, and cutting depth of 0.1 mm should be recommended for the smaller surface roughness R_z values.

KEYWORDS: Hard turning; cutting speed; feed rate; depth of cut; surface roughness.

1. INTRODUCTION

Hard turning has become an important cutting process, especially in the field of manufacturing parts that require high accuracy and high strength. Many studies have been conducted to better understand the mechanism, performance, and factors influencing this process [1]. An important factor in the hard turning process is the performance of the cutting tool. Studies have shown that the cutting tool materials greatly affects machining efficiency. Ceramic and carbide tools are often used in hard turning due to their resistance to wear and high temperatures. The performance of ceramic and carbide cutting tools in hard turning of HRC 62 steel was shown in [2,3]. The results showed that ceramic tools have a longer life and provide a smooth machining surface than carbide tools. However, ceramic tools are susceptible to breakage and cracking when machining at high speeds and loads, while carbide tools have better mechanical durability [3]. Machining parameters such as cutting speed, feed rate, and depth of cut have the great influences on the surface quality and accuracy of the machined part. The influence of machining parameters on surface roughness when hard turning of AISI D3 tool steel was reported in [4]. The results show that increasing cutting speed and reducing tool feed improves surface roughness. However, when the cutting speed is too high, the machining temperature increases, leading to surface burning and reducing the quality of the machined surface. The effect of depth of cut on dimensional accuracy and tool life during hard turning of H13 steel was reported in [5]. The results show that a small depth of cut helps maintain better dimensional accuracy and prolongs tool life. On the contrary, a large depth of cut leads to faster tool wear and reduces dimensional accuracy. Surface quality and accuracy are two important factors that determine the effectiveness of the hard turning process. Many studies have focused on improving these two factors through optimizing machining parameters and using different types of cutting tools. The cutting parameters were optimized to improve surface quality in hard turning of AISI 52100 steel [6]. The cutting speed of 180 m/min, feed rate of 0.05 mm/rev, and depth of cut of 0.2 mm were the optimal parameters to achieve a surface roughness of R_a 0.3 µm. Through the literature review, it can be seen that the studies on the influence of cutting mode on surface roughness in hard turning of DIN 17350 tool steel are still limited. Therefore, the authors made a study on the effects of cutting speed, feed rate and depth of cut on surface roughness R_a during hard turning of DIN 17350 tool steel.

2. MATERIAL AND METHODS

The turning experimental set up was shown in Figure 1. Surface roughness R_z values were measured by MITUTOYO SJ-210 Portable Surface Roughness Tester (Japan). The DIN 17350 tool steel was hardened to reach the hardness of 60÷62 HRC and the chemical composition is given by Table 1.

Table 1. Chemical composition in wt% of DIN 17350 tool steel

C	Si	Mn	Ni	S	P	Cr	Mo	W	V	Ti	Cu
0.85 - 0.95	1.20 - 1.60	0.30 - 0.60	Max 0.40	Max 0.03	Max 0.03	0.95 - 1.25	Max 0.20	Max 0.20	Max 0.15	Max 0.03	Max 0.3

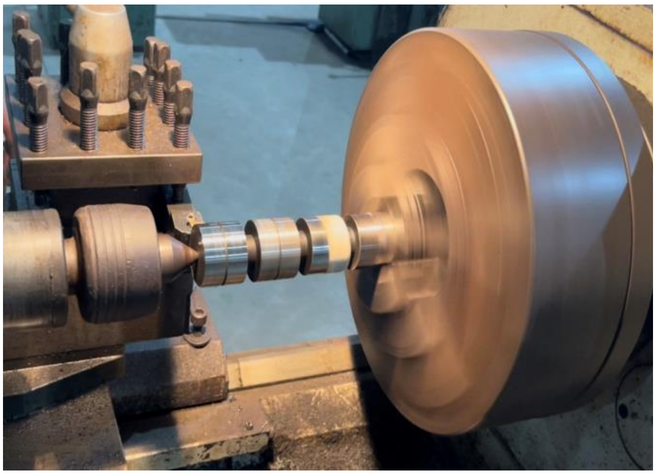

Figure 1. The experimental set up [7]

The full factorial experimental design of three factors and their levels is given by Table 2. The selection of values for input variables was developed from previous studies [7,8], and in this study, the authors increased the survey value of cutting speed to evaluate the machinability of coated carbide inserts as well as the influence trend of the surveyed parameters.

The cutting trials were implemented by following the full factorial experimental design, and the values of surface roughness R_z were measured three times right after each trial. The measured surface roughness values were taken by the average values.

Table 2. Full factorial design of three factors and their levels

Input machining parameters	Low level	High level
Cutting speed, V (rpm)	950	1400
Feed rate, f (mm/rev.)	0.05	0.15
Depth of cut, a_p (mm)	0.1	0.2

3. RESULTS AND DISCUSSION

The hard turning experiments were conducted by following the full factorial experimental design, and the R_z values were collected and processed. The main effects and interaction effects of the input parameters on the surface roughness R_z are shown in figures 2, 3.

