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Effect of erodent particle impact energy on wear of cemented carbides

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ABSTRACT

Cemented carbides match properties required for many wear related applications through the control of microstructure such as Co binder content, WC grain size, type and content of additives, etc. However, their hardness is usually raised at the expense of fracture toughness. The effect of hard erodent particle impact energy on the wear of cemented carbides containing differently sized grains (fine, medium, and coarse) and binder content (6, 8, 15 wt. %) was studied with the help of laboratory disintegrator and centrifugal erosion tester. The velocity of impingement was varied from 10 to 140 m s^{-1}. Granite particles of grain size either of 3.0–5.6 or 0.8–1.0 mm were used as erodents. Influence of erodent particle energy (velocity) on the wear rate of cemented carbides is presented in detail. In general, the wear rate can successfully be described by power-law while some of the materials tested demonstrate slightly reduced acceleration in wear rate at the highest velocities studied, which might be explained by fracture of erodent and associated shielding effect. The observed formation of cracks filled with granite particles debris and Co binder after testing at the highest impact energies is similar to that found in materials experienced to rock drilling.

1. Introduction

Cemented carbides match properties required for many wear related applications through control of microstructure (Co binder content, WC grain size, type and content of additives). However, their hardness is usually raised at the expense of fracture toughness while both of these properties are required for high wear resistance in conditions of high energy impact. The components made out of cemented carbides and subjected to the impact wear conditions are drill bits, crushers, picks for road maintenance, saw blade inserts, car wheel studs, snow plough blades, grit blast nozzles, etc.

Generally accepted specific facts about erosion of cemented carbides are: (1) cemented carbides experience very limited erodent particle embedment into the surface; (2) mechanism of erosion mainly depends on the kinetic energy of attacking particles; (3) there is the threshold velocity associated with change in wear mechanism; for example shifting from fatigue driven to direct removal; (4) cemented carbides have mixed ductile-brittle response at the microscopic level; (5) the maximum erosion rate is found between 30 to 90° angle of impingement; (6) cemented carbides with fine grains and low binder content are prone to brittle fracture; (7) if the number of WC grains in the impact zone is small then their brittle fracturing is possible while impact zone encountering more than 10 grains can response in a ductile manner; (8) the basic steps of cemented carbide's erosion include removal of binder, fracture of WC grains, cracking between grains and breakaway of unsupported WC grains [1–5]. Additionally, it was shown that binder metal from the subsurface layer could be squeezed toward the surface that leads to rearrangement of WC grains (compaction of subsurface layer), possible fracture of grains due to creation of new contact points between grains and utilization of binder metal toward creation of mechanically mixed layer [6,7]. Fine carbides fragments can be mechanically mixed with the binder metal that leads to increase in macro hardness and reduction of wear rate [6,7].

The effect of fine debris retained on the surface by electrostatic field was noted as an additional important aspect [8]. The debris act as the third bodies and result in growth of local stresses and facilitating binder removal. The deceleration in the growth of erosive wear rate with an increase of impact velocity was observed at a velocity region of 20–50 m s^{-1} [8] or higher than 150 m s^{-1} [9]. Silica sand was used as erodent in both cases.

The resistance of materials to erosive wear is usually studied using particles of the size less than 1 mm [1–12]. Impacts by coarser particles are studied with the help of an impeller type tester [13], a device with a pin hitting gravel [14] or a disintegrator type device (abrasive impact wear tester, AIWT) [15,16]. Fresh

