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Influence of the cutting parameters on the flank wear of CBN inserts in the hard turning process

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Abstract
The hardened SKD11 steel has a high hardness about 60HRC, good wear resistance and high toughness. Hard turning is an important machining process because all manufacturers are continually seeking ways to manufacture their parts with lower cost, higher quality, rapid setups, lower investment, and smaller tooling inventory while eliminating non-value-added activities. This study focuses on analyzing the effect of machining parameters on flank wear after hard turning of SKD11 steel using CBN inserts. The effect of machining parameters and interacted between them on the flank wear were analyzed by using the full factorial design having the centeral trials. The results investigated that the cutting speed and feed rate are the most significant parameters effecting on the flank wear in the hard turning of SKD11 steel using high CBN inserts. The interacted effects between depth of cut and feed rate, cutting speed and feed rate also strongly affects on the flank wear in the hard turning of hardened SKD11 steel using CBN inserts. The results of ANOVA analysis for the flank wear indicated that the need to investigate and use the curve model to describe the effect of the cutting parameters on the flank wear.

Keywords: *Hard turning, CBN, Flank wear, SKD11, ANOVA*

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I. INTRODUCTION

With many outstanding advantages, hard turning is a finishing method applied more and more widely in industries. In the hard turning process, the most important thing is the selection of cutting tool material and grade. The hard turning process is commonly applied to machine the hardened alloy steel with high hardness (hardness > 45 HRC). It is used to replace the grinding process because of its preferable features such as having high accuracy, surface roughness, lower investment, creation of compressed residual stress, and not using cooling lubrication [1]. A basic knowledge of each cutting tool material and its performance is important when making the correct selection. Recently, with the development of cutting tool materials, some new tool materials have been used in the hard turning process such as CBN, PCBN and ceramic (Smith & Smith, 1993) [2]. In where, the CBN is the cutting tool material that can be used to machine the parts having the hardness more than 60 HRC or the parts also have irregular surfaces.

Kishawy and Elbestawi [3] investigated the surfaceintegrity of AISI D2 steel of 62 HRC machined using PCBNtools under high speed conditions. They used cutting speedsin the range 140–500 m/min, feeds 0.05–0.2 mm/rev, depthsof cut 0.2–0.6 mm and tools with edge preparations, sharp,chamfered (20◦ × 0.1 mm) and honed (radius 0.0125 mm).Their results showed that, at cutting speeds above 350 m/min,the surface roughness increased with increase in tool wearand this was attributed to material side flow. In addition,defects such as micro-cracks and cavities were observed onthe machined surface. The density of these micro-cracks wasfound to depend on the cutting speed and feed used. Theirstudy of machined surface structure revealed a thermallyaffectedwhite layerformed due to phase transformationwhenmachined with chamfered or worn tools but not with sharptools.Narutaki and Yamane [4] investigated tool wear whenmachining hardened tool steel, casehardening steel and highspeed steel work materials of hardness in the range 10–66HRC. They used PCBN tools with high CBN content (~90%with metallic binder) and low CBN content (60–70% withceramic binder).Whenmachining softer steels(e.g. 10 HRC),low CBN content tools performed better in terms of flankwear. This was attributed to lower attrition wear due to greaterbonding strength of the tool which consisted of a higher volume of binder. These tools also showed better wear resistancewhen machining hardened tool steel and case hardening steel.

