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Thermally induced surface integrity changes of ground WC-Co hardmetals

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Abstract

Ground hardmetals are exposed to high temperatures during both processing (e.g. coating deposition) and use (e.g. as a cutting tool). However, studies on thermally induced changes of surface integrity are limited. Here we address this by means of FIB/FESEM and EBSD investigation, with special focus on the binder phase characterization. Our findings indicate that thermal treatment causes two main surface modifications. First, an unexpected microporosity appears in the binder within the subsurface layer when ground surfaces are heated. Second, the metallic phase underneath the ground surface experiences metallurgical changes, in terms of grain and crystallographic phase structures. The mechanisms responsible for these modifications of the binder are discussed in terms of grinding-induced and thermally-reversed phase transformation as well as recrystallization phenomena. We also note that no additional heat treatment related changes such as microcracking and carbide fragmentation in the subsurface layer, are discerned.

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Keywords: Grinding; Thermal effect; Surface integrity; Cemented Carbides

1. Introduction

WC-Co cemented carbides, often termed as hardmetals, are composite materials containing ceramic particles embedded in a metallic binder. As a result of such unique combination, they exhibit excellent mechanical and tribological properties, such as high hardness, strength, fracture toughness, and wear resistance. In modern industry, hardmetals serve as the backbone material for cutting and metal-forming tool applications [1,2].

Due to its relatively high hardness, diamond wheel grinding is commonly applied to machine hardmetal tools and components. As a consequence of such abrasive operation, it is now established that surface integrity of cemented carbides is altered, particularly in terms of surface texture, subsurface damage and residual stress state; and thus, mechanical and tribological performance are also affected [3,4].

During both processing (i.e. coating deposition) and effective operation of hardmetal tools, large amount of heat is typically generated [2,4,5]. For instance, temperatures at the cutting edge of inserts during machining may reach values ranging from 650ºC to 1200ºC [5,6]. Such high temperatures could result in material degradation and affect the tool life. Within this context, it is essential to study how the surface integrity is affected by grinding and a subsequent exposure to high temperature.

The mechanical properties of WC-Co cemented carbides, such as toughness and fatigue, are strongly dependent on the local mechanical response of the metallic binder phase (even though it is the minority phase) [7]. In grinding-related studies, however, no special attention has been considered on possible alterations taking place in the binder, as compared to those occurring in the hard/brittle carbides and the global damage such as, e.g., microcracks that develop both at the surface and subsurface levels.

In this study, the main objective has been to evaluate thermally induced effects on the surface integrity of ground hardmetals with emphasis on the microstructural and

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metallurgical changes induced within the binder. It should be noted that the relief of grinding-induced compressive residual stresses, by means of thermal annealing, is not addressed in this investigation. Related to this issue, the authors has reported on studies concerning mechanical strength, scratch resistance and contact damage response of hardmetals elsewhere [8-10].

2. Experimental details

The hardmetal studied in this work is a WC-13wt.% Co grade with a carbide mean grain size of about 0.7 μm. Fig. 1 schematically outlines the process steps used to obtain the different surface finish variants investigated. The grinding operation using a diamond abrasive wheel and coolant followed an industrial protocol, commonly implemented for inserts by SECO Tools AB. The resulting surface condition is referred to as G in this study. To assess thermally-induced changes of the ground hardmetal surfaces, some G specimens were heat-treated at 920 °C for 1 h in vacuum [11,12]. The ground and thermal treated condition is referred to as GTT.

Subsurface features of the two conditioned samples were examined using a dual beam Zeiss Neon 40 work station, equipped with focused ion beam (FIB) and field emission scanning electron microscopy (FESEM). A series of cross-sections orthogonal to the grinding surface were FIB-milled, and imaged by FESEM.

In order to explore more details about the deformation phenomena within the binder phase, electron back scattered diffraction (EBSD) was used to inspect the cross-sections. EBSD data acquisition was conducted using a Zeiss Supra 40 high resolution SEM, using 20 kV voltage. In doing so, the specimen was tilted 70° against the electron beam. Data was collected across an area 30 × 20 μm^2 in size with a step size ranging between 31 - 35 nm. Crystallographic phase maps were then constructed by employing the Channel 5 software.

