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The Effect Of Machining Parameters On Surface Roughness In The Fully Interrupted Hard Turning Process With Cbn Insert By Taguchi Methods

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Abstract
In recent years, Hard turning is a potenial machining process to replace for grinding process due to large advantages such as material removal rate, good surface integrity, and friendly environment. In addition to the cylindrical surfaces, hard turning is also used for turning the discontinuous surfaces. However, the intermittent hard turning process has many difficulties due to vibration and tool wear. The vibrationt and tool wear affect the surface roughness, the quality and cost of the workpiece. This study focuses on analyzing the effect of cutting parameters on surface roughness in the interrupted hard turning process using Taguchi method on Minitab software. The studying results show that the feed rat is the most influencing factor on surface roughness, followed by cutting depth and cutting speed. In addition, the interaction effects between out factors on surface roughness in the interrupted turning process was also analyzed in this research. Surface roughness can reach minimum values with a cutting depth of 0.2 mm, a cutting speed of 120 m/min and a feedrate of 0.08 mm/rev.

Keywords: *Interrupted, hard turning, SKD11, CBN, Surface roughness, Taguchi*

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I. INTRODUCTION

The hard turning process is widely used to machining hardened parts with hardness over 45 HRC. This process is used to replace for the grinding process because it has many advantages such as accuracy and high surface quality, low costs and no cutting fluid [1]. In the hard turning process, the cutting part of the tool must work under a difficult condition such as large cutting force, high cutting temperature, friction and abrasion ... Currently with the development of material technology, many types of new cutting tools is manufactured and used in machining hard process such as CBN, PCBN and Ceramic [2]. In which, CBN is used to cut the parts having hardness over 60HRC and especially can be used for the interrupted machining proces. In 2005, Pavel studied the effects of tool wear on the surface roughness during the interrupted hard turning process using PCBN inserts [3]. In 2009, Adilson Josse de Oliveira analyzed the tool wear in the interrupted hard turning process using PCBN and Ceramic inserts [4]. The researched results show that the PCBN inserts have the longer tool life than the ceramic inserts when machining the discontinuous surfaces. In 2011, De Godoy compared the efficiency of the interrupted hard turning process when using CBN and Ceramic inserts [5]. The results showed that the CBN had more advantages in the hard interrupted machining process. However, the study has only analyzed the effects of the cutting speed with low CBN and the low interruption surfaces. In 2012, Dogra analyzed the tool life and surface layer structure when turning the hard discontinuous surface with Carbide coated TiN and CBN [6]. The research results show that the CBN are more effective for the hard interrupted turning, but only studied workpieces 50HRC hardness and with only two factors: cutting speed and the feed rate. Recently, Nayak et al. (2019) has analyzed the effects of cutting parameters on the main cutting force and tool wear when interrupted turning using CBN inserts [7].

Thus, these studies mainly focus on the interrupted hard turning processes with workpieces having hardness over 60HRC, and low or medium interruption surfaces. Therefore, this article focuses on the analysis of the effects of cutting parameters on surface roughness in the fully interrupted hard turning process using CBN inserts.

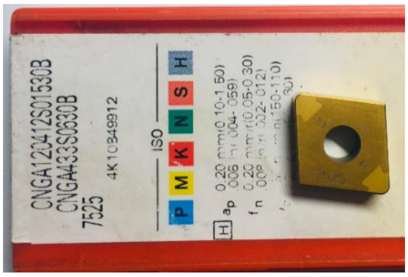
II. EXPERIMENT AND METHOD

The machining process is carried out on the CNC QTS200 turning center manufactured by Japan. The experimental devices are shown on the figure 1.