However, when machining high speed steels, high CBN content tools performed better. This was attributed to the greater volume of CBN in the tool resisting abrasion by hard carbide particles in the work material. Chou et al. [5] investigated the performance and wear behaviour of high CBN content (92% with metallic (cobalt) binder) and low CBN content (70% CBN with ceramic (TiN) binder) PCBN tools when turning hardened AISI-52100 steel of 61–63 HRC. Their test results showed that low CBN content tools generated better surface finish and had lower flank wear rates than high CBN content ones. From an SEM study of built-up layers1 on the flank wear scars of these tools, they suggested that built-up layers on low CBN content tools are not as strongly bonded as those on high CBN content tools and that adhesion interacted with built-up layer as a dominant wear mechanism. The observed greater adhesion on high CBN content tools was attributed to a higher affinity of the metallic binder to the built-up layer while the accelerated abrasive wear was attributed to plucked out CBN particles due to loss of binder. Poulachon et al. [6] studied the wear behaviour of low CBN content PCBN tools when turning hardened steels AISI D2, AISI H11, 35NiCrMo16 and AISI-52100, each steel with hardness 54 HRC. During their tool wear tests, these four steels showed different flank wear rates under identical conditions. Based on a study of worn tool flanks and the microstructure of the steel work materials, they identified presence of various hard carbides in the steel as the major influencing factor on tool wear which caused wear grooves on tool flank by abrasion. The observed differences in wear rates were attributed to different hardness values of the various carbides in the steels. Luo et al. [7] machined AISI-4340 steel with hardness values 35, 45, 50 and 55 HRC using PCBN tools (with TiC and Al2O3 binder) and concluded that the main tool wear mechanism is due to abrasion of the binder by hard carbide particles in the steel work material

The hard turning process is the complex machining process. It is difficult to investigate the effect of all possible factors on the the flank wear in the hard turning process. Some researchers analyze the effect of workpiece hardness on the flank wear. Others have analyzed the effect of cutting tool geometry on the flank wear. In this study, the effect of all three cutting parameters on the flank wear when hardening steel SKD 11 with 60HRC hardness was analyzed by the full factorial model.

II. EXPERIMENT AND METHOD

The trials of this research are performed in the machining lab with the experimental setup as figue 1.All the trials were performed in the CNC turning center QTS 200 made by Mazak Company. The CBN 7015 inserts of the sandvik were used for this study. The CBN 7015 grades' speed capabilities, more secure edge line and consistent tool life results in lower cost per component. The workpieces are made by the hardened SKD11 steel (60HRC) and have dimension 60 mm x 110 mm. these workpieces have six axial slots cutted before hardening. The chemical composition of SKD11 steel are shown in table 1.

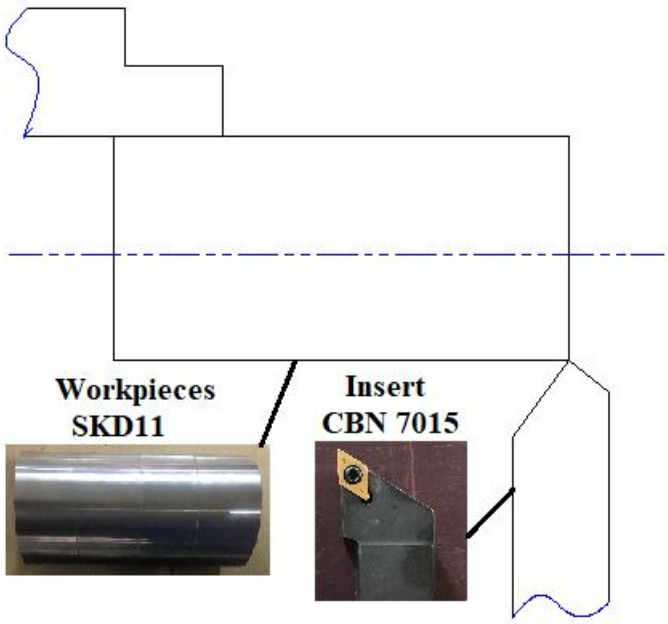

Figure 1. The experimental devices

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

In this research, Minitab 19 Software is applied to build experimental model. A full factorial model was designed with input parameters and two levels. This experimental model have 10 experiments including 8 factorial points and 2 center points. The ranges of the input parameters are given in table 2. The experimental matrix and the results of the surface roughness and the flank wear are shown in table 2.The flank wear width is measured by the digital microscope of Keyence company after cutting the cutting length of 200 m. The results of measured flank wear are shown in the table 3.

