

Influence of WC and Co in Cutting Cemented Carbides with PCD and CBN Tools

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Abstract. In this study, turning of the cemented carbides that their WC particle size was standardized were carried out with the PCD and the cBN tools. The WC particle diameter of cemented carbides was about 2 μ m and the Co contents were 10, 15, 20 and 25%, respectively. The influence of the WC particle size and Co contents was investigated. Summary of results are shown as follows: (1) In turning with the PCD tool, the more the Co contents increase, the more the tool wear increases. (2) In turning with the cBN tools, the more the Co contents of the work material increase, the more the tool wear decreases. (3) In turning of the cemented carbides contained the larger quantity of Co, the cBN tools are more effective than the PCD tool.

Introduction

Cemented carbides have high hardness, and they are used for not only cutting tools but also dies. Commonly, the grinding of their products is used for finish machining. On the other hand, the cutting is sometimes used in the efficient processing. However, it is well known that cemented carbides are difficult-to-cut materials and the tool wear is very severe in cutting with the PCD tool [1]-[5]. It is necessary to make clear the machinability in cutting the cemented carbides in detail. In previous study, the tool life was compared among four kinds of cemented carbides. The turning [6], the micro cutting in the SEM [7] and the mist and wet turning [8] were carried out to make clear the tool wear mechanism. As these work materials were not standardized the WC particle size and Co contents, the relationship between tool life and the WC particle size, Co contents could not be made clear. Then in this study, the turning of the cemented carbides that the WC particle diameter was standardized was carried out. The Co contents were 10, 15, 20 and 25%, respectively. The tool wear was measured and the worn flank was observed.

Experimental Method

Work Materials. The work materials are four cemented carbides. Their structures are shown in Figure 1. The diameter of WC particle contained in them is standardized and is about 2 μ m. The Co contents are 10, 15, 20 and 25%, respectively. Their mechanical properties are shown in Table 1. As the Co contents increase, both the hardness and the compressive strength decrease.

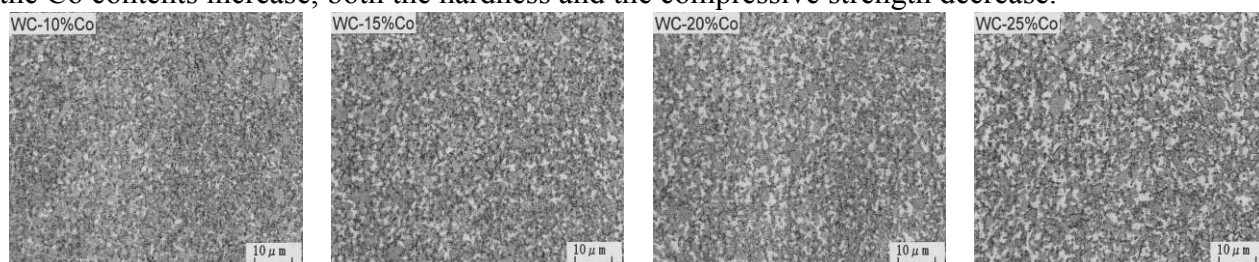


Fig. 1 Structures of cemented carbides

Table 1 Mechanical properties of cemented carbides

Cemented carbide	Density [Mg/m ³]	Hardness [HV]	Compressive strength [GPa]
WC-10%Co	14.55	946	3.570
WC-15%Co	14.05	924	3.535
WC-20%Co	13.60	904	3.485
WC-25%Co	13.15	885	3.237

Tool Materials. The PCD(Poly Crystalline Diamond) and three kinds of cBN(cubic Boron Nitride) tools were used. Their mechanical properties are shown in Table 2. The hardness and transverse rupture strength of the PCD tool is the highest among them. The symbols of three cBN tools are cBN-1, cBN-2 and cBN-3, respectively. The grain contents of cBN-1 and cBN-2 are 50-60 volume %, and one of cBN-3 is 80-90 volume %. The grain size of three cBN tools is similar. The bonding material of cBN-1 and cBN-2 is TiN, and one of cBN-3 is Co.

Table 2 Mechanical properties of tool materials

Tool	Grain contents [Vol%]	Grain size [μm]	Bonding material	Hardness [HV]	Transverse rupture strength [GPa]
PCD	91	12.5	Co	10000	1.70
cBN-1	50 – 60	2	TiN	3200 – 3400	1.00 – 1.10
cBN-2	50 – 60	3	TiN	3200 – 3400	0.95 – 1.10
cBN-3	80 – 90	3	Co	3900 – 4200	0.95 – 1.10

Cutting Experiment. The turning test was carried out with the CNC lathe. The cutting conditions are shown in Table 3. The cutting speed is different in case of the PCD and cBN tools. The feed rate is 0.1 mm and the depth of cut is 0.1 mm. When flank wear width became more than 0.3 mm, the cutting test was stopped.

