A MULTISCALE DESIGN APPROACH TO THE EXPERIMENTAL ABRASION CHARACTERISTICS OF ADVANCED CERMETS

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MOTIVATION

WC-Co cermets, also referred to as cemented carbides are the most widely used hard materials for tribological applications. Constantly rising prices of both W & Co and the economic downsides alerts the replacement of WC and Co. WO_3 is a toxic substance formed in air on tungsten carbide during application tends to sublimate above 750°C and it is water soluble at room temperature. The replacement of Co is also driven by its potential carcinogenic nature of its reactive oxide Co_3O_4. Niobium, a refractory metal similar to tungsten offers the possibility to partially or even completely replace tungsten in cemented carbides. NbC is as a refractory carbide with a melting temperature of 3522°C, it is thermally stable and has very low solubility in Fe, Ni and Co. In addition, the related oxide Nb_2O_5 is thermodynamically stable with a melting point of 1512°C. Replacement of WC by NbC in WC-Co would automatically require the need to also replace the Co binder, due to the relatively poor wettability of Co and NbC. NbC-Ni and especially NbC-Fe or NbC-Mo based materials would be a "non-critical and harmless" substitute for WC-Co materials.

At present, the mechanical and especially the tribological properties of NbC-based cermets are largely unexplored. The tribology of cemented carbides mainly focuses on two main areas of application, mainly the cutting inserts which are our main focus in this research and secondarily wearing parts such as wire drawing dies, fuel injectors/nozzles, tooth burrs, etc. The tool wear can vary significantly based on cutting speed and feed rate, but flank wear due to abrasion is the dominant wear mechanism in cutting tools (Figure 1). Abrasive wear are classified into two body and three body abrasion, which can be further divided into open and closed system. In the turning test, it is difficult to study only the abrasion damage of the cutting tool by controlling the input parameters such as speed, feed rate and depth of cut. Additional factors such as temperature will also experience on the cutting edge. Therefore, these parameters are taken as input and the abrasion is simulated experimentally using different wear tests, such as the scratch test and pin abrasion test in the laboratory according to ASTM standards.

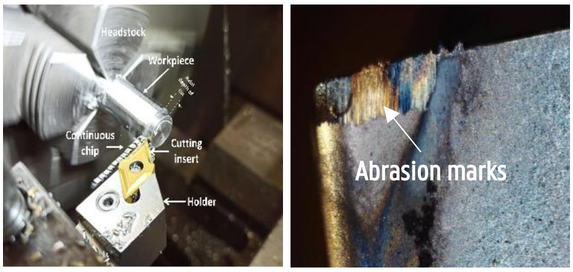

Figure 1 Tool wear of the cutting inserts (XTC).

OBJECTIVES

In the context above, the objective of this work encompasses two topics below (preceded by a literature review):

1. The abrasion resistance of the NbC-based cermets for cutting tools and wear parts shall be determined by simulating two body and three body abrasion on a laboratory scale. As a reference material, WC-Co will be used to compare the performance of the newly developed NbC-cermets. These tests provide data that can be used to create wear maps and rank materials based on their tribological response.
2. Aim to create wear mechanism signatures based on the worn surface response and relate them to the wear rate of the tribological data. Wear maps can be used as valuable information to develop or select materials based on their wear resistance and to validate them in

real test cases. By mapping different combinations of operating and environmental conditions, the work regime and potential application area for the newly developed material can be clearly identified.

APPROACH

To achieve the objectives, laboratory scale experimental studies were selected to simulate the abrasive wear from micro to macro scale. Based on the asperity interaction, the abrasion studies are classified into single and multi-asperity abrasion.

The single asperity contact is accomplished by means of scratch testing (see Figure 2), which is ideal to investigate the influence of asperity interaction on the different microstructural features. Since the contact is between the test sample and indenter, a better and easy understanding of the interaction can be made from the observed wear mechanisms. Tests under different operating conditions such as load, speed, contact geometry will be performed to observe phenomena i.e., carbide cracking and partial removal of individual phases.

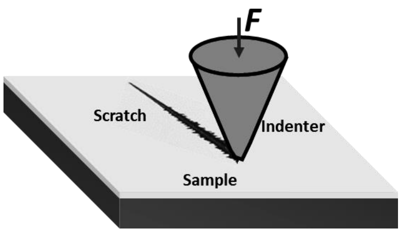

Figure 2 Schematic of scratch test.

Single asperity contacts can be considered as an ideal condition, but the influences of the abrasive morphology may not be completely revealed and the repeated interaction, often encountered in real applications, is absent. Therefore, a multi asperity abrasion test will be performed for tribological characterization of the NbC-cermets. Existing standards such as ASTM G132 & G65 can be used for characterizing the abrasion resistance (shown in Figure 3). These two standards also relate to cutting tool and wear part applications from the view point of contact kinematics. The cutting tool application finds itself more suitable with ASTM G132 standard testing, whereas wear parts can be related to a three body contact using ASTM G65 standard. Due to the nature of contact and the different counterface, these two systems experimentally simulate the mechanical interlocking of the abrasion process and the effects of wear on the particle generation process can be clearly studied. The operating conditions such as load and speed will be based on calculations adapted from literature.

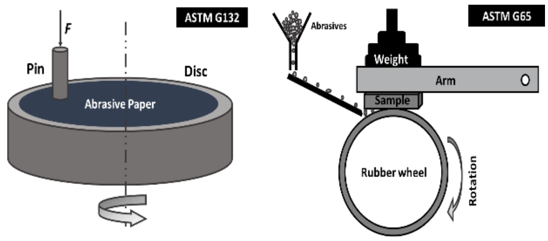

Figure 2 Schematics of ASTM G132 and ASTM G65 tester.

Scanning electron microscopy (SEM) and optical microscopy (OM) will be performed using the post-mortem approach to reveal the morphological features in the X-Y plane. The characteristics of the wear mechanism due to mechanical interlocking between the asperities such as micro-ploughing, micro-cracks, cutting and partial binder removal are confirmed by this approach. In addition, the Z-depths will be characterized by 3D white light interferometry, which is also used to evaluate material removal. The roughness parameters (amplitude, wavelength and hybrid) will be taken into account for the results of multi-asperity tests.

Finally, the creation of wear maps helps to find the threshold for different operational regimes, such as mild, transition and severe wear. It is already known that the tribological reactions are the result of the system response in which multiple factors such as contact kinematics, surface condition, operating conditions and environmental conditions play a crucial role. It will be mapped to separate these individual parameters and also the synergistic effect of these influencing factors. The tribo-map will be built based on the signatures of the quantitative mechanism signatures. The mechanism may have two mild and severe extremes. Since mild to severe transition may not be clearly segregated, it is beneficial to use quantitative microscopy to understand the segregation.

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