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Research Paper

Effect of cutting parameters on surface roughness in dry hard turning of 90CrSi steel

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Abstract: *Hard machining is applied widely in industrial production because this technology not only meets the increasing requirements for quality and productivity but also is environmentally friendly. The content of this article presents an experimental study on the effect of cutting condition on surface roughness values R_a in hard turning of 90CrSi steel (60-62 HRC). Factorial experimental design 2^{k-p} with the support of Minitab 19 software was applied to investigate the influence of cutting speed, feed rate, and depth of cut on R_a. The obtained results show that the feed rate has the greatest influence on surface roughness. As the cutting speed increases, reducing the feed rate and depth of cut will contribute to decrease in roughness value R_a. Furthermore, reasonable sets of technological parameters on cutting modes are proposed.*
Key words: *Hard turning, hard machining, surface roughness, cutting condition, 90CrSi steel.*

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I. Introduction

Hard turning has received a lot of attention and is becoming a support/alternative solution for grinding process due to its high productivity, suitable for complex profiles, reduced use of cutting oil and good surface quality [1]. However, the conditions in cutting zone are very severe because the friction, cutting forces and temperature are very large, so there are strict requirements on the selection of cutting parameters and cutting tool material [2-6]. The dry hard turning technology developed and first applied in industrial production has shown many advantages such as improving productivity and ensuring quality in terms of dimensions and surface quality. Besides, the selection of cutting tool materials such as CBN, ceramic, carbide, etc. and the appropriate cutting parameters is very important factors for successful hard turning. Machining in the dry condition also contributes to environmental protection by eliminating the coolant [7,8]. This is a new hard machining technology and increasingly widely applied in production practice. Besides, the quality of the machined surface is a very important parameter because it affects the mechanical properties and working performance of the parts. The most important factors to evaluate the quality of the hard machined surface are surface roughness, topography, micro-hardness, white layer thickness, chemical composition of the surface material [7]. Among them, the surface roughness has a great influence on the fatigue strength and surface characteristics of the product, and this is also the most common parameter to evaluate whether the machined products are satisfactory or not. Therefore, it is necessary to study the effect of the cutting condition on surface roughness of the machined surface. 90CrSi steel is a tool steel widely used in the mechanical engineering industry because of its high hardness and strength, and this steel type is often used to make shafts, dies, cutting tools, etc. Studies on the effect of cutting parameters on surface roughness in hard turning of 90CrSi steel are still limited. Therefore, the authors are motivated to make a study on the effect of cutting condition on surface roughness in hard turning of 90CrSi steel (60 ÷ 62 HRC).

II. Material And Method

The experiment was carried out on a CS-460x1000 Chu Shing lathe (Figure 1). The CNMG120404-TM T9125 coated carbide inserts were used (Figure 2). After each cutting trial, the surface roughness measurement was performed by SJ-210 Mitutoyo (Japan) surface roughness tester with the cut-off length of 0.08 mm, measuring speed of 0.25 mm/s, and the retraction speed of the probe of 1mm/s.

Figure 1. CS-460x1000 Chu Shing turning machine

Figure 2. CNMG120404-TM T9125 coated carbide inserts

The factorial experimental design 2^{k-p} with the support of MINITAB 19 software was used to investigate the effect of cutting parameters including cutting speed, feed rate and depth of cut on the surface roughness values of the machined surface. The input parameters and their levels are given in Table 1. The experiment was carried out according to the experimental plan and the measured surface roughness R_a values are given in Table 2.

Table 1. Input cutting parameters and their levels

Input cutting parameters	Symbol	Low level	High level	Response
Cutting speed	v_c (rev./min)	650	1400	Surface roughness R_a (μm)
Feed rate	f (mm/rev.)	0.05	0.15	
Depth of cut	a_p (mm)	0.1	0.2	

Table 2. Factorial experimental design and the measured surface roughness R_a

StdOrder	RunOrder	PtType	Blocks	v_c (rev./min)	f (mm/rev.)	a_p(mm)	R_a(μm)
4	1	1	1	1400	0.15	0.1	0.561
8	2	1	1	1400	0.15	0.2	0.640
6	3	1	1	1400	0.05	0.2	0.491
7	4	1	1	650	0.15	0.2	0.976
3	5	1	1	650	0.15	0.1	0.611
1	6	1	1	650	0.05	0.1	0.520
5	7	1	1	650	0.05	0.2	0.399
2	8	1	1	1400	0.05	0.1	0.428

III. Results And Discussion

The main influence of the investigated variables on the surface roughness value R_a is shown in figure 3. From the obtained results, it can be seen that increasing the cutting speed contributes to decrease the surface roughness values. The feed rate has the greatest influence on the surface roughness. As the feed rate increases, the roughness values increase sharply [7]. Also, the increase of cutting depth causes the growing surface roughness.

The interaction effect between the investigated variables is shown in Figure 4. From figure 4, it can be seen that the interaction between the feed rate and the depth of cut has the greatest influence on the surface roughness R_a. Furthermore, the interaction effects between cutting speed and feed rate as well as cutting speed and depth of cut have less influences on the studied response.

