EFFECT OF ADDITIONAL CURRENT ON CUTTING MECHANISM OF FREE MACHINING STEELS IN TURNING

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Abstract It is well known that the electro motive force generated at an interface between tool and workpiece in cutting influences on the shape of built-up edge and the tool life. There is, however, few reports about the current flow in the closed circuit of tool-workpiece-machine on the behavior of deposited layer called “belag” observed in machining workmaterials such as calcium deoxidized steel and BN added steel and so on. This paper deals with the machinability of steels in turning with additional current. Tested workmaterials were plane carbon steel JIS S45C and BN added steel which has good machinability at high cutting speed. Turning tests were performed by carbide tool P30 in order to investigate the influence of electrical conditions of closed circuit system on the cutting mechanism of BN added steel. The tool life, cutting force, chip geometries and others were investigated practically and these results were discussed.

Key words turning, carbide tool, tool wear, free machining steel, belag, AlN, electrical current

1 INTRODUCTION

It is well known that the electro-motive force EMF is generated at tool-workpiece interface in metal cutting. This thermoelectric voltage is generally mV order. The electric current depends on the resistance of its circuit through the closed system. In previous reports [1-7], it was investigated that the thermo current in the closed circuit system influenced on the cutting mechanism. When the tool holder was electrically insulated from the workpiece and machine tool, tool wears after turning steels and cast irons were reduced than those of un-insulated cutting[4]. Additional current supplied from outer power source also influenced tool wear. Only a few mille ampere current supply increased tool life about two times as long as that of conventional cutting [2]. However, reports about its effect agree with one another, further investigation is required to clarify that. Though it is obvious that thermoelectric current influenced somewhat on cutting mechanism.

Recently high speed and high efficient machining is strongly required. The causes of tool damage are classified into mechanical wear and thermal wear. Thermal wear contains plastic deformation, texture changes, oxidation, diffusion, chemical reaction, electro-chemical reactions and so on. The higher cutting speed becomes to achieve high efficient machining, the more thermal wear causes. So several kinds of free machining steel were developed and used for various purposes and required to be

Table 1 Chemical compositions and hardness of workmaterials

	Chemical compositions of workmaterial mass%							Hardness Hv
	C	Si	Mn	S	Sol.Al	N	B	
S45C	0.44	0.21	0.75	0.012	0.019	125 ppm	63ppm	240
S45C-BN	0.44	0.19	0.74	0.018	0.026	-	-	232

improved its machinability at higher cutting speed.

There is, however, few reports about the effect of electric current in the closed circuit system on the behavior of deposited layer called “belag” observed in cutting free machining steels such as calcium deoxidized steel [8] or BN added steel [9,10]. This paper deals with the machinability of BN (Boron nitride) added steel in turning with additional current. Tested workmaterials were plane carbon steel JIS S45C and BN added steel, which has good machinability at high cutting speed in turning. Concerning the BN added steel, AlN is observed at the tool wear region of P grade carbide tool after turning at high cutting speed [9]. One of the main reasons of outstanding machinability of BN added steels is that the deposited layer containing AlN acts as a diffusion barrier at tool-chip interface.

Turning tests were performed by carbide tool P30 in order to investigate the influence of electrical condition of the closed circuit system on the cutting mechanism. The tool life, cutting force, chip geometries and others were investigated practically and these results were discussed.

Table 2 Cutting conditions

Work:	JIS S45C, S45C-BN
Tool:	Carbide P30 (SNGN120408)
Cutting speed	60~300m/min
Depth of cut	0.5mm
Feed rate	0.1mm/rev
Coolant	dry

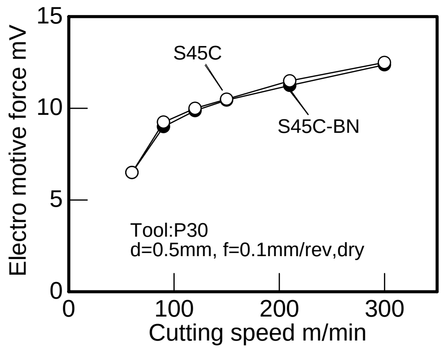

Fig. 1 EMF in turning of two tested workmaterials with carbide tool P30 for various cutting speed

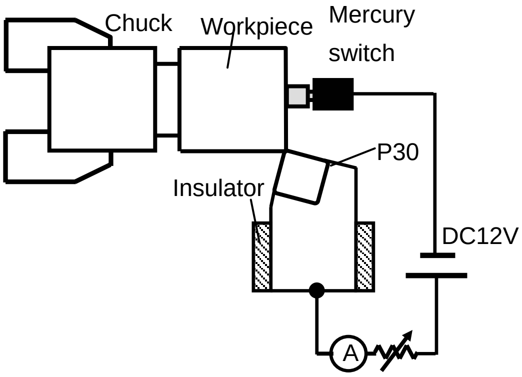

Fig. 2 Schematic of experimental set up (positive direction)

2 EXPERIMENTAL PROCEDURE

Table 1 shows the chemical compositions and hardness of the workmaterials tested. Plane carbon steel JIS S45C was used for the standard. BN added steels contain approximately 80 ppm of boron, 150 ppm of nitrogen and a certain level of Al. All of these steels were normalized under the conditions of 850 deg. C. for 2 hours.

