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Effect of Tool Thermal Characteristics on Hardened Steel Turning Performance

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ABSTRACT

The white layer formed in hard cutting is widespread due to the intensive property of hardened steels and it also has important effects on machined surface integrity and service performance. In order to study the issue about the formation of white layer and concluding the relationship between the characteristics of white layer, tool flank temperature and the thermal conductivity, we used SCM415 (carburizing and quenching) as the object to carry out a series of high-speed dry cutting tests and observing the white layer by using optical microscope Axio Scope A1 in this paper. By analyzed these results we found that the temperature of tools is lower when the thermal conductivity of tool is higher and the greater the thermal conductivity of tool is, the more obvious the influence of the temperature change on the flank face is. When the flank temperature increased, the thickness of white layer increased. However, the white layer thickness is reduced, when the flank temperature are more than a certain range. Flank wear in a certain range can reduce the thickness of white layer and improve the surface quality.

INTRODUCTION

Hardened steel as one of the typical materials that high hardness, high strength and high wear resistance is widely used in related engineering field. In traditional machining, grinding is generally used as the finishing process of hardened steel. However, low productivity, high pollution and high cost are the disadvantages of the traditional machining. With the development of high speed cutting technology, the high hardness materials can be processed directly and make cutting instead of grinding become a reality (This technology is also known as hard cutting).

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Compared with the traditional grinding process, hard cutting has the advantages of high productivity, less equipment investment, high overall processing accuracy and clean [1]. Tönshoff H K [2] et al in grinding and hard turning contrast tests found that acquiring the same quality of the machined surface, hard turning than grinding time can be reduced by 60%. The process is not expected to be widely used in industry, though the hard turning has such a big advantage [3]. The main reason is the processing stability or the surface integrity is not easy to be insured. The white layer formed by hard cutting is easy to cause early spalling failure and formation of fatigue crack and it also seriously affects the performance and surface integrity of the work piece. Moreover, the formation mechanism of the white layer in the international scope is still in the stage of argument [4-5]. Accordingly, exploring the mechanism and the main influencing factors of the white layer is an important research in the field of hard cutting.

In the current study, scholars generally thought the white layer in hard cutting is caused by mechanical load or thermal load or the two combined action. There are Duan Chunzheng [6], Dai Sujiang [7], Chen Tao [8], and N. Baizeau [9], T. Jouini [10] et al used the different cutting parameters, different tool wear and changing the tool angle to carry out experiments. They pointed out the relation between the change of white layer and the change of processing conditions then further analyzed the mechanism of white layer formation. Most of them are believed that the white layer is caused by these factors about high cutting temperature, high cooling rate, severe friction and extrusion between the tool with the work piece and so on. However, few scholars taken a discussion from the effects of cooling characteristics of cutting tools with temperature in cutting area and the relation between the thickness of white layer and real-time cutting temperature, etc.

In order to study the relation between thermal conductivity, tool flank temperature and white layer formation, different cutting parameters, different flank wear and different thermal conductivity of PCBN tool were used in hardened steel SCM415 cutting heat and surface characteristics tests. And then, optical microscope was used to help us analyze the microstructure of the white layer.

EXPERIMENTAL PROCEDURE

In this paper, the horizontal CNC lathe (CY—K360n/1000) was used for testing is the production of the Yunnan machine. PCBN tools with the same geometric parameters but different thermal conductivity were used in tests. The characteristics of the tools are shown in Table I. Cutting parameters and flank wear VB are shown in Table II. Tool flank temperature T in cutting was measured by two-color pyrometer with fiber coupling. As shown in Figure 1, when the tool nose contacts the $\phi 0.6mm$ through-hole of the work piece, the flank heat radiation will be received by the optical fiber which in the hole. The heat radiation signal is transmitted to the two-color pyrometer through the optical fiber. Then, the heat radiation signal received by the two-color pyrometer is converted into temperature data. The microstructure of the white layer was observed by optical microscope after the metallographic samples made by cold inlaid.

RESULTSAND DISCUSSION

Effects of Tool Thermal Conductivity on Flank Temperature

The relationship between tool thermal conductivity and flank temperature is shown in Figure 2.On the one hand, from the overall trend, high tool thermal conductivity can reduce the tool flank temperature. On the other hand, when tool thermal conductivity is $40-60(W/m\cdot K)$ and $50-70(W/m\cdot K)$, the effect of tool thermal conductivity on flank temperature is relatively small. As well, when tool thermal conductivity is increased to $60-80(W/m\cdot K)$, the effect of tool thermal conductivity on flank temperature is significantly enhanced.

