Novel cutting tools having micro textured surface for steel cutting

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Abstract

In order to improve wear resistance of cutting tools in the steel cutting, cutting tools with periodical stripe-grooved surfaces on their rake face have been developed in our study. In this paper, several cutting tools with various texture dimensions were fabricated and the detailed relationship between the texture dimensions and the wear resistance was investigated. Also, the influence of the cutting conditions, such as cutting speeds and the presence or absence of the fluid supply, on the optimal texture dimension was evaluated in order to provide guidelines for developing tools with textured surfaces.

1. Introduction

In the cutting of steel materials, one of the most important factors of a cutting tool is how to prevent tool wear resulting from the high mechanical stress and heat generated at tool-chip interface. To solve the problem, we adopted a surface engineering approach, namely, a functionalization of tool surfaces by textures [1]. Our previous studies have led to the development of several prototype cutting tools with various surface textures on their rake face [2-3]. As for the steel cutting, we developed periodical stripe-grooved surfaces for cutting tools, referred to as “micro stripe texture”, to improve tool wear resistance. As a result, face milling experiments on medium carbon steel showed that the textured surfaces significantly decreased crater wear on the tool rake face [3]. However, in order to establish this study as a practicable technology, it is necessary to understand the detailed anti-wear behavior of the textured rake face and provide guidelines for determining texture dimensions under various cutting conditions.

In this study, several cutting tools with various texture dimensions were fabricated and their wear resistances were evaluated. Moreover, the influences of the texture dimensions and the cutting conditions on the anti-wear behaviors were investigated.

2. Micro stripe texture for cutting tool surface

2.1 Cutting tool with micro stripe textured surface

In order to generate the surface texture on the tool rake face, laser surface texturing (LST) using femtosecond laser was employed. Applying this method, periodical rectangular grooves (micro stripe texture) were generated on the rake face of a WC-Co cemented carbide cutting tool (Sumitomo Electric Hardmetal Corp., SEKN42MT: ISO P10-type, Non-coated tool) [3]. The micro stripe grooves that are 5 μm deep and 20 μm wide/apart were generated on the rake face of the WC-Co cemented carbide cutting tool with a 100-μm-wide chamfer as shown in Fig. 1. In order to evaluate the influence of groove directions, two types of cutting tools with different textured surfaces were manufactured. The cutting tool with micro stripe grooves parallel to main cutting edge is named MS-1 (Fig. 1), and the one with micro stripe grooves orthogonal to main cutting edge is named MS-2.

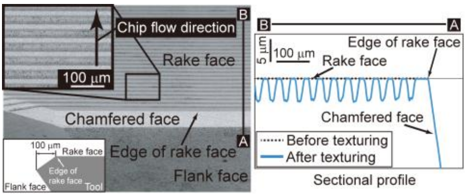


Figure 1: Developed cutting tool with micro stripe texture (MS-1)

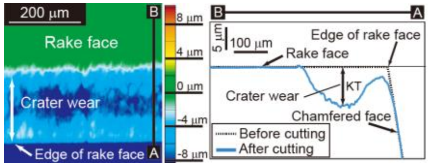
Table 1: Cutting conditions

Workpiece	Medium carbon steel (C: 0.51-0.55 %)	
Tool (Insert)	Cemented carbide P10	
Tool geometry	Axial rake angle	20 deg.
	Radial rake angle	-3 deg.
	True rake angle	12.4 deg.
Cutting speed	200 m/min (800 rpm)	
Depth of cut	2 mm	
Feed rate	0.20 mm/rev.	

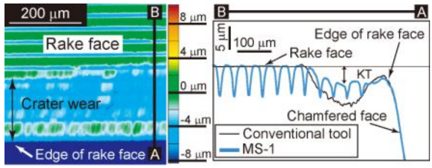
2.2 Wear resistance of micro stripe textured rake face

Face milling experiments involving both a cutting tool with a polished surface (conventional tool) and the developed tools (MS-1, MS-2) were conducted on a medium carbon steel (carbon content: 0.51-0.55%). Table 1 lists cutting conditions. An emulsion-type cutting fluid was supplied at a flow rate of 12.6 L/min in wet cutting experiments.