The cutting tool is the CBN 7525 inserts of Sandvik manufactured, with the code according to ISO CNGA120412S01530B, as shown in Figure 1C. CBN 7525 contains 90% of fine CBN, commonly used in machining gray cast iron and interrupted surfaces.

a, *CNC QTS200 turning center*

b, Workpiece



c, CBN inserts

d, Roughness gause

Figure1. Experimental setup

In the study, the workpieces are made by SKD11 steel with chemical composition as in Table 1. This is a steel grade according to Japan's JIS standard, which is commonly used for high-wear parts. SKD 11 steel has many good properties such as smooth machined surface, high wear resistance, good permeability and low quenching stress. These trials uses 60mm x 100mm cylindrical SKD11 steel which has been heat treated to a hardness of 60HRC and has 6 slots on the cylinder surface as shown in Figure 1b. During the machining process, the surface roughness is measured by a Mitutoyo SJ-210 roughness gauge – Japan (as shown in Figure 1.d).

Table 1. Chemical composition of SKD11 steel

C	Si	Mn	Cr	Mo	V	Fe
1.63	0.25	0.45	11.89	0.89	0.37	Balance

The study used Taguchi method to analyze the influence of technological parameters on surface roughness value in the interrupted hard turning proces. Based on the proposal of the cutting tool manufacturer and the results of previous publications, the study selected the initial set of survey parameters as in Table 2. With survey parameters with cutting speed (V), feed rate (f) and depth of cut (d) have 3 levels of values, experimental design L9 was selected to analyze the influence of cutting mode parameters on output factors. From there, the experimental matrix is established as in Table 3.

Table 2 input parameters and their levels

Parameters	Units	Levels		
		-1	0	1
A – Depth of cut (d)	mm	0.1	0.15	0.2
B - Cutting speed (v)	m/min	120	140	160
C – Feed rate (f)	mm/rev	0.08	0.12	0.16

III. RESULT AND DISCUSSION

Effect of cutting parameters on surface roughness in the interrupted hard turning process

After machining, the surface roughness value was measured with a standard length of 0.8mm and the results obtained are shown in Table 3.

Table 3. Experimental results

No.	*d (mm)*	*V (m/min)*	*f (mm/rev)*	*Ra (μm)*
1	0,1	120	0,08	0,405
2	0,1	140	0,12	0,751
3	0,1	160	0,16	1,543
4	0,15	120	0,12	0,645
5	0,15	140	0,16	1,46
6	0,15	160	0,08	0,495
7	0,2	120	0,16	0,859
8	0,2	140	0,08	0,254
9	0,2	160	0,12	0,387

Analysis of variance for surface roughness value when turning intermittent hardening of SKD11 steel is determined by Minitab software. The analysis results show that the average value of the surface roughness with different levels for each survey parameter and the order of influence of the parameters on the surface roughnes value is shown in Table 4. The results shows that the feed rate is the most influential parameter, the depth of cut is the 2nd most influential factor and the cutting speed has the 3rd most influential influence on the average value of the surfaceroughness.

Table 4. the average value of the surface roughness and the level influence of the parameters

Level	**d (mm)**	**V (m/min)**	**f (mm/rev)**
1	0.8997	0.6363	0.3847
2	0.8667	0.8217	0.5943
3	0.5000	0.8083	1.2873
Delta	0.3997	0.1853	0.9027
Rank	2	3	1

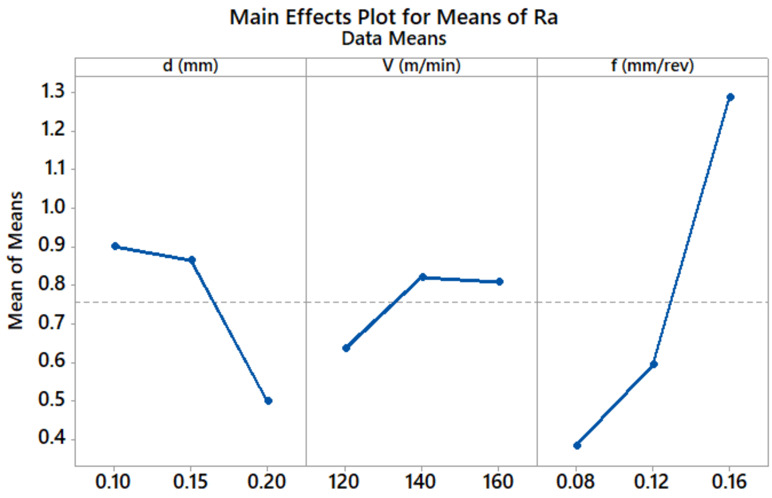
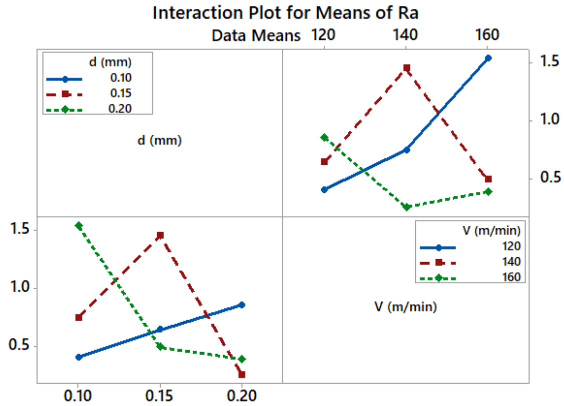


