A lattice Monte Carlo model of solid particle erosion: An application to brittle fracture

Alejandro Mora*, Abayomi Alabi* and Siegfried Schmauder*

* Institute for Materials Testing, Materials Science and Strength of Materials (IMWF)
University of Stuttgart
Pfaffenwaldring 32, D-70569 Stuttgart, Germany
e-mail: alejandro.mora@imwf.uni-stuttgart.de
web page: http://www.imwf.uni-stuttgart.de

ABSTRACT

Erosion caused by repeated impact of solid particles entrained in a moving fluid is relevant for many technical applications, for example, resulting wear and reduced service life of turbine blades, propellers, valves, etc. The lattice Monte Carlo Model of Solid Particle Erosion (LMC-SPE model) is based on a three dimensional representation of the target surface by a cubic lattice, where each cell embodies a small portion of the material susceptible to ductile or brittle fracture and subsequent removal. This is a coarse grained description where a real variable accounts for the damage advancement within each lattice cell. The fracture mechanisms are represented as a coordinated action of simple micro-events, namely, rearrangement, internal damage propagation, and detachment of lattice cells. The simulation is driven by a kinetic Monte-Carlo method where the rate at which the micro-events are applied is given by an erosion probability distribution that depends on time and represents the dynamical transfer of impact energy. Hardness, toughness, and other material properties as well as velocity, size, and impinging angle of the particles can be incorporated as simulation parameters in a probabilistic sense.

In this work an LMC-SPE model for erosion of a class of glass submitted to impact of alumina particles is formulated. The brittle mechanism is based on the quasi-static indentation theory where lateral cracks can be formed due to particle impacts. The indentation force depends on the hardness of the target as well as on the velocity, diameter, and impacting angle of the particle. The threshold for lateral cracking depends on the Young modulus and fracture toughness of the target. It is assumed that the lateral cracks reach the surface forming a spherical cap shaped fragment which is promptly removed. The depth and length of the spherical cap can be estimated from analytical expressions and then proper micro-event rates and erosion probability distributions are determined. In spite of its simplicity and low level of detail, the LMC-SPE model can simulate the main topographic features of individual impacts and reproduce correctly dependencies of the erosion rate on velocity, size, and impact angle of the particles. As in consequence roughening regimes due to the accumulative effect of thousands of individual impacts acting on relatively large areas are simulated within reasonable computational times and compared with experimental results from literature.