Wear micro-mechanism from multi-pass abrasion of single asperity contact for advanced NbC composites

N. Rajendhran[1*], K. Pondicherry[1], S. Huang[2], J. Vleugels[2], J. Sukumaran[1], P. De Baets[1]

[1] Soete Laboratory, Department of Electromechanical, Systems and Metal Engineering, Ghent University
Tech Lane Ghent Science Park – Campus A, Technologiepark Zwijnaarde 46, 9052 Gent, Belgium
[2] Department of Materials Engineering, KU Leuven
Kasteelpark Arenberg 44 bus 2450, B-3001 Heverlee, Belgium

Constantly rising price of cobalt (Co), and the toxicity of reactive oxides (tungsten trioxide (WO_3) and cobalt tetraoxide (Co_3O_4)) arising from the cutting operation of cemented carbide (WC-Co) tool alerts for an alternative material. In addition, information on micro-scale abrasive wear and associated surface deformation mechanism in cutting tool materials is limited. Literature clearly emphasizes the change in wear mechanism with the changing operational conditions i.e., load, speed, etc. However, scarce reports were found on the response to microstructural damage during abrasive wear process. Conversely, cermets (ceramics and metal matrix composites) such as NbC and TiCN lack on the knowledge of both wear and micro-mechanisms that is prevalent during abrasive wear. Niobium carbide composited nickel (NbC-Ni) as an alternative for WC-Co in machining has been explored in the current research. The present study elucidates the correlation between the wear mechanism and factors such as surface damage due to plastic deformation, grain orientation, brittle cracks, mean free path response. These effects are clearly studied using a single asperity abrasion contact facilitated by scratch tester. Scratch test with diamond indenter (tip radius: 50µm and apex angle: 120°) was performed to simulate the abrasive grooves on the polished cemented carbide (WC-15.6 vol% Co) and NbC-Ni (6 to 18 vol% of Ni) cermet surface. A sequence of scratches such as single and multiple passes created with respect to the different loads and sliding distance. The magnitude of damage was quantitatively measured from the width and depth of the scratches using 3D white light interferometer. The transformation of damage mechanism such as grain fracture, pull out of grain due to binder extrusion, fragmentation and re-embedment of grains on the microstructure of the WC-Co and NbC-Ni were characterized through high resolution SEM microscopy integrated with energy dispersive X-ray spectroscopy (EDS). Special attention on the structural response of NbC-Ni during abrasive wear and focusing in the property enhancement of this hardmetal cermet into cutting tool operation instead of cemented carbide were further discussed.

Keywords: Scratch testing, WC-Co, NbC-Ni cermet, Abrasion, Wear micro-mechanism.

*Corresponding author: Naveenkumar.Rajendhran@ugent.be