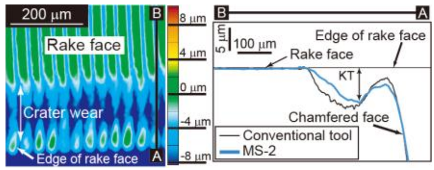
Fig. 2 shows three dimensional geometries and the sectional profiles of the rake face of the conventional and developed cutting tools after cutting for 300 m. As shown in Fig. 2 (a), severe crater wear that was 10 μm deep and 200 μm wide occurred on the rake face of the conventional tool. In contrast to this, we found that the maximum depth of the crater wear of the tool with the micro stripe grooves, which are parallel to the edge (MS-1), was significantly reduced from 10 µm (obtained in the conventional tool) to 3 µm (Fig. 2 (b)), while MS-2, which has the grooves orthogonal to main cutting edge, slightly suppressed the wear (Fig. 2 (c)). In the case of MS-2, it is considered that chips flowing over the rake face of the tool enter into the grooves and lead to increased wear. On the other hand, our previous study [3] revealed that the grooves parallel to main cutting edge bring about two main effects, such as (i) a micro-reservoir for a cutting fluid and (ii) a micro-trap for wear debris, under wet cutting conditions, resulting in the excellent wear resistance.



(a) Conventional tool



(b) MS-1



(c) MS-2

Figure 2: Rake face of the cutting tools after 25 m of cutting

3. Influence of texture dimensions on wear resistance

In order to investigate the relationship between the texture dimensions and wear resistance, several cutting tools with different texture dimensions were manufactured. Table 2 summarizes the characteristics of the prepared tools, which are identified with MS-3 to MS-6. All textures were generated parallel to the main cutting edge. Cutting experiments were conducted at cutting speeds of 150, 200, 300 and 400 m/min under wet and dry cutting conditions, respectively, until the maximum depth of crater wear when using the conventional tool reached 10 µm.

Fig. 3 shows the rate of the amount of crater wear on each developed tool with respect to that of the conventional tool under the different cutting conditions. As shown in these figures, it was confirmed that the wear resistances of the textured rake faces are strongly correlated with their dimensions and the optimum texture differ depending on the cutting conditions. Under wet cutting conditions, the textures with wider grooves such as MS-5 or MS-6 appear to be more effective

Table 2: Texture patterns

Tool name	Width of convex area	Width of concave area
MS-1	20 µm	20 µm
MS-3	50 µm	20 µm
MS-4	100 µm	20 µm
MS-5	20 µm	50 µm
MS-6	20 µm	100 µm

in suppressing crater wear as the cutting speed increases. This is attributed to the fact that the thermal load at tool-chip interface becomes a key factor in the promotion of the crater wear as the cutting speed increases, and textures that can retain more cutting fluid on the rake have an advantage in suppressing the amount of the wear. In contrast to this, the wider grooves did not always exhibit excellent wear resistance under dry cutting conditions, as shown in Fig. 3 (b). The reason for this is that, without the cutting fluid, the wider grooves show negative effects of the textured surface, such as increase in actual contact stress on the convex areas, resulting in the severe crater wear.

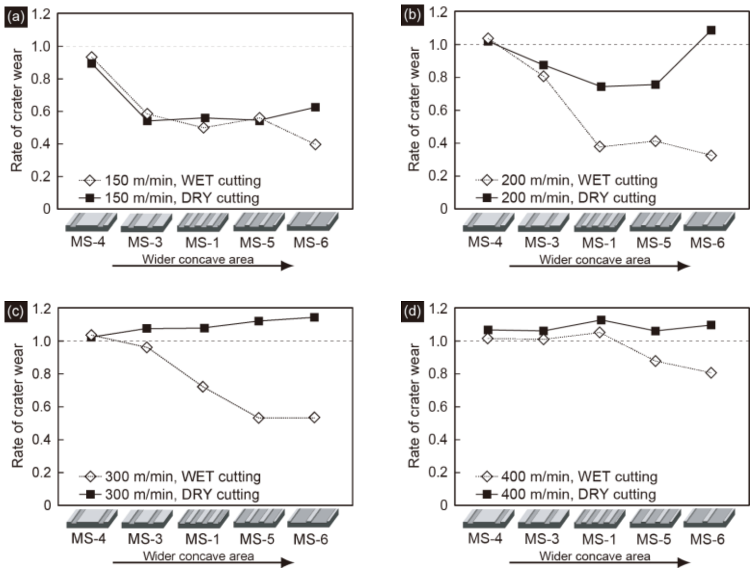


Figure 3: Rate of the crater wear of each developed tool with respect to that of the conventional tool under different cutting conditions.

4. Conclusions

Novel cutting tools with periodical grooved surfaces are developed to improve crater wear resistance in the steel cutting. Our experimental results revealed that the developed tools significantly suppress the crater wear and that the wear resistances depend strongly to the texture dimensions and cutting conditions.

References:

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