Cutting Characteristics and Machined Surface Properties of Co-Cr-Mo Alloy Plate with Cemented Carbide and cBN Tools for Artificial Hip Joints

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Abstract

The purpose of this paper is to investigate cutting characteristics and machined surface properties of Co-Cr-Mo alloy plate with cemented carbide K10 and cBN tools. The cBN tools gave better performances than the cemented carbide tools both on surface finish and cutting forces.

1 Introduction

Co-Cr-Mo alloy is one of the most difficult-to-cut materials because of its higher strength at high temperature and hardness. Co-Cr-Mo alloy has been used in a wide variety of industrial fields, and has begun to be applied to artificial joints in recent years. Although widely used, the cutting characteristics and the machined surface properties have not yet been studied adequately. Effects of cutting conditions such as depth of cut t_1, depth of cut in last pre-cutting t_L, cutting speeds, and tool materials on the surface finish and the cutting forces were determined.

2 Experimental set up

The cutting experiment has been conducted on an NC orthogonal precision cutting apparatus with a stiffness of 78.4 N/µm and a positioning accuracy of ±1µm. Co-Cr-Mo alloy plates for artificial joints were used as the work material. Cemented carbide K10 and cBN tools were used as the tool material. Oil-based cutting fluid was selected as the cutting oil in all experiments. The cutting forces were measured by a piezoelectric dynamometer. The depth of last pre-cut t_L ranged from 10 to 100 µm. The experiment has some cutting processes to exactly control deformed layer under the machined surface because the cutting forces depend on thickness of the deformed layer in the part to be cut. The thickness of deformed layer changed according to t_L. Therefore, t_L was one of the important parameter in this experiment. The depth of cut t_1 also ranged from 10 to 100 µm. Table 1 summarizes the cutting conditions.

Table 1: Cutting conditions

Work material		Co-Cr-Mo alloy
Tool material		Cemented carbide K10, cBN
Tool geometry	Rake angle α°	0
	Relief angle ε°	7
Cutting form		Orthogonal cutting
Cutting speed V m/min		5.3, 25.7, 50
Depth of cut t_1 µm		10, 30, 50, 70, 100
Depth of cut at last pre-cutting t_L µm		10, 30, 50, 70, 100
Cutting oil		Oil-based cutting fluid

Fig.1 shows the Vickers microhardness distribution in the deformed layer of Co-Cr-Mo alloy plate, which means the Vickers microhardness distribution in pre-cut surface in the experimental results as shown later. It is obvious that thickness of the deformed layer couldn't be more than 50 µm depth for every depth of cut, when cutting with Co-Cr-Mo alloy.

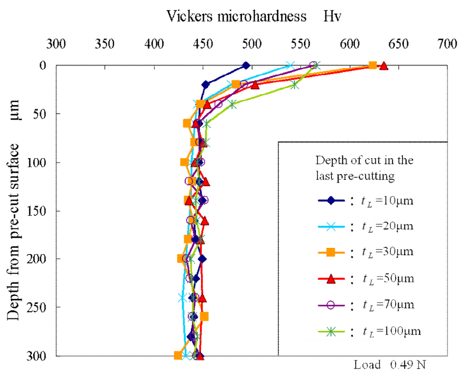


Figure 1: Vickers microhardness distribution of machined surface

3 Experimental results and discussion

Fig.2 shows the cutting forces in the case of V=25.7 m/min with the K10 and cBN tools. It is a little difficult to recognize differences between two tools at less than 50µm depth of cut where deformed region in the pre-cut surface was generated.

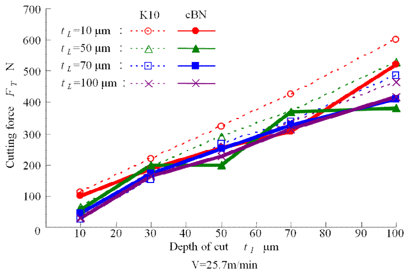


Figure 2: Depth of cut effects on cutting forces

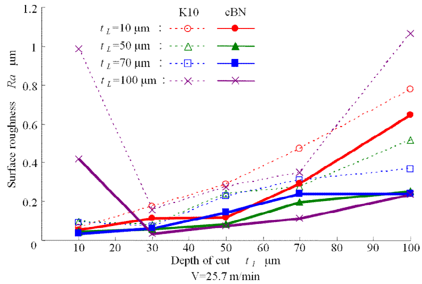


Figure 3: Depth of cut effects on *Ra*

On the other hand, the forces by the cBN tool were lower than the K10 tool at more than 50µm depth of cut where non deformed region in front of the tool edge could be found.