Table 2. input parameters and their levels

Input machining variables	Symbol	Level		Response variable
		Low	High	
Depth of cut (mm)	d	0.1	0.2	Flank wear (VB)
Cutting speed (m/min)	V	120	160	
Feed rate (mm/rev)	f	0.1	0.2	

Table 3. Experimental matric for full factorial design

StdOrder	RunOrder	d (mm)	V (m/min)	f (mm/rev)	VB (μm)
9	1	0.15	140	0.12	172.0
4	2	0.2	160	0.08	340.0
5	3	0.1	120	0.16	225.3
2	4	0.2	120	0.08	212.1
7	5	0.1	160	0.16	251.2
6	6	0.2	120	0.16	279.1
1	7	0.1	120	0.08	292.2
3	8	0.1	160	0.08	323.5
10	9	0.15	140	0.12	167.0
8	10	0.2	160	0.16	279.1

III. RESULT AND DISCUSSION

The ANOVA analysis for the flank wear of CBN inserts in this research is analyzied with significance level $\alpha = 0.05$. The table 4 shows the results of the ANOVA analysis for the flank wear. The results indicated that the cutting speed, feed rate, the interaction V-f and d-f have P value < 0.05, which means a significant effect on the flank wear in the hard turning process using CBN inserts. The results of ANOVA analysis also showed the need to investigate and use the curve model to describe the effect of the cutting parameters on the flank wear.The influence level of the input factors on the flank wear is also clearly shown on the pareto chart, figure 2. The factors with influence coefficients larger than the standard influence coefficient (12.7) have a great influence on the flank wear.

Table 4. Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	8	31812.9	3976.6	318.13	0.043
Linear	3	6538.2	2179.4	174.35	0.056
d (mm)	1	41	41	3.28	0.321
V (m/min)	1	4282.8	4282.8	342.62	0.034
f (mm/rev)	1	2214.5	2214.5	177.16	0.048
2-Way Interactions	3	5484.9	1828.3	146.26	0.061
d (mm)*V (m/min)	1	624.8	624.8	49.98	0.089
d (mm)*f (mm/rev)	1	2639	2639	211.12	0.044
V (m/min)*f (mm/rev)	1	2221.1	2221.1	177.69	0.048
3-Way Interactions	1	1875.8	1875.8	150.06	0.052

d (mm)*V (m/min)*f (mm/rev)	1	1875.8	1875.8	150.06	0.052
Curvature	1	17914.1	17914.1	1433.12	0.017
Error	1	12.5	12.5		
Total	9	31825.4			

