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CHARACTERIZATION OF SURFACE DEGRADATION AND WEAR DAMAGE OF CEMENTED CARBIDE IN ROCK DRILLING

Kumar Babu Surreddi1, Karin Yvell1, Susanne Norgren2,3 and Mikael Olsson1

1Materials Technology, Dalarna University, Sweden
2Sandvik Mining and Rock Technology, Rock Tools division, Sweden
3Department of Engineering Sciences, Uppsala University, Sweden
E-mail: kbs@du.se, kyy@du.se, susanne.m.norgren@sandvik.com, mol@du.se

ABSTRACT:

In this work, worn top hammer drill bit buttons after underground drifting in Granodiorite are analysed using scanning electron microscopy (SEM), Auger electron spectroscopy (AES) and electron backscatter diffraction (EBSD) to understand the dominant surface failure and wear mechanisms on the flank wear land region, i.e. the outer side of the gauge row cemented carbide buttons. SEM shows that the worn surface of the flank wear land is partly covered with islands of a thin rock material transfer layer and that the exposed cemented carbide show deformed, cracked and fragmented WC grains. AES gives that the transferred rock material is mainly located on the surface but may penetrate into cemented carbide microstructure to a depth of 1-2 WC grain diameters. Finally, EBSD reveals that the deformation of the cemented carbide in the flank wear land region is located to a thin zone, about ~10 μm in depth.

Keywords: Rock drilling; Auger Electron spectroscopy; EBSD; Surface degradation; Wear.

INTRODUCTION

Top hammer drill bits equipped with cemented carbide buttons are commonly used in rock drilling applications and the major lifetime-limiting factors are the wear and surface damage of the drill bit buttons. The wear mechanisms have been extensively studied for the past decades. These studies usually reveal a smooth worn surface with extrusion of cobalt, plastic deformation, cracking and fragmentation of WC grains and penetration of rock material in the worn cemented carbide surface [1-2]. In this study, the surface failure and wear mechanisms of cemented carbide buttons from a drill bit used for drilling in Granodiorite have been characterized by scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDS), Auger electron spectroscopy (AES) and electron backscatter diffraction (EBSD).

MATERIALS AND METHODS

The drill bit, Rock Tools bit 7738-5348A-XT48, investigated in the present study had a diameter of 48 mm and was equipped with 9 spherical cemented carbide buttons (10 mm diameter), see Fig. 1a. The cemented carbide buttons were manufactured from a WC-Co grade of 96 wt.% WC, 4 wt.% Co and a mean WC grain size of 2 μm. After 320 m drilling in Granodiorite, an abrasive but easy drilled granite mineral, all 6 gauge row cemented carbide buttons showed extensive wear resulting in a flank wear region, see Fig. 1b.

The flank wear land regions of the worn buttons were characterized using an SEM (Zeiss Ultra 55) equipped with an EDS system (Oxford Instruments Inca) and an EBSD system (Oxford Instruments HKL Nordlys). AES analysis using a PHI-700Xi Scanning Auger Nanoprobe was performed at an acceleration voltage of 10 kV and a beam current of 10 nA. AES depth profiling was performed using 4 kV Ar+ ion sputtering. Cross-sections of the cemented carbide buttons, aimed for SEM, EDS and EBSD analysis, were prepared by precision fracturing or precision cutting followed by conventional metallographic grinding and polishing techniques using a standard colloidal silica suspension (0.04 μm) in the last step.

RESULTS AND DISCUSSION

When observed in the SEM and AES instruments at a high magnification the flank wear regions display a smooth appearance with areas covered by a thin layer of adhered rock material and areas of exposed cemented carbide, see Figure 2. AES depth profiling of these layers shows that they are mainly composed of the main elements of the rock material, i.e. O and Si, and that the layer thickness is typically < 1 μm.

Figure 1 a) Top of the rock drill bit with worn cemented carbide buttons. b) Detail of the flank wear land region analyzed in this work.
Areas of exposed cemented carbide, see Figure 3, show a severely deformed cemented carbide microstructure with deformed, cracked and fragmented WC grains in a “binder” of adhered rock material, Co and fine WC fragments. It should be noted that the “binder” is very thin and can be revealed only at a low acceleration voltage (< 3-5 kV).

Figure 2. a) Flank wear land region showing a thin layer of adhered rock material before (a) and after 10 min of ion sputtering (b), corresponding to a sputter depth of 0.5 µm.

Figure 3. Flank wear land region showing deformed and cracked WC grains in the surface. The darker areas correspond to a “binder” mainly consisting of rock material. SEM SEI mode at 20 kV (a) and 3 kV (b) accelerating voltage. Note that exactly the same area is imaged in (a) and (b).

Fractured cross-sections located in the middle of the flank wear land region reveal surface regions where the rock material has penetrated into the cemented carbide microstructure, see Fig. 4. This mechanism was found to be relatively rare and the rock material penetration depth was always very small, not exceeding 2-3 WC grain diameters. Unfortunately, the roughness of the fractured surface made it difficult to analyze the interface between the penetrated rock material and the WC-Co microstructure.

Figure 4. Fractured cross-sections of worn cemented carbide in the middle of the flank wear land region.

Figure 5 shows a Grain Orientation Spread (GOS) map obtained from a polished cross-section within the centre of a flank wear land region. GOS measures the degree of orientation change between every pixel in the grain and the grains average orientation and can be used to quantify the degree of plastic strain induced in the microstructure [3]. The GOS map of a worn peripheral cemented carbide button, see Fig. 5c, clearly reveals a deeper deformation in the flank wear land region, ~10 µm in depth, as compared to the unworn region outside the flank wear land.

Figure 5. a) and b) Overview and detail of polished cross-section of worn peripheral cemented carbide drill bit button. c) EBSD GOS map of the two rectangular regions in Fig. 5b showing the extension of the surface deformation within the flank wear land region.

CONCLUSIONS

- The flank wear land regions of the gauge row cemented carbide drill bit buttons show rock material transfer layers and plastic deformation, cracking and fragmentation of individual WC grains.
- The transferred rock material is mainly located on the surface but may penetrate into cemented carbide to a depth of 1-2 WC grain diameters.
- The surface deformation within the flank wear land is limited to a depth of ~10 µm, i.e. corresponding to the top 4-5 layers of WC grains.

REFERENCES


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