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The effect of fine erodent retained on the surface during erosion of metals, ceramics, plastic, rubber and hardmetal

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ABSTRACT

Fine particles originating from a mixture of erodent particles or being the residues of broken particles, might retain on the surface of an eroded material by electrostatic field. This results in the presence of a fine third body between an attacking original erodent particle and a material surface during collision that leads to higher and more localised stresses. Hardmetal, alumina, zirconia, Al 5083, Hardox 400, AISI 316, rubber and plastic were studied to assess the effect of the fine third body on wear mechanism and wear rate under erosive conditions of impact velocities ranging from 10 up to 80 m s^{-1}. Four batches of silica sand erodent particles were tested: (1) naturally occurring (0–1000 μm), (2) fine-sized (0–120 μm), (3) coarse-sized (600–1000 μm), and (4) mixture of fine and coarse (0–50 plus 600–1000 μm). A pronounced effect of fine hard third body was observed for alumina under almost all velocities as well as for rubber, hardmetal and zirconia at high velocity. Soft metals (Al 5083, AISI 316, Hardox 400) are not sensitive to the presence of a fine erodent retained on the surface. The response of plastic to erosion depends mainly on energy of eroding particles (coarse particles induce a higher wear rate).

1. Introduction

The solid particle erosion or erosive wear is a damage and loss of materials caused by collision and interaction of discrete hard particles with the surface. Often, this process is considered as a two-body process [1–4]. However, it was observed that fine eroding particles originating from the mixture of the erodent particles or being the residues of broken particles, which appeared at an impact velocity as low as 5 m s^{-1}, might retain on the surface of an eroded material by electrostatic field [5]. This results in the presence of the fine third body between the impacting erodent particle and the material surface during collision (Fig. 1).

Combination of particles of original and fine sizes results in localised stresses with high stress concentrations. The Hertzian contact stress [6] created by particles with diameter of 20 μm (Fig. 1B) is order of magnitude higher than that for particle of 600 μm (Fig. 1A) pressed against the plain surface with the same force. Fractured fragments with fine size and angular shape might be the source of high localised stresses if are retained on the surface during attack by particle of larger size (Fig. 1C). This may cause fracture of subsequent erodent particles, fine erodent retained on the surface (and fragments of ceramic grains of hardmetal, for example) that is influencing the mechanism of wear.

In addition to generation of high localised stresses, hard fine particles can provide preferential removal of soft binder between ceramic grains in hardmetals (or other composite materials). It is usually stated as the first step in hardmetal degradation mechanism followed by fracturing and fragmentation of individual unsupported WC grains [7,8]. As it is illustrated in Fig. 1, the direct removal (cutting) of binder in hardmetals by coarse intact erodent particles (Fig. 1A) is hardly possible (due to difference in size) and can be realized mainly by the fine third body with a size comparable to the size of mean free path between ceramic grains (Fig. 1C).

A minor effect of the presence of fine-grained solid additives to silica sand on wear rate of hardmetals, hardened steels, white cast irons and hard coatings in erosive conditions was indicated by Kleis and Kulu [9]. However, a four-fold increase in wear rate was observed for mild steel and pure metals after addition of fine dust particles into stream of erodents. Mixtures of the sand with starch, chalk, portland cement, talc, gypsum, lime, NaCl, $MgSO_4$, $Ca(OH)_2$ $CaCO_4$ and MgO_2 were tested. No plausible explanation of this effect has been presented. Mixtures of the differently sized particles of the same erodent material were not studied [9]. To the best of the authors' knowledge, there is no publication available that describes the effect of the fine particles added to coarser erodent (of the same erodent material) on dry erosive wear of variety of materials tested under the wide range of impact velocities.