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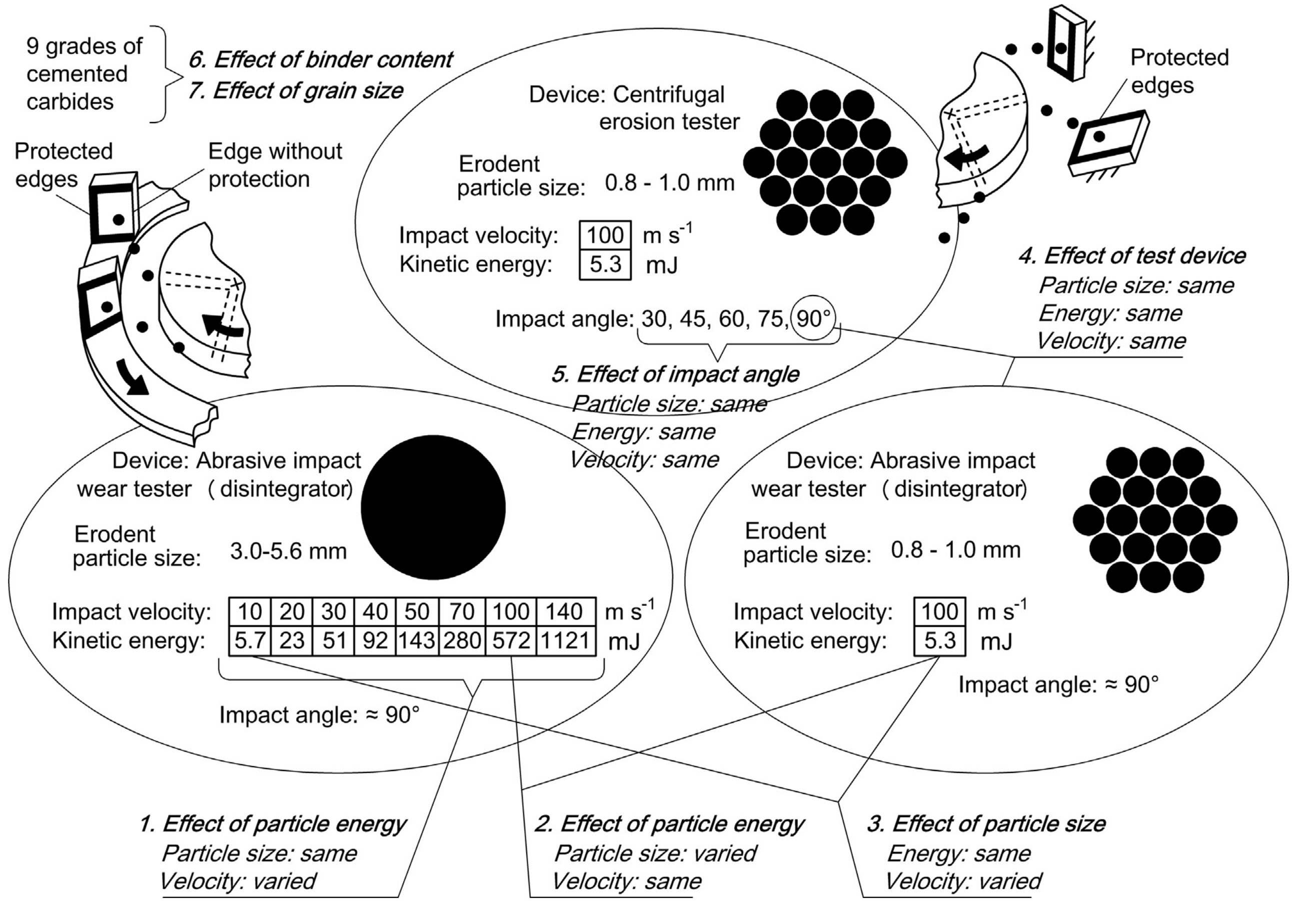

Fig. 1. Overview of the parameters and effects studied in the current work. Schematic representation of the principles of abrasive impact wear tester (AIWT) and centrifugal erosion tester (CET) is shown in the upper corners of the figure.

Table 1
Hardness and Palmqvist fracture toughness of tested materials.

Co content	WC size	*Hardness HV10*	*Palmqvist fracture toughness K_{IC}, $MPa\cdot m^{1/2}$*
6 wt. %	**Fine**	1750 ± 70	6.9 ± 0.6
	Medium	1605 ± 58	9.5 ± 0.6
	Coarse	1190 ± 45	13.2 ± 0.7
8 wt. %	**Fine**	1510 ± 63	9.8 ± 0.6
	Medium	1390 ± 55	11.5 ± 0.7
	Coarse	1090 ± 40	16.4 ± 0.8
15 wt. %	**Fine**	1350 ± 52	12.5 ± 0.6
	Medium	1130 ± 35	16.5 ± 0.8
	Coarse	890 ± 41	19.0 ± 1.1
Hardox 400		385 ± 12	–

abrasive particles are continuously supplied only in AIWT scheme. In the impeller and AIWT devices, the particles are free to move during test. AIWT allows testing of materials in a wide range of impact velocities from 5 to 200 m s^{-1}. The aim of the current work was to assess the effect of granite erodent particle impact energy on wear of cemented carbides with varied binder content and size of WC grains and to compare cermets behaviour to the conventional wear resistant alloy Hardox 400 used as the reference material, Fig. 1. It was aimed at providing information regarding the possible threshold velocities (change in wear rate vs impact velocity dependencies). The results of tests by AIWT under conditions of various impact velocity of the travelling particles keeping similar impact energy when fine particles travel with high velocity and coarse ones travel with low impact velocity were compared. Results obtained with the help of AIWT were compared to results obtained with the help of the centrifugal erosion tester that has been performed for the first time to author's best knowledge. Also, an effect of impact angle was thoroughly studied. The results were compared to previously obtained by authors applying ASTM G65 (low stress abrasive), medium stress abrasive and combined medium stress abrasion with impacts devices [17].

2. Materials and methods

2.1. Materials

The WC-Co cemented carbides with different carbide grain sizes (fine, medium, and coarse) and cobalt content (6, 8, and 15 wt. %) were produced by a conventional PM routine at Tallinn University of Technology, Laboratory of Powder Metallurgy (Table 1). All powders were commercially sourced and the description is provided elsewhere [17]. Sintering was performed by hot isostatic pressing (HIP) at different temperatures depending on the cobalt content: 1390 °C (15 wt % Co) and 1450 °C (6 wt % or 8 wt % Co) [17]. The carbide grains size of the sintered samples was determined by linear intercept method (BS EN ISO 643:2012) and were measured to be within the range of 0.2–1.0, 0.5–2.0 and 2.0–10.0 micrometres for fine, medium, and coarse - grained hardmetals, respectively [17]. The conventional wear resistant alloy Hardox 400 (C max 0.32; Si max 0.7; Mn max 1.6; P max 0.025; S max 0.01; Cr max 1.4; Ni max 1.5; Mo max 0.6; B max 0.004; wt. %