Table 3 Cutting conditions

Cutting tools	PCD	cBN-1, cBN-2, cBN-3
Cutting speed V [m/min]	15	10
Feed rate f [mm/rev]	0.1	
Depth of cut t [mm]	0.1	
Tool configuration	(-5, -5, 5, 5, 30, 0, 0.8)	
Cutting method	Dry	

Results and Discussion

Tool Wear and Chip in PCD Tool. Figure 2 shows the relation between the flank wear width and the cutting distance when all work materials are turned with the PCD tool. The more the Co contents increase, the more the tool wear increases. It is clear that the Co contents affect on the flank wear in cutting the cemented carbide of WC particle diameter 2 μm. Figure 3 is the optical micro photograph of the flank face and the rake face at when the flank wear width becomes 0.3mm. The symbol of L is a cutting distance. The face wear of all work materials is little. Figure 4 is the SEM photograph of the flank face at when the flank wear width becomes 0.3mm. The adhesion on the flank face seems to be the largest in turning WC-10%Co. Figure 5 is the optical micro photograph of chips. The chip configuration in WC-25%Co is a continuous type and one in WC-10%Co is a segmented type and small.

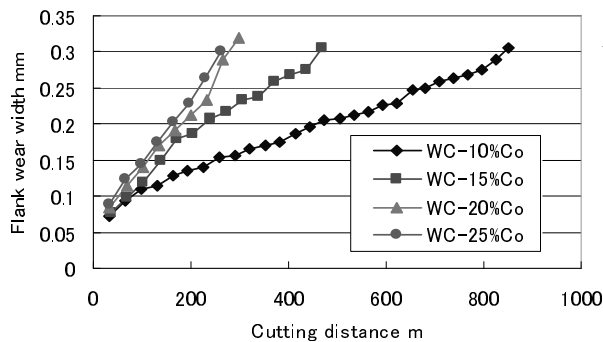


Fig. 2 Relation between flank wear width and cutting distance (PCD)

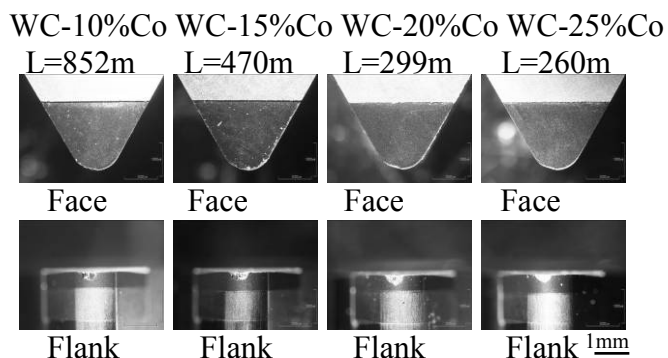


Fig. 3 Optical micro-photographs of PCD

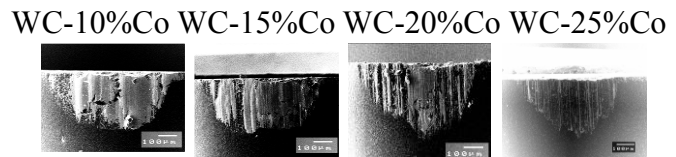


Fig. 4 SEM photograph of flank wear (PCD)

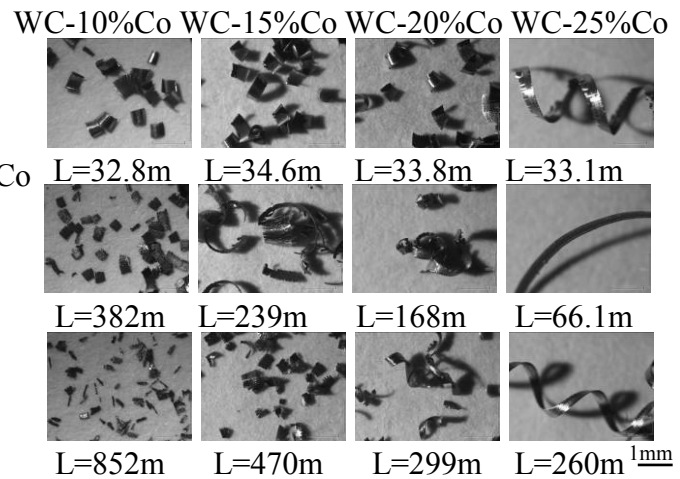


Fig. 5 Optical micro-photographs of chips (PCD)

Tool Wear and Chip in cBN-3 Tool. Figure 6 shows the relation between the flank wear width and the cutting distance with cBN-3 tool. In contrast to the PCD, as the Co contents increase, the tool wear decreases. The wear progress of the cBN-1 and the cBN-2 were similar to that of the cBN-3. Figure 7 is the optical micro photograph of the flank face and the rake face at when the flank wear width becomes 0.3mm. Figure 8 is the SEM photograph of the flank face at when the flank wear width becomes 0.3mm. The adhesion seems to be small. Figure 9 is the optical micro photograph of chips. The chip configuration is a segmented type.