Effect of material, shape and size of erodents as well as number of particles striking the surface per unit time, particle kinetic

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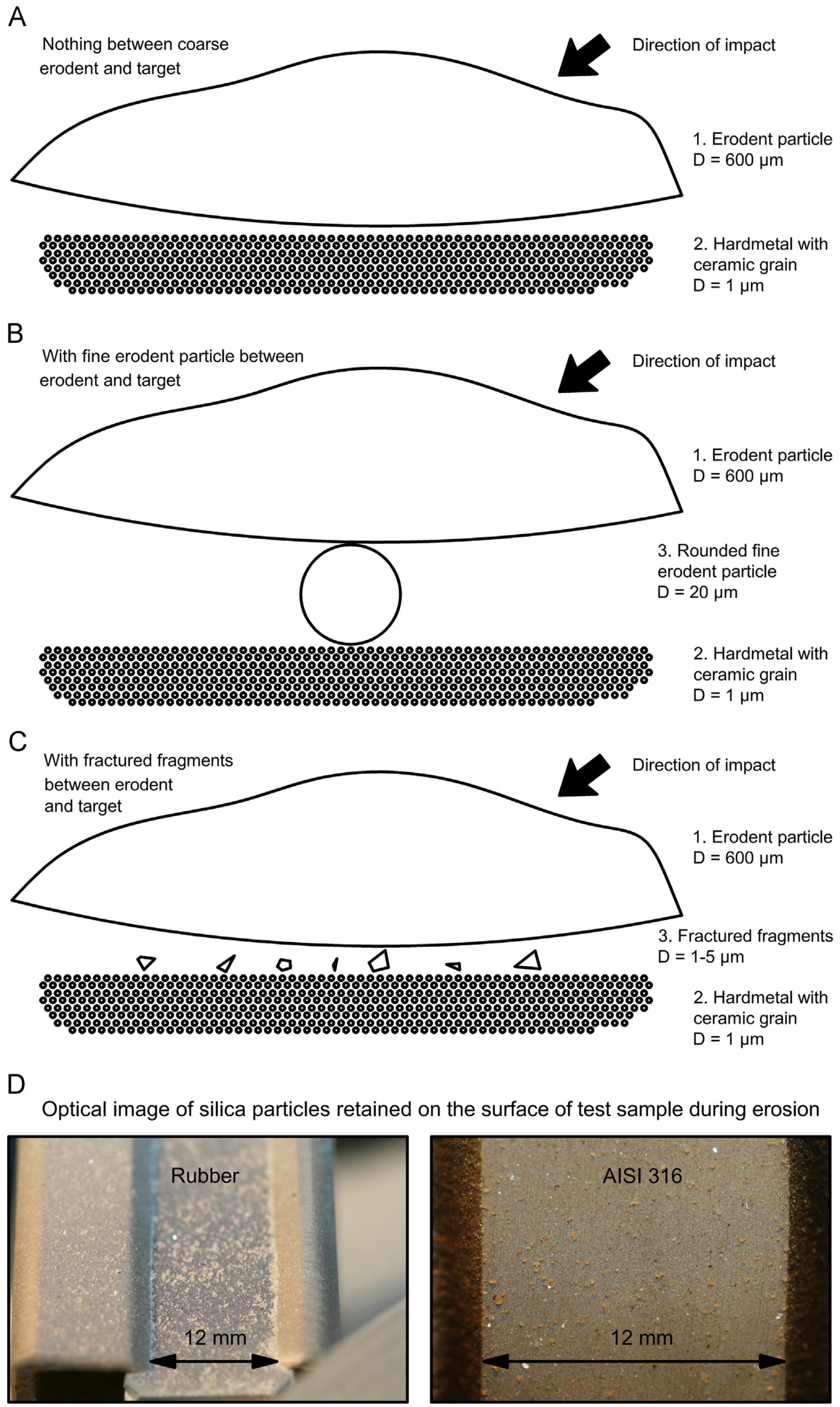

Fig. 1. Visualisation of the relative sizes of large erodent particle, fine erodent particle, fractured fragments of erodent and carbide grain in a hardmetal drawn in same scale. Optical images of samples are providing the evidence of particles presence on the surface.

energy, interference between particles striking and rebounding from the surface has been thoroughly examined [6,10–15]. The wear rate during dry erosive wear increases with an increase in particle size up to limiting size (50–100 μm) beyond which it becomes independent of particle size [15]. Particles with size larger than threshold value are not able to provide significant