3. Results and discussions

Grinding is a severe abrasive process, involving thousands of diamond grains with sharp edges cutting the workpiece surface. Meanwhile, the ascribed thermal effect is inhibited by the cooling lubricant. The corresponding subsurface damage scenario may be assessed by direct examination of FIB-milled transverse-sections, perpendicular to the grinding direction (Fig. 2). A well-defined thin (in-depth) surface layer, highlighted by dashed white lines, is clearly distinguished for the G sur-

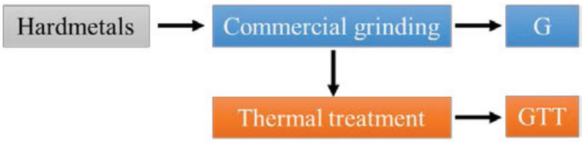

Fig. 1. Scheme of material removal and thermal annealing processes followed for attaining the surface finish variants studied.

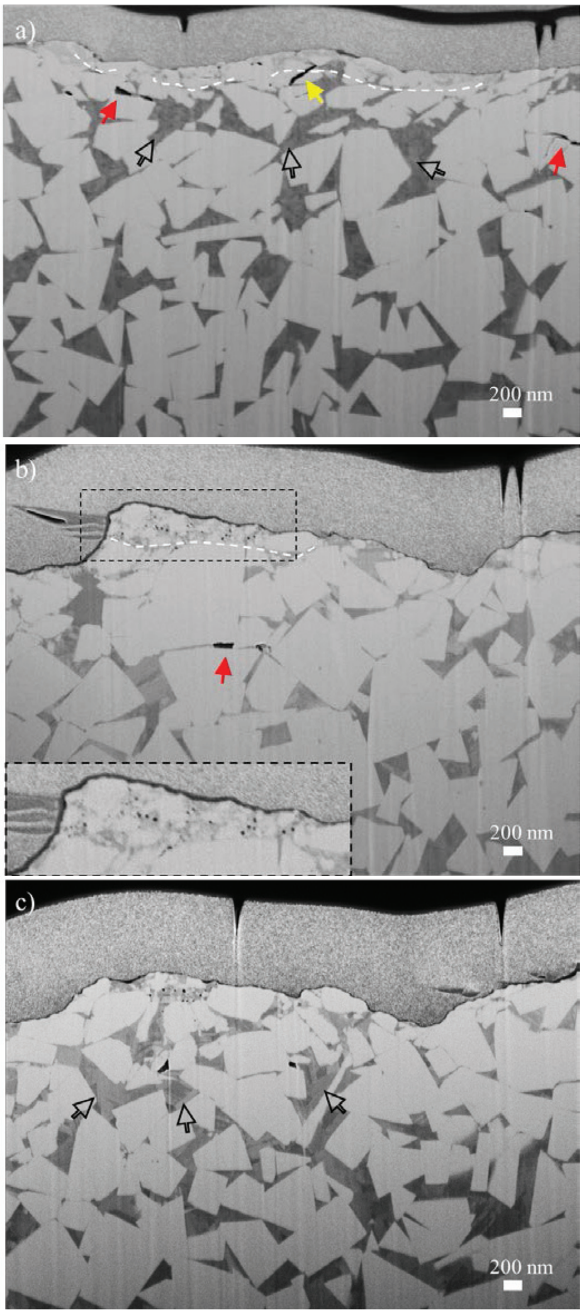

Fig. 2. FIB cross-sections showing subsurface damage: (a) G; and (b), (c) GTT. Cracks following either WC/Co interface or transgranular paths are indicated by red and yellow arrows in (a) and (b), respectively. Subsurface layer containing fragmented WC grains and smeared Co phase is identified, from the underneath bulk material, by dashed white lines. Dashed rectangle at the left bottom corner in (b) is the enlarged view of the dashed rectangle at the left top. Black outlined arrows in (a) and (c) point out the representative Co region to highlight its morphology features, respectively.