Effect of Flank Temperature on White Layer Thickness

The relationship between flank temperature and white layer thickness is shown in Figure 3. In the cutting experiment of three kinds of flank wear value, all white layer thicknesses increase with the increase of flank wear at first. However, when flank temperature reaches a certain value, white layer thickness decreases with the increase of flank temperature, which indicates that the cutting temperature is not the only factor that affects white layer thickness [11]. In addition, by comparing between the $VB=0mm$, $VB=0.1mm$ and $VB=0.05mm$ curve, it is found that white layer thickness not entirely along with the increase of flank wear at the same flank temperature, but in a certain range of flank wear surface can obtain the best quality.

CONCLUSIONS

(1) Flank temperature decreases with the increase of tool thermal conductivity. The greater tool thermal conductivity is, the more obvious the influence on the flank temperature change is.

(2)In a certain range of the flank temperature, white layer thickness increases with the increase of flank temperature. However, when flank temperature reaches a certain value, white layer thickness decreases with the increase of flank temperature, which indicates that the cutting temperature is not the only factor that affects white layer thickness.

TABLE I. CHARACTERISTICS OF CUTTING TOOL.

Tool Name	CBN $(vol\%)$	Thermal conductivity $(W/m\cdot K)$
PCBN I	45-55	40-60
PCBN II	65-75	50-70
PCBN III	85-95	60-80
PCBN IV	85-95	100-110

TABLE II. CUTTING PARAMETERS AND FLANK WEAR.

Cutting speed $v(mm)$	Feed rate $f(mm)$	Depth of cut $a_p(mm)$	Flank wear $VB(mm)$
100,150,200	0.08	0.2	0.,0.05,0.1

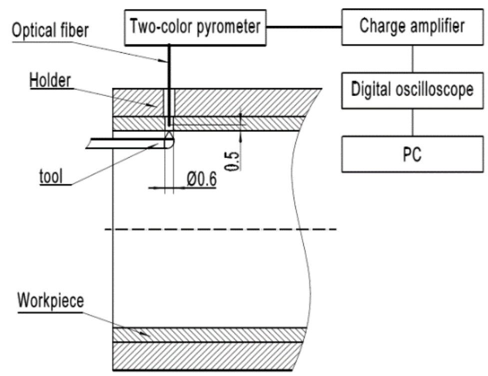

Figure 1. Detection device for tool flank temperature.

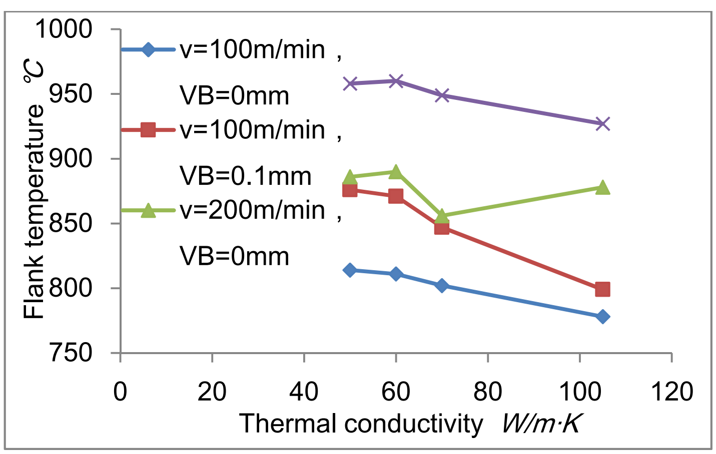

Figure 2. Relation between thermal conductivity and tool flank temperature.

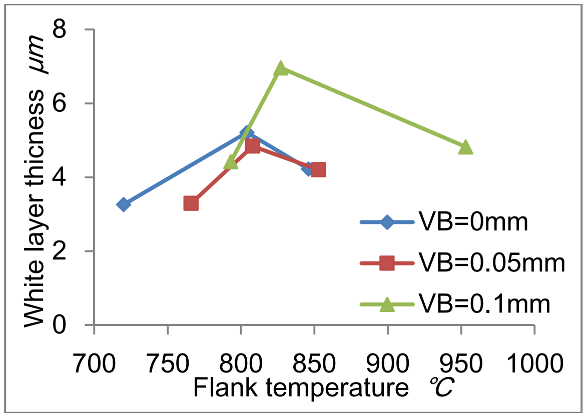

Figure 3. Relationship between flank temperature and white layer thickness.

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