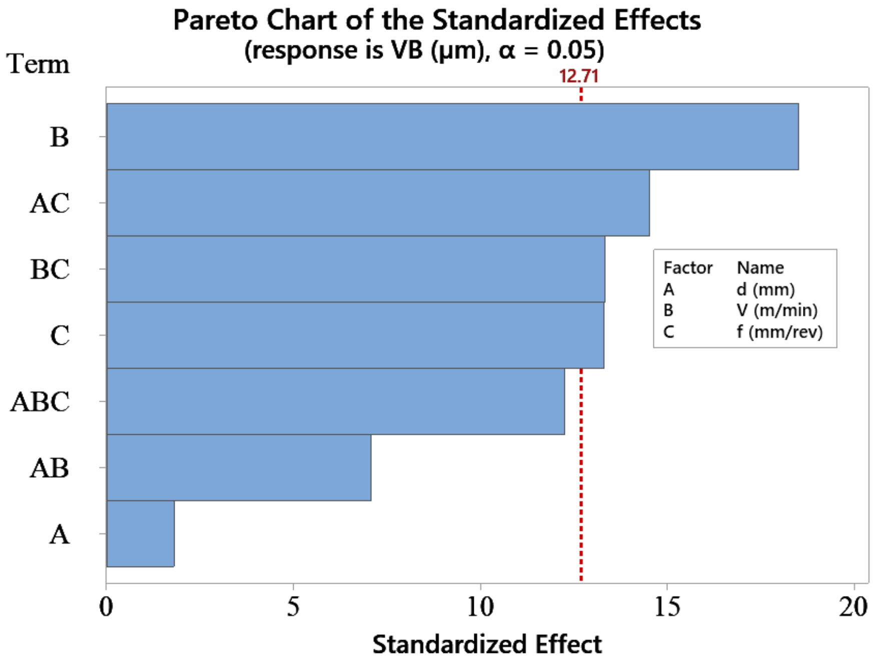

Figure 2. Pareto plot for the flank wear

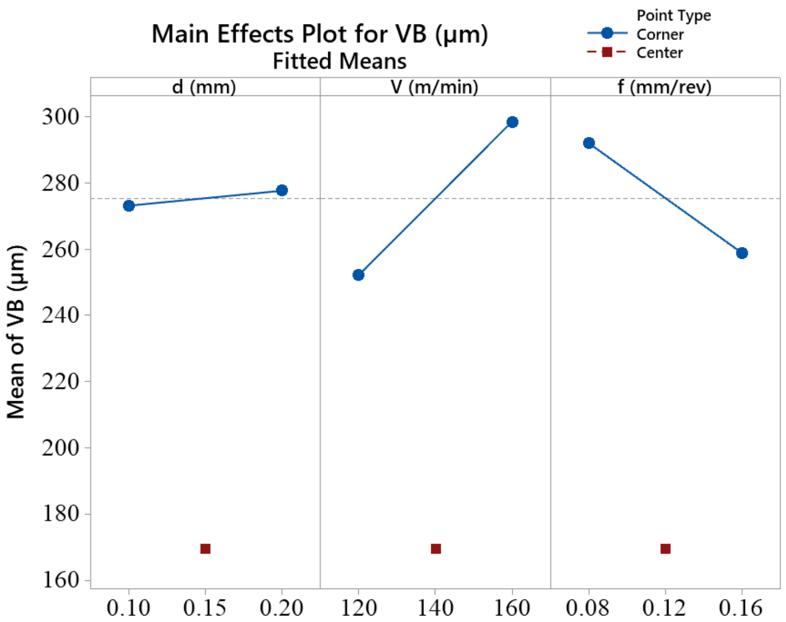

Figure 3. The main effects of the cutting parameters to the flank wear

Figure 3 describes the effects of the machining parameters on the flank wear of CBN inserts in the hard turning the hardened SKD11 steel. The result shows that the cutting speed is the most influential factor in the flank wear. In the investigated range, the feed rate is also a significant effect on the flank wear but less. Cutting depth influences very little to the flank wear. The interacted effects between the cutting parameters to the flank wear were shown in figure 4. The results showed that the interaction of V*f and d*f was largely influenced on the flank wear. With a low cutting speed of 120 m/min, the flank wear does not change with increasing feed rate and depth of cut. With a cutting speed of 160 m/min, the flank wear increases with a reduction in the feed rat from 0.16 to 0.08 mm/rev and decreases with reducing the cutting depth from 0.2 mm to 0.1 mm. With a small cutting depth, the flank wear increases with the feed rate decreases to 0.08 mm/rev.

