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Effect of cutting edge preparation of coated tools on their performance in milling various materials

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ABSTRACT

The cutting edges of coated tools are commonly treated in separate production steps during tool manufacturing. Various methods can be employed, focusing on the cutting edge strengthening by its rounding or by more complicated geometries including chamfer and optimized tool wedge radius and angles. The efficiency of diverse cutting edge preparations on the wear behaviour of coated tools, in milling different materials, was investigated in the framework of a cooperative project of the Scientific Committee "Cutting" of the International Academy for Production Engineering (CIRP). In this activity twenty academic and industrial partners were involved according to a predefined project plan.

Introduction

The positive effect of an appropriate cutting edge geometry on the cutting performance of coated tools, has been recorded in several publications [1–5]. In this context, the tool wedge rounding affects significantly the developed mechanical and thermal loads during the material removal and thus, the cutting performance of the applied tools.

Related examples when milling Inconel 718 are demonstrated in Fig. 1a, whereas the developed stress fields in the cutting edge region of coated tools at different edge radii are demonstrated [6]. The stress fields were calculated by the DEFORM and ANSYS software packages, as described in [6,7]. Comparisons of the

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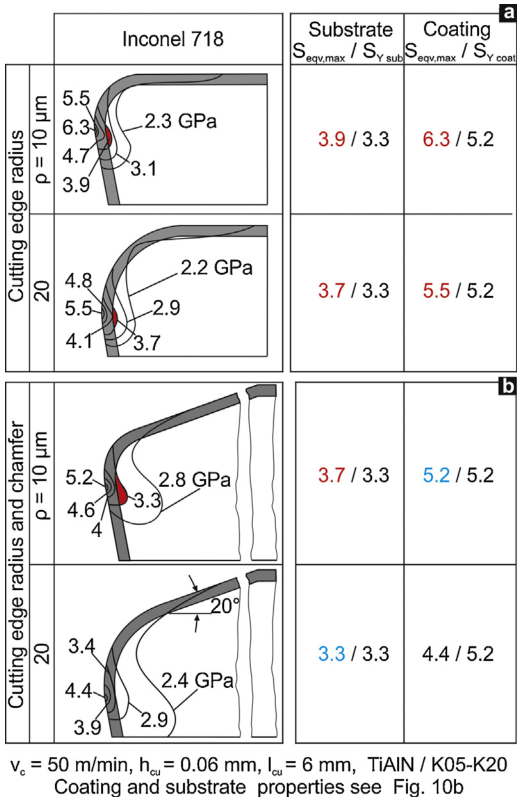

Fig. 1. Stress distribution in the cutting wedge region at various: (a) cutting edge radii (b) cutting edge radii, with chamfer on the rake.

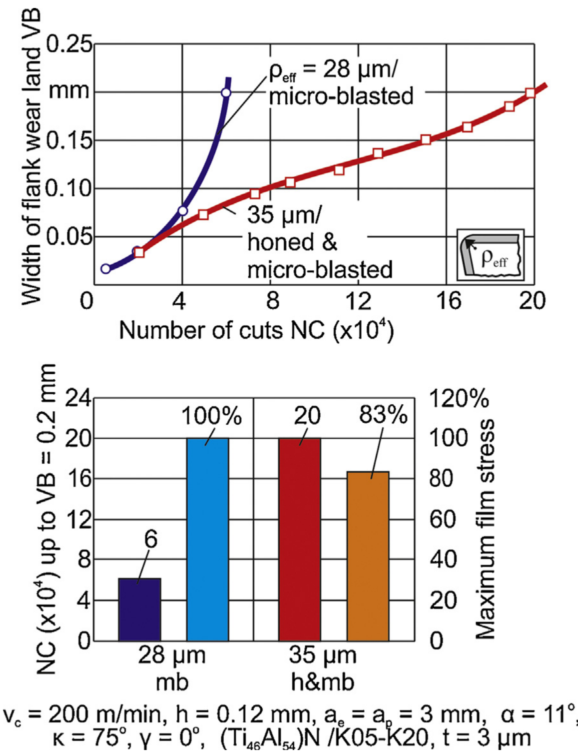

Fig. 2. Comparison of the flank wear development at variously-treated cutting edges.

developed maximum stresses in the substrate and coating with their yield stresses respectively, are also shown in Fig. 1a. In these examples, simulating orthogonal cutting, no chamfer between the tool wedge roundness and rake exists. The reduction of the substrate and coating loads using a larger cutting edge radius is obvious.

However, even at a cutting edge radius of 20 μm, which is commonly used in commercial industrial applications, the developed maximum stress, in both substrate and coating, exceed the corresponding yield stresses respectively. To overcome this problem, the cutting wedge can be further strengthened by introducing an inclined chamfer, as exhibited in Fig. 1b. The application of this chamfer, along with increased edge radii, further diminishes the developed stresses. In the case of the cutting edge radius of 20 μm, combined with a chamfer inclined at 20°, the developed maximum stresses are comparably the lowest and the yield stresses of the coating and substrate are not exceeded (see Fig. 1b).

Beside the cutting edge geometry, the tool wedge rounding methods may affect significantly the wear behaviour of a coated tool [1,8–10]. An example of improving the cutting performance of coated cemented carbide inserts, when their cutting edges are honed and additionally micro-blasted, is illustrated in Fig. 2. As previously described, the increase of the wedge radius diminishes the developed stresses in the film during the material removal process. However, the tool life gain is significantly higher in the case of the honed and additionally appropriately micro-blasted cutting edge, due to the enhanced coating adhesion, as explained in [8].

The aim of the conducted cooperative work was to study the efficiency of various cutting edge rounding methods as well as the effects of these treatments on the wear behaviour of coated tools when milling characteristic metallic materials. Taking into account the results presented in Fig. 1, concerning the effect of the wedge geometry on the tool loads, chamfered cutting edges at an inclination angle of 20° were employed. The initial cutting edge radius was chosen to be approximately 10 μm. This radius had to be further increased by diverse tool wedge rounding methods for detecting their potential effect on the coated tool cutting performance.

Layout of the investigations and experimental details

Cutting conditions adjustment when milling various materials

As test materials, hardened steel 42CrMo4, stainless steel 304L and, the difficult to cut Inconel 718 and Ti4Al6V were selected. These materials are commonly used in many industrial applications. With respect to the effect of the developed thermal and mechanical cutting loads as well as of the material properties on the tool wear evolution, the milling conditions had to be appropriately adjusted. In this way, it was intended to have comparable mechanical and thermal loads during cutting and, moreover, moderate tool wear evolution for enabling its accurate recoding.

The thermal loads of the cutting edge were approximated by the DEFORM software package, simulating orthogonal cutting. In milling hardened steel 42CrMo4 and Inconel 718 at the cutting conditions shown at the bottom of Fig. 3, the developed cutting temperatures in the tool are lower than 350 °C (see Fig. 3a). The maximum cutting temperature develops at the chamfer position 1. However, the highest mechanically-loaded transient region from the flank to the chamfer (position 2) is less thermally affected. The maximum cutting temperature in this tool area is less than 250 °C in both material cases. Moreover, the temperature fields monitored in Fig. 3b demonstrate the significantly higher temperatures