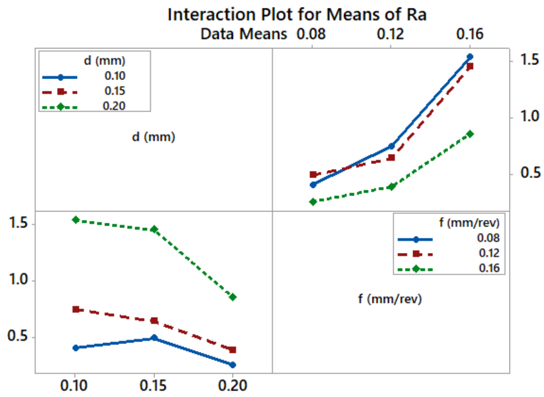
Figure 2. Effect of cutting parameters on surface roughness

The influence of the cutting parameters and their interaction on the average value of surface roughness is shown in Figures 2-3. The figure 2 show that the surface roughness reaches the smallest value when machining with a cutting depth of 0.2 mm, a cutting speed of 120m/min and a feed rate of 0.08 mm/rev. The feed rate is the most influential factor, the surface roughness value increases slowly with increasing the feed rate from 0.08 mm/rev to 0.12 mm/rev and increases rapidly as the feed rate continues to increase to 0.16 mm/rev.

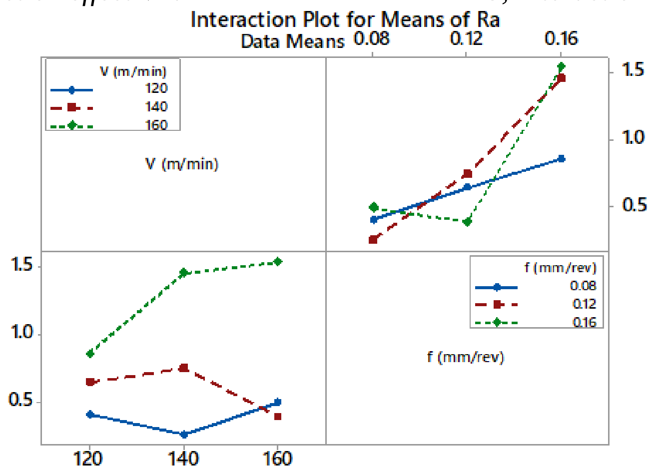
Surface roughness was little changed when cutting speed was reduced from 160 m/min to 140 m/min, but decreased sharply when cutting speed was reduced to 120 m/min. The reason is that the interrupted hard turning has high velocities, and strong vibrations, and shocks occur, which causes increasing the surface roughness. With a small cutting depth, the surface roughness is little changed, but increasing the cutting depth to 0.2 mm can reduce the surface roughness. The reason is that with a small depth of cut, slippage may occur during the cutting process, increasing the surface roughness. However, increasing cutting depth can increase cutting force, cause tool wear and reduce tool life. Therefore, further studies are needed to determine the appropriate cutting parameters.