Turning tests were carried out at the cutting conditions shown in Table 2. Tested tool was carbide tool P30 that has the form of SNGN120408. In turning, cutting was interrupted in order to measure the width of flank wear by a micrometer-equipped microscope and the maximum crater depth by a surface roughness-measuring instrument.

It is well known that in metal cutting the EMF is generated at tool-work interface by seebeck effect. This EMF is often used in order to investigate cutting temperature in tool-workpiece thermocouple method. Fig. 1 shows EMF in turning two tested workmaterials with the carbide tool P30 for various cutting speed. Each EMF voltage increased with the increase of cutting speed and reached at 16mV at the cutting speed 300m/min. Electrical resistance of the machine tool influences the current in closed system tool-workpiece-machine. In order to avoid its influence, cutting test were performed with outer circuit without machine tool shown in Fig. 2. In this paper, the current direction corresponding thermo electric current is positive direction and opposite is negative directions as shown in Fig. 2. Electrical conditions which cutting test were carried out shows as follows,

Conventional: The closed circuit is composed with tool, workpiece and machine tool.

Insulated: Tool holder is electrically insulated from the machine tool.

Additional current: the DC power is supplied in the closed circuit that consists of tool, workpiece, mercury switch and variable resistance as shown in Fig. 2.

Short-circuit: Tool holder is insulated from machine tool and connected to mercury switch adopted workpiece directory.

3 EXPERIMENTAL REZULTS AND DISCUSSIONS

Fig. 3 shows the wear progress curves of the carbide tool P30 when turning S45C and S45C-BN at the following conditions; conventional, insulated, short-circuit and cutting with additional current at the cutting speed 200 m/min. When conventional turning S45C, flank wear width VB increased rapidly from the initial cutting. On the other hand, in the case of S45C-BN, flank wear rate were very small. According to flank wear when turning both S45C and S45C-BN, there wasn’t remarkable difference among the wear progress of conventional cutting, insulated cutting, cutting with additional current 5mA of any directions. This tendency was observed about crater wear. However in the case of turning S45C-BN with short-circuit (+7mA) and with additional current 10mA of any directions, maximum crater depth was reduced radically to almost half the others. The effects of electric current in closed circuit were remarkably found on the maximum crater depth than on the flank wear. When turning S45C, adhered workpiece was observed on the rake face, so these appearance crater depth might show smaller crater depth than actual crater depth.

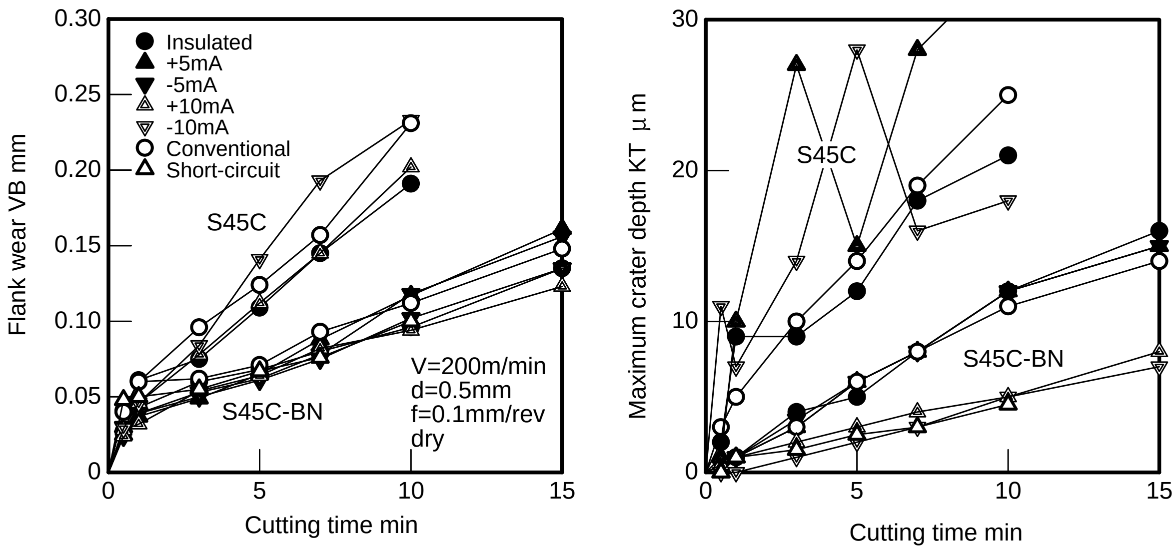

Fig. 3 Wear progress curves of carbide tool P30 when turning S45C and S45C-BN under following conditions, conventional, insulated, short-circuit and with additional current at the cutting speed 200 m/min