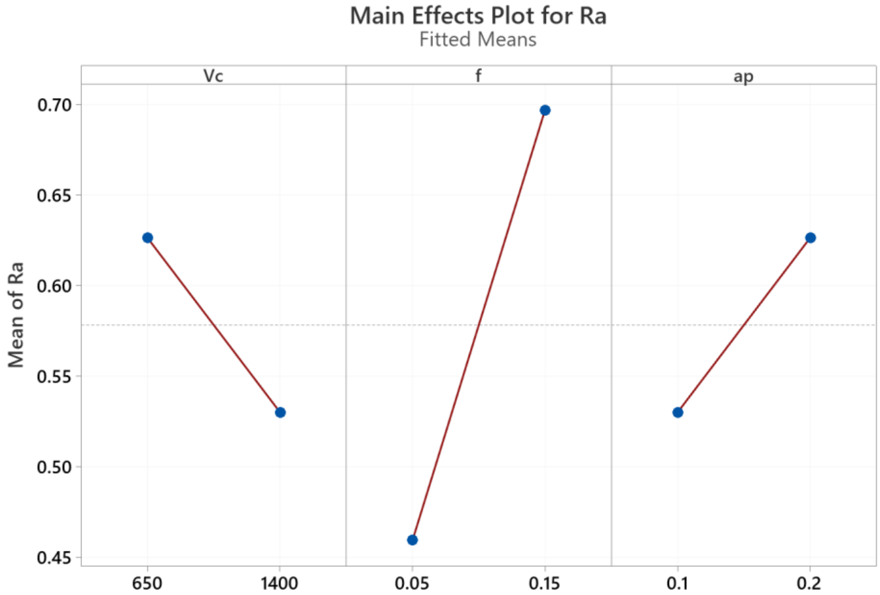

Figure 3. Main effects of cutting parameters on surface roughness R_a

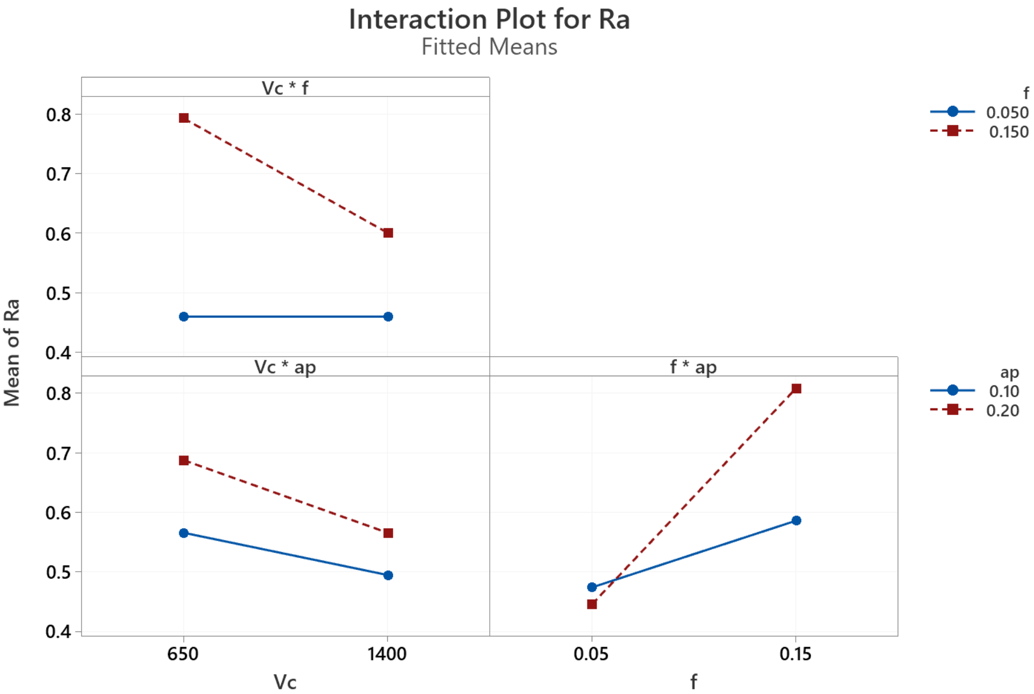

Figure 4. Interaction effects of cutting parameters on surface roughness R_a

The contour plot of the interaction effect between feed rate and cutting speed when keeping cutting depth a_p =0.15 mm is shown in figure 5. To achieve small surface roughness, it is recommended to choose cutting speed between 650 and 1400 rpm, the feed rate should be kept between 0.05 and 0.06 (mm/rev.). The contour plot of the interaction effect between cutting depth and feed rate when keeping cutting speed v_c=1025 rpm is shown in Figure 6. For better surface quality, it is recommended to choose a_p= 0.1 - 0.2 mm and f = 0.05 - 0.06 mm/rev. The contour plot of the interaction influence between depth of cut and cutting speed when keeping the feed rate f=0.1 mm/rev. is shown in

Figure 7. The cutting speed in the range from 1350 to 1400 rpm and a_p = 0.1 - 0.11 mm should be used to give the smallest roughness values in the survey range.