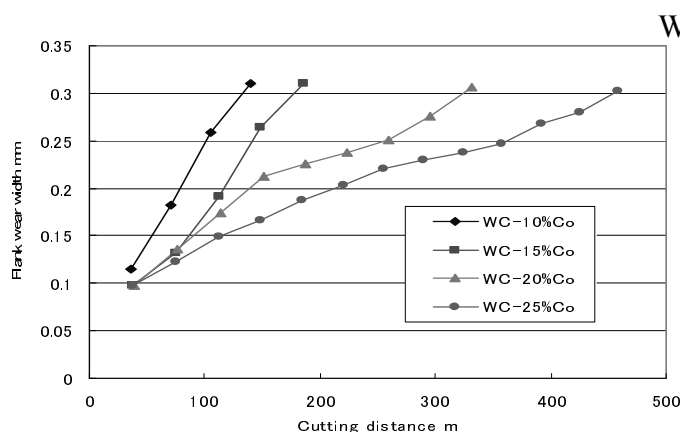


Fig. 6 Relation between flank wear width and cutting distance (cBN-3)

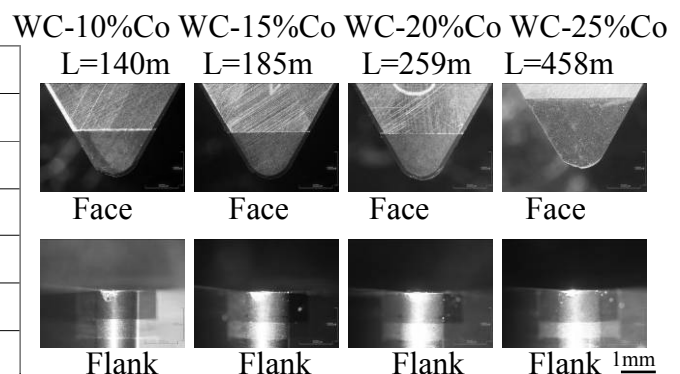


Fig. 7 Optical micro-photographs of cBN-3

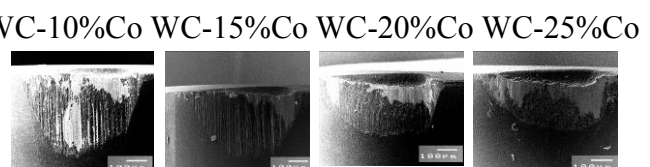


Fig. 8 SEM photograph of flank wear (cBN-3)

Figure 10 shows the relation between the flank wear width and the cutting distance in cutting WC-25%Co with different cBN tools. The flank wear of the cBN-3 is the smallest and one of the cBN-1 is the largest. As shown in Table 2, it is clear that the grain contents and the bonding materials effect on the flank wear width. As compared Fig.2 with Fig.6, the flank wear width of cBN-3 is smaller than one of PCD in cutting WC-20%Co and WC-25%Co.

Conclusions

The main results obtained are as follows:

(1) In turning with the PCD tool, the more the Co contents increase, the more the tool wear increases.

(2) In turning with the cBN tools, the more the Co contents of the work material increase, the more the tool wear decreases.

(3) In turning of the cemented carbides contained the larger quantity of Co, the cBN tools are more effective than the PCD tool.

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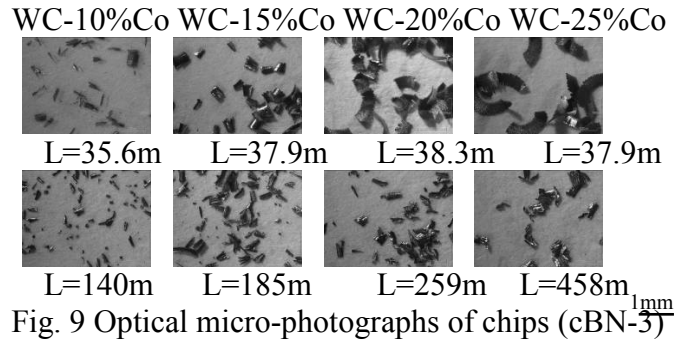


Fig. 9 Optical micro-photographs of chips (cBN-3)

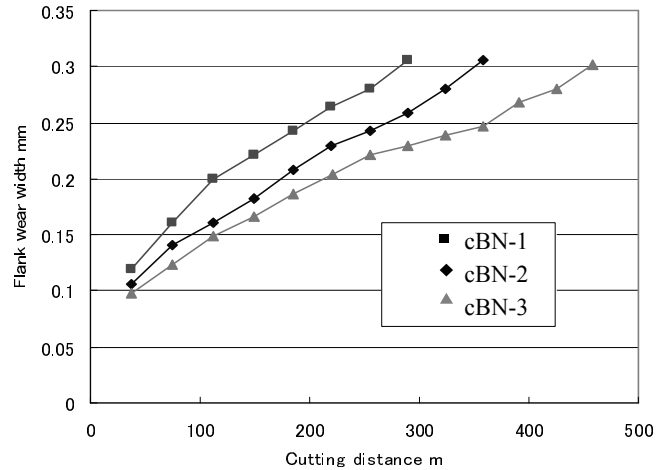


Fig. 10 Relation between flank wear width and cutting distance (WC-25%Co)