Fig.3 shows surface roughness *Ra* on the same cutting condition as in Fig.2. The roughness *Ra* value also presented slight differences between the two tools at less than 50µm depth of cut. However, the cBN tools offered lower *Ra* values than the K10 tools at more than 50µm depth of cut. It is noteworthy that the cBN tools provided smoother surfaces even at larger depth of cut.

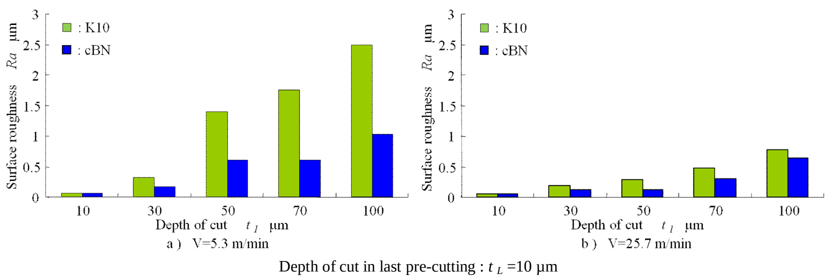


Figure 4: Cutting speed effects on *Ra*

Fig.4 shows cutting speed effects on the roughness *Ra* in the case of t_L=10 µm. The cBN tools provided smoother surface than the K10 tools in all cutting speeds. It is interesting that the roughness *Ra* by the cBN tools were much lower than the K10 tools at over 50 µm depth of cut and V=5.3 m/min as shown in Fig.4 a). The roughness *Ra* were definitely reduced by the two tools as the cutting speed increased. Higher cutting speeds inevitably localized deformation and fracture region around the tool edge, which results in lower surface roughness.

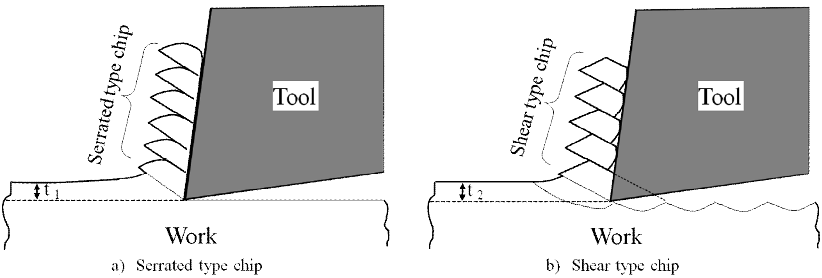
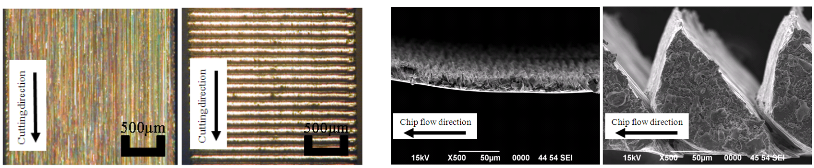


Figure 5: Serrated and shear type chip formation

Fig.5 illustrates chip formation mechanisms of both serrated and shear type. Serrated type chip has a number of trapezoidally-shaped segments like a saw tooth, where adiabatic localized shear periodically occurred. Nevertheless, this type can achieve a relatively smooth machined surface because there is no crack generated from the tool tip which results in overcutting.

Meanwhile, the shear type chip usually causes overcutting beyond the nominal depth of cut. The experimental results indicated that serrated type chip formation is generated at less than 50 µm depth of cut, whereas shear type chip formation was seen at more than 50 µm. As the cutting speed increased, smaller t_1 and t_L produced the serrated chip formation [1], however, larger t_1 and t_L in cBN tool cutting produced serrated type chip formation.

Fig.6 shows micrographs of machined surfaces and chip with the K10 tool in serrated and shear type chip formation.



i) t_L=10, t_1=10 µm ii) t_L=10, t_1=100 µm

a) Machined surface

i) t_L=10, t_1=10 µm ii) t_L=10, t_1=100 µm

b) Side surface of chip

Cutting speed : V=25.7 m/min

Figure 6: Machined surface and chip in serrated and shear types chip formation

References:

[1] T. Kaneeda, T. Nishi & K. Kinugawa, Cutting characteristics of Co-Cr-Mo alloy for artificial joint, The Bulletin of Okayama University of Science, 44, A (2008) pp.117-122.