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Investigation of contour hard milling of AISI D2 tool steel using carbide inserts

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Abstract
The work presented in this paper shows an experimental investigation on the influence of cutting parameters including cutting speed and feed rate in contour hard milling of AISI D2 steel (52 HRC) using carbide inserts. The factorial experimental design was utilized to investigate the effects of input cutting parameters on hard milling performance in terms of surface roughness. The work results show that the feed rate has the strongest effect on surface roughness value. Besides, the combination of high cutting speed and low feed rate will contribute to bring out the better surface quality. Moreover, the cutting fluid eliminated not only reduces the manufacturing cost but also creates the environmental friendly characteristic, which is suitable for sustainable production.
Keywords: *Hard milling, hard machining , cutting parameter, dry cutting, difficult-to-cut material*

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I. Introduction

In recent years, hard machining technology is increasingly interested and widely applied to partially or completely replace the grinding process [1]. The main reason is that hard machining provides high productivity and flexibility and can be also used to machine a variety of surfaces with good surface quality [2]. Especially in mold industry, it becomes easy to directly cut the materials after heat treatment with high hardness, so hard milling plays an increasingly important role [3].

Moreover, the dry machining is a method to eliminate the use of cutting fluids, which contributes to minimize the cost from using and treating cutting oil and also completely reduces the negative impact on the environment [4]. Therefore, hard milling in the dry condition is considered an environmentally friendly technology. In recent years, there has been some studies on hard milling using several types of cutting tools such as carbide, ceramic, CBN, and so on [1,5,6]. Research results have shown outstanding advantages such as productivity and surface quality [6].

AISI D2 is the tool steel commonly used for molds and tools requiring high strength and good wear resistance. Besides, this steel has good hardening ability and can reach high hardness up to 60-62 HRC. However, in the state after heat treatment, this steel has poor machinability and is classified as difficult-to-cut material [7]. Therefore, the selection of cutting tool material and cutting condition plays an important role in productivity and product quality. Therefore, the author studied the influence of cutting speed and feed rate on surface roughness in contour hard milling of AISI D2 tool steel (52 HRC).

II. Material and Method

The workpiece samples of AISI D2 alloy steel have the chemical composition shown in Table 1. The hardness of AISI D2 workpiece is 52HRC. The cutting trials were carried out on Muraki KV-700 vertical milling machine (Figure 1) by following the factorial design 2^{k-p} with two variables (k = 2) with the help of Minitab 18 software. The input cutting parameters and their levels are given by Table 2. The depth of cut is fixed at 0.12 mm. The carbide inserts with the designation of APMT 1604 PDTR LT3000 were used. The surface roughness was measured three times after each cutting trials and taken by the average values. The number of teeth is two.

Table 1 – Chemical composition in % of AISI D2 tool steel

Chemical composition (%)										
C	Si	Mn	Ni	Cr	Mo	W	V	Cu	P	S
1.4 - 1.6	0.4	0.6	0.5	11.0 -13.0	0.8 -1.2	0.2 - 0.5	≤ 0.25	≤ 0.25	≤ 0.03	≤ 0.03

Table 2. The input cutting variables and their levels

Input machining parameters	**Low**	**High**
Cutting speed, V (m/min)	120	160
Feed rate, f (mm/min)	0.05	0.15

Figure 1. Muraki KV-700 vertical milling machine used for conducting the experiments

III. Results and Discussion

The cutting trials were done according to experimental design, and the surface roughness values were measured and processed. The main effects of the input parameters on the machined surface roughness are shown in Figure 2. It can be seen that for increasing the cutting speed, the surface roughness decreases, which is completely consistent with the previous study [4,7]. Meanwhile, when increasing the amount of feed, the surface roughness value increases sharply due to the increase in the area of the cross-section of a cut layer. Hence, the feed rate has the greatest influence on the machined surface roughness.