Fig. 4 shows the relationship between cutting speed and cutting force when turning tested steels at various electric conditions. Principal force, thrust force and feed force decreased with the increase of cutting speed when turning both steels except for under 100m/min built up edge was generated. In the case of S45C, principal force of the insulated cutting was same as that of conventional cutting and cutting with additional current showed larger cutting force than that of conventional cutting. In the case of S45C-BN, additional current and insulated cutting showed smaller cutting force than those of conventional cutting.

Fig. 5 shows the shear angle ϕ when turning S45C and S45C-BN at various electric conditions. These shear angle were obtained by calculating from chip thickness measured with micrometer. It is shown that the shear angle increased with cutting speed. The shear angle when turning BN added steel was larger than that of S45C. The shear angle of insulated cutting was larger than that of conventional cutting and additional current caused the largest shear angle when turning both workmaterials.

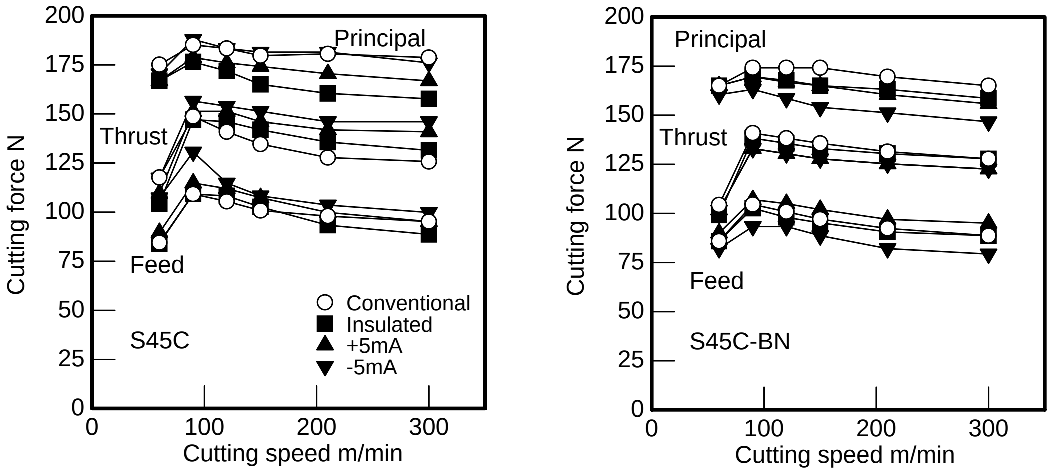

Fig. 4 Relationship between the cutting speed and the cutting force when turning tested steels under various electric conditions

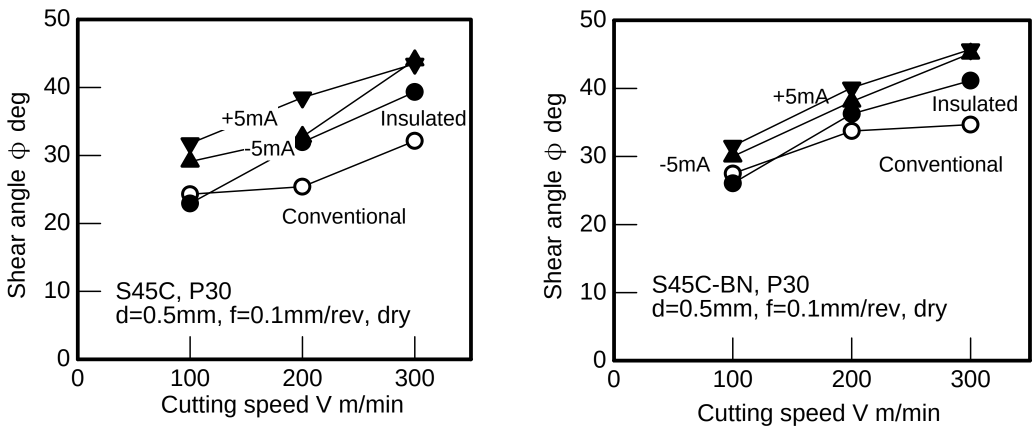

Fig. 5 Shear angle ϕ when turning S45C and S45C-BN with P30 carbide tools under various electric conditions

Fig. 6 shows the relationship between the tool wear of carbide tool P30 when turning S45C and S45C-BN at the cutting speed 200m/min for 10 min and electrical current in the closed circuit. When turning S45C, dispersion of measured maximum crater depth was larger than that of S45C-BN. It seems that the measured depth was smaller than the actual one because of adhesion of the workmaterials. So plots of crater depth in turning S45C shows maximum value from cutting start until 10min.