From Figure 2, the feed rate and depth of cut have the strongest impact on surface roughness R_z. When the feed rate and depth of cut increase, the values of surface roughness R_z rapidly go up. It can be explained by the increase in the area of the cross-section of the cutting layer [3]. In contrast, the machined surface quality is improved when the cutting speed increase due to the reduction of cutting forces and cutting heat [4].

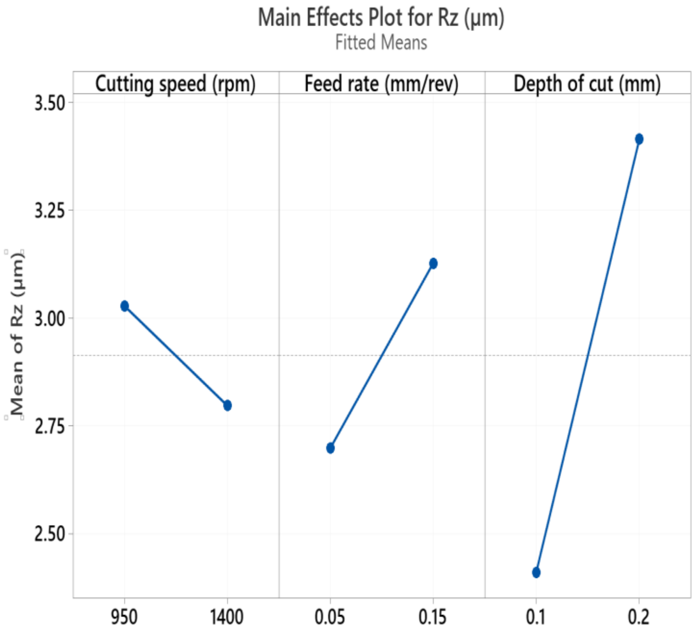

Figure 3. Main effects of input variables on surface roughness R_z

The interaction effects of the input parameters on the surface roughness R_z are shown in Figure 3. It can be observed that the interaction effects of cutting speed and feed rate as well as the cutting speed and depth of cut have significant influences on the output variable. The interaction between the feed rate and depth of cut has little impact. Through these obtained results, technologists can understand the influence trends and interaction effects of input parameters, from which they can select and conduct further studies to determine reasonable value ranges. Based on the experimental results, cutting speed of 1400 rpm, feed rate of 0.05 mm/rev, and cutting depth of 0.1 mm should be recommended for the smaller surface roughness R_z values.

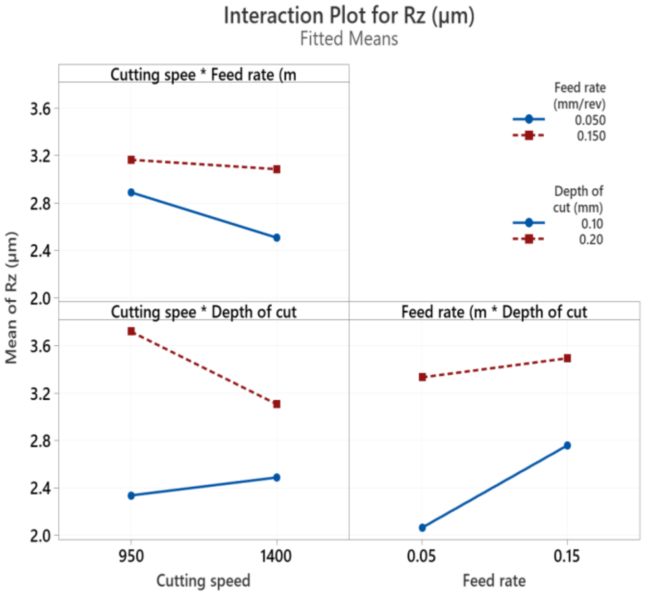

Figure 4. Interaction effects of input variables on surface roughness R_z

4. CONCLUSION

In this present study, an experimental study on the effects of cutting speed, feed rate and depth of cut on surface roughness R_z in hard turning process of DIN 17350 tool steel (60÷62HRC) was made. The full factorial experimental planning design with the help of Minitab 19 software was applied. The main effects and interaction effects of input machining parameters were evaluated. Feed rate and depth of cut cause the stronger impact on the objective function R_z than cutting speed. Also, the interaction effects of cutting speed and feed rate as well as the cutting speed and depth of cut have significant influences on the output variable. The interaction between the feed rate and depth of cut has little impact. Moreover, cutting speed of 1400 rpm, feed rate of 0.05 mm/rev, and cutting depth of 0.1 mm should be recommended for the smaller surface roughness R_z values, which will play an important role for future studies in hard turning.

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