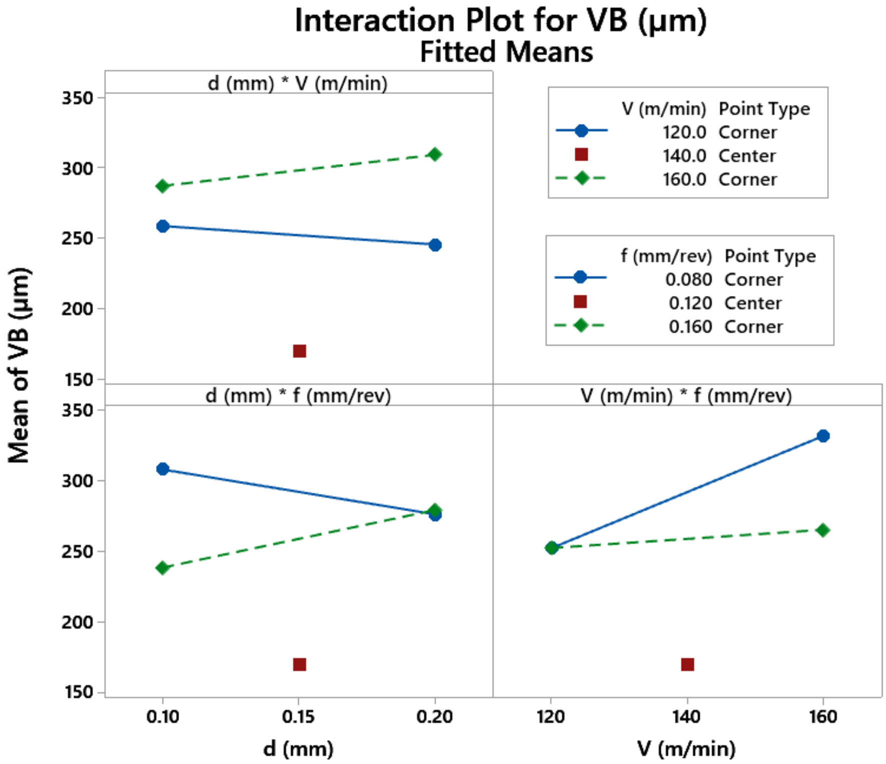

Figure 4. The interaction effects of the cutting parameters to the flank wear

IV. CONCLUSION

The effects of cutting parameters on the flank wear of CBN inserts in the hard turning process of hardened SKD11 (60HRC) have been analyzed by using the full factorial design in the Minitab 19. The cutting speed and feed rate strongly affect on the flank wear in the hard turning of SKD11 steel using CBN inserts. The interaction effects V*f and d*f also significantly affects the flank wear of CBN inserts. The results also indicated that the lineal model is not suitable for describing the effect of the cutting parameters on the tool wear in the hard turning process using CBN inserts. A response Surface Methodology design should be applied for determining the curve model to describe these effects.

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REFERENCES

[1]. Davim, J. P., & Astakhov, V. P. (2011). Machining of Hard Metals.
[2]. Smith, G. T., & Smith, G. T. (1993). Cutting Tool Technology. In CNC Machining Technology. https://doi.org/10.1007/978-1-4471-1748-3_2
[3]. H.A. Kishawy, M.A. Elbestawi, Tool wear and surface integrity during high speed turning of hardened steel with PCBN tools, Proc.Instn. Mech. Eng. 215 (Part B) (2001) 755–767.
[4]. N. Narutaki, Y. Yamane, Tool wear and cutting temperature of CBN tools in machining of hardened steels, Ann. CIRP, vol. 28/1/1979
[5]. Y.K. Chou, J.E. Evans, M.M. Barash, Experimental investigation on CBN turning of hardened AISI-52100 steel, J. Mater. Process. Technol. 124 (2002) 274–283
[6]. G. Poulachon, B.P. Bandyopadhyay, I.S. Jawahir, S. Pheulpin, E. Seguin, The influence of the microstructure of hardened tool steel workpiece on the wear of PCBN cutting tools, Int. J. Mach. Tools Manufact. 43 (2003) 139–144.
[7]. S.Y. Luo, Y.S. Liao, Y.Y. Tsai, Wear characteristics in turning high hardness alloy steel by ceramic and CBN tools, J. Mater. Process. Technol. 88 (1999) 114–121.