DFG-Project Schm 746 / 135-2

LATTICE MONTE CARLO MODELING OF SOLID PARTICLE EROSION (PART II)

The complex interplay among diverse physical mechanisms that drive abrasive wear of surfaces exposed to the impact of solid particles (or water droplets or impact loads due to the collapse of cavitation bubbles) represents a major theoretical and experimental challenge. The accumulation of damage and fracture on materials during erosion cannot be described by a universal analytical framework because the involved physical mechanisms depend strongly on the specific material properties and the energy and frequency of the impacts among other parameters. Established and current techniques like, for example, finite element methods (FEM) or smoothed particle hydrodynamics (SPH) can provide detailed descriptions of the effect of the individual impacts including crater formation and damage accumulation. However, due to unfeasible computation times and numerical instabilities those methods cannot be applied for thousands or millions of impacts.

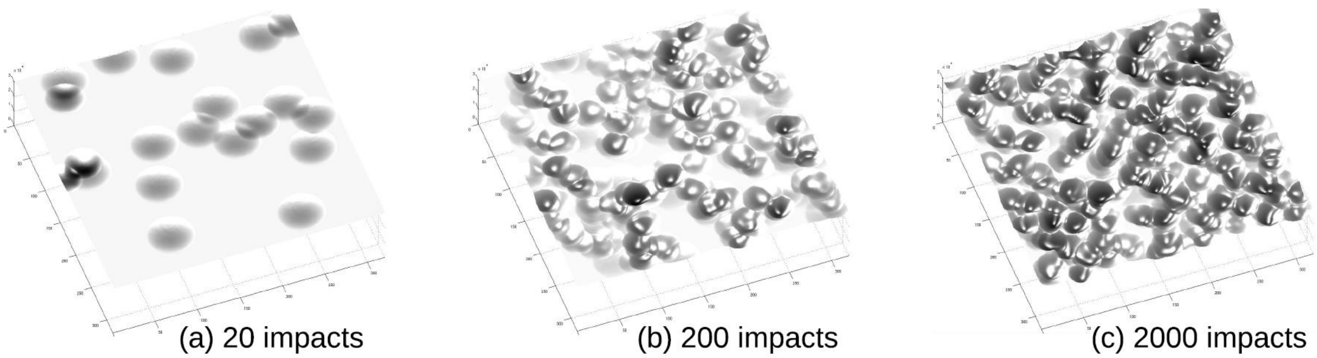

Fig. 1: Characteristic evolution of erosion on a brittle target due to uniformly distributed random particle impacts represented with the LMC-SPE model.

The Lattice Monte Carlo Model of Solid Particle Erosion (LMC-SPE model) has been proposed to simulate erosion regimes beyond the scope of traditional methods. The LMC-SPE model is based on a representation of the target surface by a cubic lattice, where each cell embodies a small portion of the material susceptible to damage, fracture and subsequent removal. This is a coarse grained description where a real variable f_a accounts for the ''damage advancement'' within each lattice cell. This variable is a quantification of the degree of damage in form of cracks, fragmentation, work hardening, etc. The erosion mechanisms are represented as a coordinated action of simple micro-events acting on the lattice cells, namely, cell rearrangement, “damage advancement” (update of the variable f_a on each cell), and cell detachment. The LMC-SPE model can describe the erosion evolution including the dependencies of the steady state roughness and erosion rate on velocity, size, and local impact angle of the particles as it has been shown in the case of a glass submitted to impact of alumina particles in the previous project.

The main goal of this renewal proposal is to develop further the LMC-SPE framework and applying it to three different model systems: Solid particle erosion of a brittle material (improvement of a previously developed model), water droplet erosion on ductile materials, and cavitation erosion on metallic surfaces. For all cases, simulations of the effect of single impacts based on established methods (FEM and or SPH) will be used to derive probabilistic rules for the micro-events for the corresponding LMC-SPE representations. Then simulations of thousands of impacts taking into account the effect of evolving impact conditions (incubation period, surface roughness, and damage accumulation) can be implemented in order to reproduce diverse experimental scenarios. Direct comparisons and validation with experimental results will give insights how to control erosive wear in practical applications.

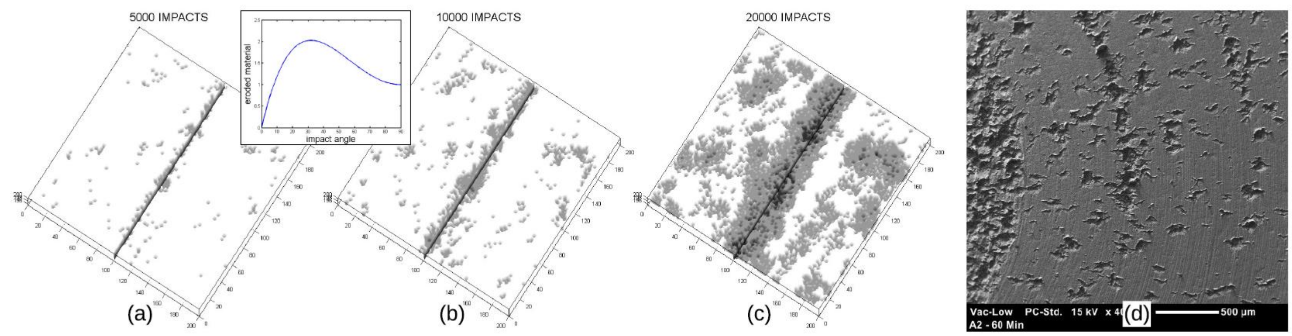

Fig 2: (a-c) LMC-SPE prototype simulation of water droplet erosion on a ductile surface with a preexisting notch. (d) Experiments of water droplet erosion on metallic surfaces with initial grooves machined with a turning lathe.

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