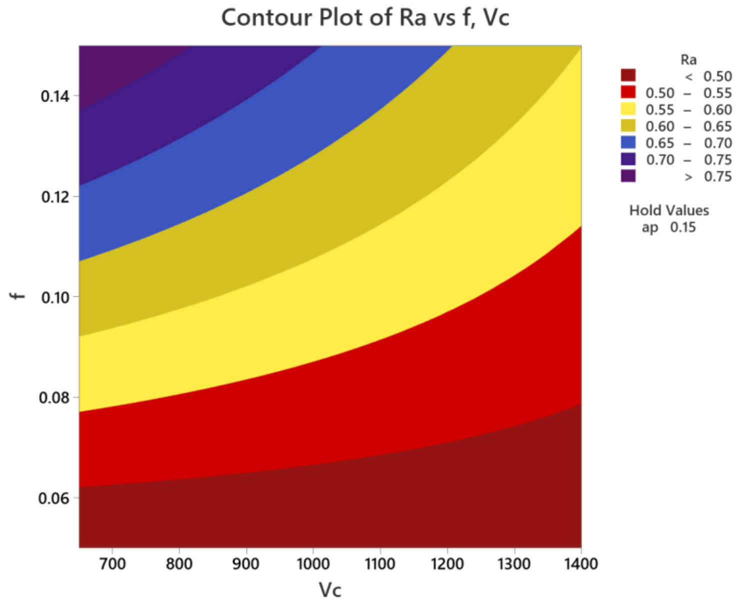

Figure 5. The contour plot of the interaction influence of feed rate and cutting speed on surface roughness R_a

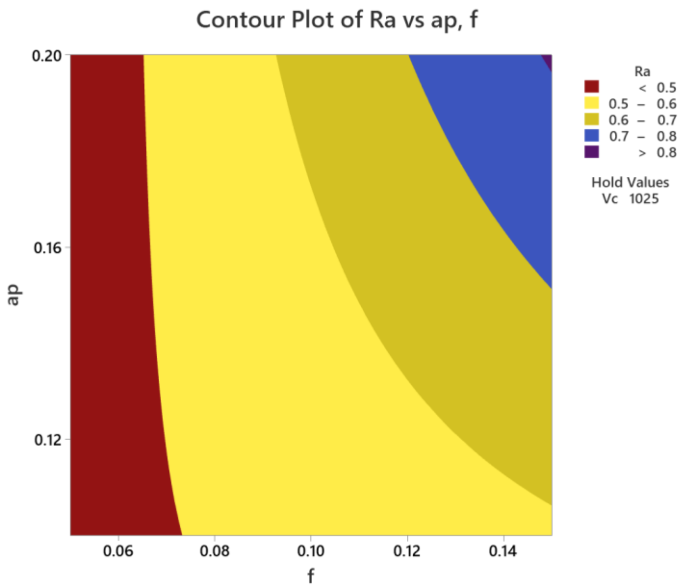

Figure 6. The contour plot of the interaction influence of depth of cut and feed rate on surface roughness R_a

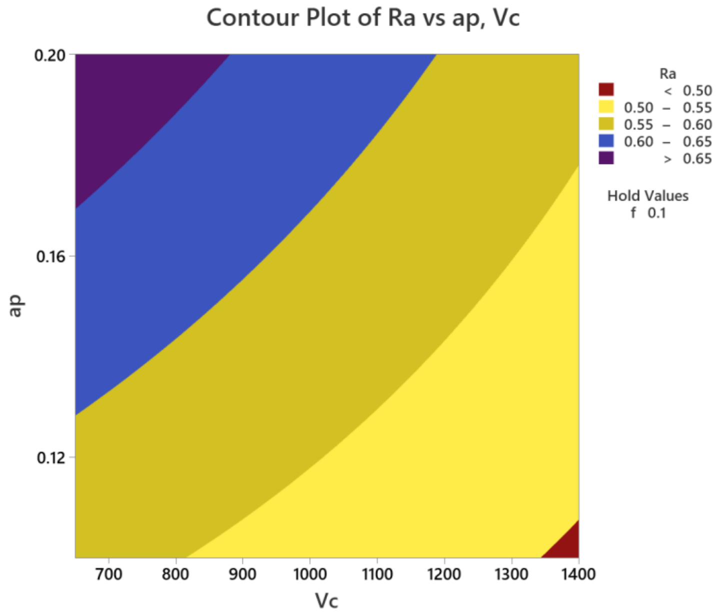

Figure 7. The contour plot of the interaction influence of depth of cut and cutting speed on surface roughness R_a

IV. Conclusion

In this paper, experimental studies were carried out to investigate the effect of cutting parameters including cutting speed, feed rate and cutting depth on surface roughness value R_a in hard turning of 90CrSi steel (60-62 HRC) by coated carbide inserts. Factorial experimental design 2^{k-p} with the support of Minitab 19 software was applied to investigate the influence of cutting speed, feed rate, and depth of cut on the surface roughness R_a. The main effects of each parameter and the interaction effects were investigated and evaluated. The study has proposed a set of reasonable cutting parameters to achieve small surface roughness values. In particular, high cutting speed with low feed rate and depth of cut will contribute to reduce the surface roughness values.

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