*a, Interaction effect V*d*



*b, Interaction effect d*f*



*c, Interaction effect V*f*

Figure 3. Interaction effect of the cutting parameter on the surface roughness

Taguchi analysis also allows to evaluate the influence of the interaction between the survey parameters on the average value of the surface roughness, as figure 3. The results show that the interaction between cutting speed and depth of cut has a great influence on the surface roughness (Figure 3a). With a small cutting depth (0.1mm), the surface roughness increases when increasing the cutting speed. With a large feed rate, the surface roughness decreases when increasing the cutting speed. This may be due to the fact that in the interrupted hard turning with a small depth of cut, slippage may occur, and the slippage increases with increasing cutting speed. The interaction between depth of cut and feedrate has less effect on surface roughness (Figure 3b). While the interaction between cutting speed and feed rate also significantly affects the surface roughness value (Figure 3c). With cutting speeds from 120 m/min to 140 m/min, the surface roughness value increases as the feed rate increases. This shows that with low cutting speed, the cause of increased surface roughness is due to geometric factors. When the cutting speed is large at 160 m/min, the surface roughness value increases again when reducing the feed rate from 0.12 mm/rev to 0.08 mm/rev. This result suggests that more slip can occur when the feed rate is reduced, which increases vibration and is the cause of increased surface roughness.

Effect of cutting parameters on S/N ratio of surface roughness value in the interrupted hard turning process

The influence of the survey parameters on the surface roughness value in the interrupted hard turning process has determined by analyzing the signal-to-noise ratio S/N for surface roughness with

Minitab software. The signal-to-noise ratio the surface roughness value is calculated at different levels for each survey parameter. The level of influence of the parameters on the S/N ratio value of the roughness valueis shown in Table 5. The analysis results show that the feed rate and depth of cut have the strongest influence on the S/N ratio of the surface roughness value.

Table 5. The level influence of the parameters on the S/N ratio

Level	d (mm)	V (m/min)	f (mm/rev)
1	2.190	4.327	8.621
2	2.210	3.701	4.847
3	7.156	3.529	-1.911
Delta	4.966	0.798	10.532
Rank	2	3	1

The influence of the machining parameters on the S/N ratio of the surface roughness value is shown in Figure 4. The results show that the ratio S/N increases rapidly when the feed amount is reduced and has the greatest value with the feed amount 0.08 mm/rev. At the same time, the s/N ratio is almost unchanged when changing the cutting speed in the range from 120 m/min to 160 m/min. The S/N ratio also did not change much with increasing depth of cut from 0.1 to 0.15mm and increased rapidly with increasing depth of cut from 0.15mm to 0.20mm.

