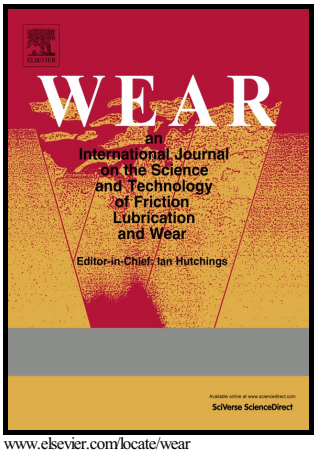

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Understanding the diffusion wear mechanisms of WC-10%Co carbide tools during dry machining of titanium alloys

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ABSTRACT

The diffusion wear between a WC-10%Co tool and a Ti54M titanium alloy was investigated by studying the reaction between both the materials using a diffusion couple and studying their behavior during a machining test. In addition to the scanning electron microscopy (SEM) study, electron probe microanalysis (EPMA) was conducted to quantitatively analyze the chemical composition in the reactive layers after different holding times at 1100 °C. The diffusion couple revealed a rapid formation of TiC carbides at the interface. The layer growth is parabolic and is mainly toward the Ti54M side. The formation of three affected zones was observed. On the tool side, the two affected zones displayed a continuous decrease in the WC content, as well as a significant enrichment in the Co amount with no WC in the Co rich zone and a decrease in the W and C contents. On the Ti54M side, the tool elements diffused into the alloy material, with the diffusion lengths of C and Co being much longer than that of W. The solubilities of C and Co remained low while that of W was almost 8–9 wt.%. The WC dissolution and compositional modification caused a degradation in the mechanical integrity of the tool surface, leading to crater damage. The machining experiments validated this mechanism and tool elements could be found in the adhered titanium layer.

Keywords: Titanium alloy; WC-Co; Thermal Diffusion; Tool wear mechanisms.

1. Introduction

The diffusion wear between the chip and the rake face during machining is an issue that has been widely investigated for metal cutting operations. Most of the studies deal with tool wear in steel machinability applications. Different analytical models have been used to study the diffusion process during machining [1–5]. Naerheim et al. [6] used a dynamic model to analyze the wear diffusion during steel machining with a WC-TiC-Co carbide cutting tool. According to them, the elements of the cutting tool like tungsten (W), carbon (C), and cobalt (Co) tend to diffuse into the chip which is continuously renewed. This renewal does not allow a saturation of the diffusing elements at the tool-chip interface, which does not stop or decrease the crater wear rate. In another case, Qi et al. [7] showed that during the machining of austenitic stainless steel deoxidized with calcium, the diffusion wear is limited by the formation of an adhering layer, which is composed of inclusions containing Ca mainly and Al and Si. This adhering layer limited the diffusion of the tool elements into the chip and stopped the TiC grains from being torn out by the chip flow. A quasi-static diffusion model was used to describe the wear. In addition, Bittès [8] showed that the diffusion was slower during the machining of improved machining steel than during the machining of standard steel. In this case, the experiments