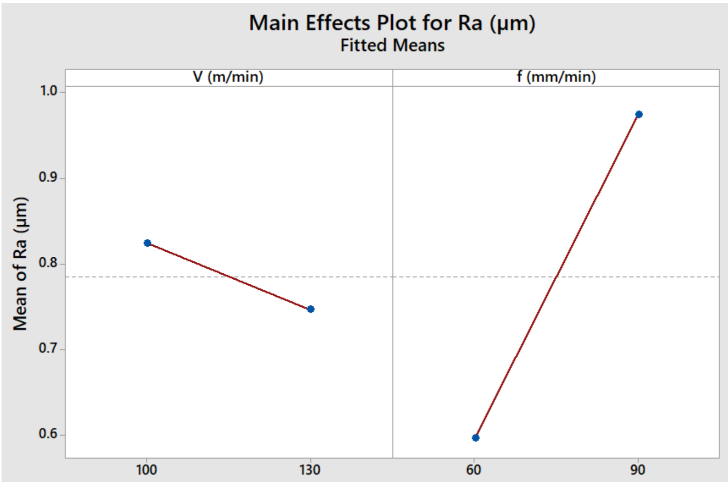

Figure 2. Main effect plot of input machining factors on surface roughness R_a

From figure 3, it shows that the surface roughness Ra less than 0.6 µm can be obtained by using V = 115-130 m/min and f = 60-62 mm/min. The surface plot showing the interaction effect between cutting speed and feed rate on surface roughness (Figure 4). The combination of high level of cutting speed and low level of feed rate will give the lowest surface roughness values.

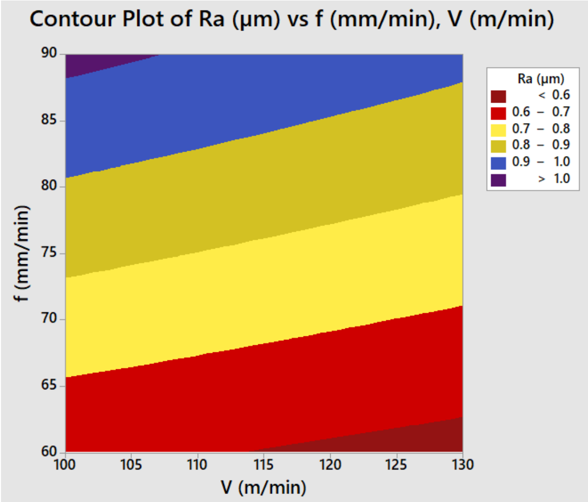

Figure 3. Contour plot of cutting speed and feed rate on surface roughness R_a

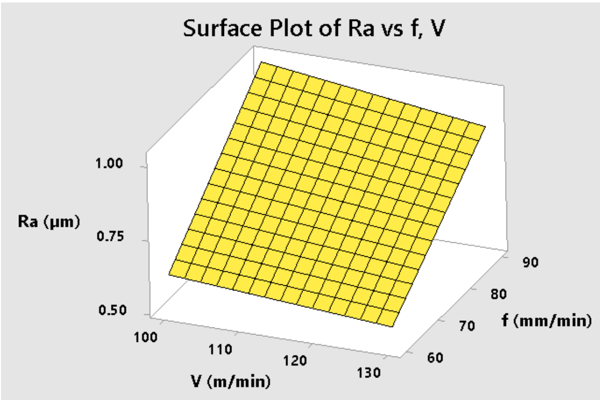

Figure 4. Surface plot of cutting speed and feed rate on surface roughness R_a

(a) **(b)**

Figure 5. Machined surface of the tools for twisting and cutting steel rod Ø6 with V=130 m/min, (a) f= 90 mm/min, (b) f=60 mm/min

To verify the experimental results, the author used the recommended cutting parameters to contour hard milling for the tools for twisting and cutting steel rod Ø6. Figure 5 shows the product images after contour hard milling with V = 130 m/min combined with feed rates at two different levels. For V =130 m/min and f= 90 mm/min, R_a value is 0.925 µm (Figure 5a) and reduces to 0.568 µm with V =130 m/min and f= 60 mm/min (Figure 5b). Accordingly, it can be concluded that the surface quality is significantly improved by reducing the feed rate.

IV. CONCLUSION

In this paper, dry contour hard milling using coated carbide inserts was successfully carried out for manufacture the tools for twisting and cutting steel rod Ø6. The factorial experimental designed was used to study the effect of cutting variables including cutting speed and feed rate on surface roughness was studied. The obtained results reveal that the feed presents the strongest influence on surface roughness, followed by cutting speed. The technical guides for choosing cutting speed and feed rate were provided in order to apply in practice more easily and effectively. The smaller values of surface roughness can be achieved by using higher cutting speed and lower feed. In further research, more work will be focused on optimizing cutting condition and surface microstrcture.

Acknowledgments

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