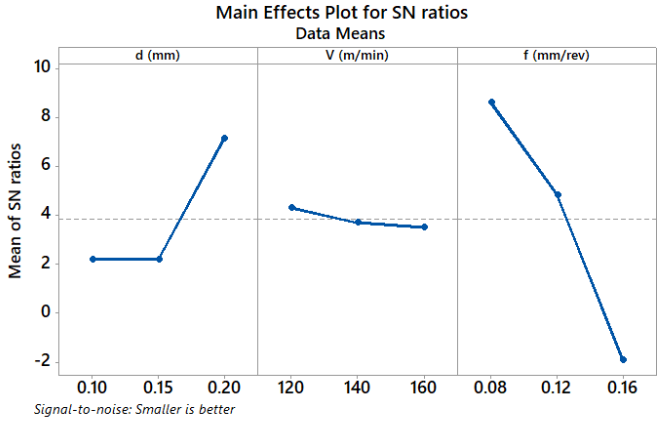
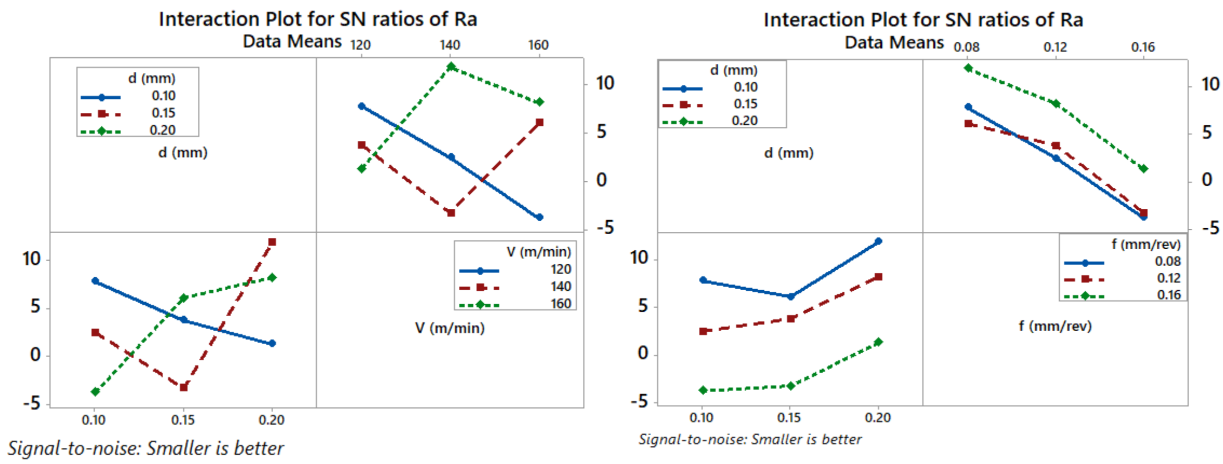
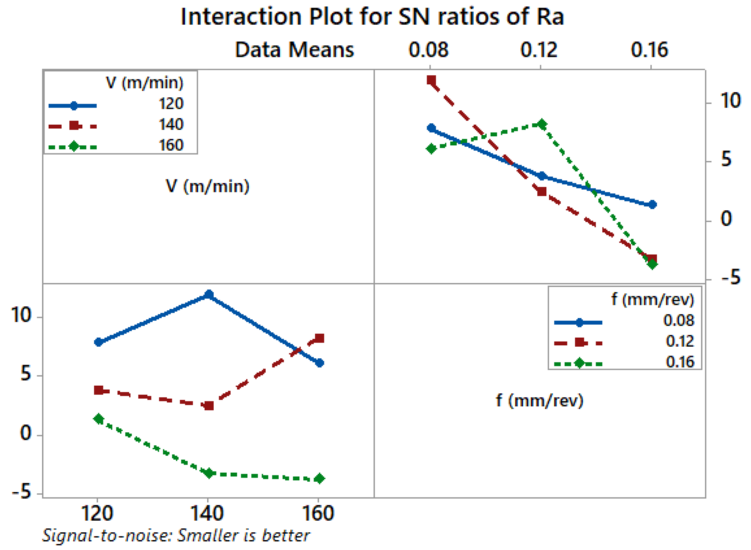


Figure 4. Effect of cutting parameters on the S/N ratio for surface roughness

The interaction effect between the survey parameters on the S/N ratio of the surface roughness is also analyzed and shown in Figure 5. The results also show that the interaction between the machining parameters has a great influence on the S/N ratio of the surface roughness value. In particular, the interaction between cutting speed and depth of cut has the greatest influence on surface roughness, figure 5a. The results shown in Figure 5a show that the ratio S/N for roughness increases as the cutting speed decreaseswith a small cutting depth (0.01 mm). The interaction between depth of cut and feedrate has little effect on the S/N ratio for the surface roughness value (Figure 5b). While the interaction between cutting speed and feedrate has a significant effect on the S/N ratio for surface roughness.



*a, Interaction effect V*d* *b, Interaction effect d*f*



*c, Interaction effect V*f*

Figure 5. Interaction effect of the cutting parameter on the S/N ratio for the surface roughness

IV. CONCLUSION

The influence of the cutting parameters and their interaction on the surface roughness value when turning discontinuous surface hardening of SKD11 steel (60HRC) was analyzed using the Taguchi method. The results have shown that the feed rate and depth of cut are the factors that greatly affect the surface roughness value. While the cutting speed has less influence on the surface roughness value. The study also shows a set of machining parameters for the minimum surface roughness value V 120 m/min, d 0.2 mm and f 0.08 mm.

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