When turning medium carbon steel at these cutting speed, high cutting temperature promotes the tool wear particularly thermal damage like diffusion, oxidation and so on. It is said that at tool-chip interface under high cutting temperature, Co and C contained in carbide tool diffused into workmaterials, Fe diffused into tool, so that the wear resistant of tool was decreased and tool wears was promoted. However when turning BN added steel, AlN deposited on tool surface and acts as diffusion barrier.

In the case of current direction was negative, the flank wear when turning S45C decreased with the increase of current flow. On the other hand in the case of current was negative direction, it increased with the increase of current flow. It was thought that the increase of negative direction current promoted tool wear. However, in the case of BN added steel AlN belag prevented increase of tool wear. According to crater wear when turning S45C-BN in spite of flow direction, current flow became more than 5mA, crater depth decreased to almost half that of others. As is observed, effect of additional current was shown more remarkably on crater depth than flank wear. The cause of the decrease of crater wear isn't obvious yet and required further investigation.

We can say that the direction of current flow influence not on the tool wear in turning S45C-BN but on that of S45C. In the given cutting conditions, most optimum cutting condition was the case that turning BN added steel in the case of current flow in closed circuit system was 10 mA.

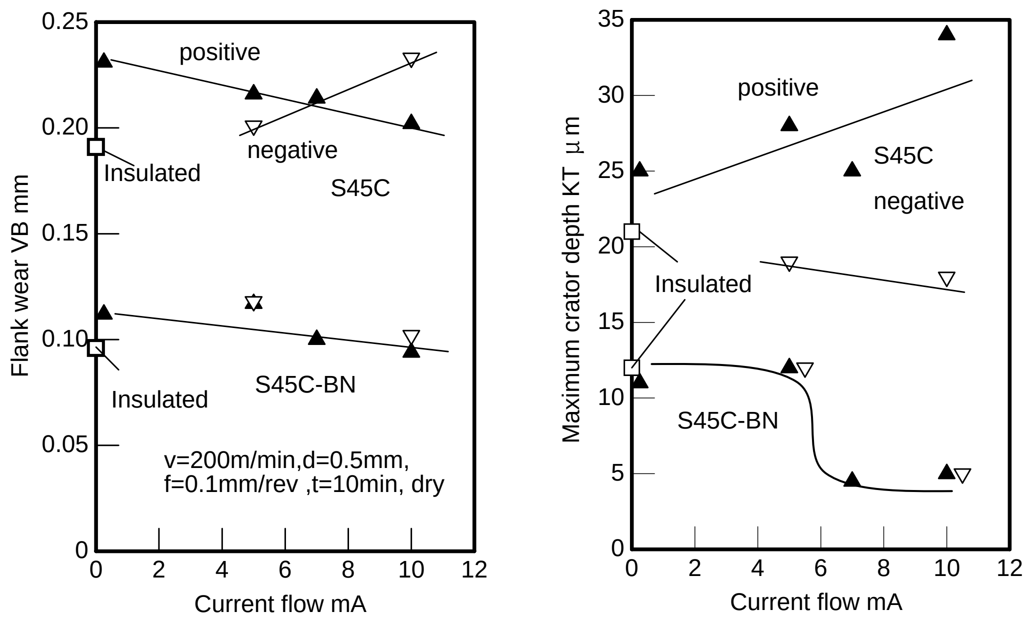

Fig. 6 Relationship between the tool wear of carbide tool P30 and the current flow in closed circuit when turning S45C and S45C-BN at the cutting speed 200m/min for 10 min

4 CONCLUSIONS

High speed turning of carbon steel with P grade carbide tool was conducted at the cutting speed of 60～300m/min. The relationship between tool wear and additional current was discussed. The results can be summarized as follows:

1) When current flow in the closed circuit became up to about 7mA, tool wear in turning S45C-BN reduced, especially crater depth were reduced remarkably.
2) Cutting force was reduced with increase of current flow in the closed circuit when turning S45C-BN, although they increased with the increase of current in the case of S45C.
3) When turning with tool insulated from machine tool and with additional current, shear angle became larger with the increased of electrical current in circuit than that in turning both S45C and S45C-BN.

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