High-speed abrasive wear phenomena: closing the gap between experiment and simulation

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The understanding and experimentation of abrasive wear mechanisms at high speeds is still poorly investigated in literature. This mainly is due to limitations of suitable, well instrumented test rigs for fundamental, single abrasive wear events. Standard scratch-tests which are often utilized for studies of abrasion phenomena operate in the low-speed range up to some mm/s, while applications suffering from abrasive wear often operate at speeds exceeding 1 m/s (e.g. rolling, machining).

Numerical simulations, especially using particle-based methods, are capable of simulating these fast deformation processes, but rely on precise material parameters. For this work we used results from a high-speed compression test on a conventional aluminum alloy to adapt a suitable material model (Johnson-Cook). Then, a series of scratch events with increasing depth was simulated by the particle-based Material Point Method (MPM) implemented in LAMMPS.

For experimental comparison a pendulum test was conceived. By adjusting the balance point of the swing arm, having a length of 1 m, a velocity of 8 m/s was achieved at its tip. In order to produce an abrasive wear event similar to scratch testing, a diamond tip of Rockwell-C shape was mounted at the tip of the swing arm. Lateral force measurement was conducted by a fast piezoelectric transducer. Several scratches with different depths were performed and their force signal acquired. Unfortunately, the force signal of the piezoelectric transducer highly depends on the dynamic behavior of the system and cannot be calibrated statically. Therefore, the results of the numerical simulation were utilized to calibrate the force signals of the piezoelectric transducer.

Scratch topographies and abrasive mechanisms were well comparable between experiment and simulation. For future investigations, the calibrated force sensor can be used to acquire high-speed abrasion-relevant material parameters for unknown metallic materials by back-engineering via the numerical simulation. This will significantly increase the precision compared to material parameters gained by standard mechanical testing at low speeds (e.g. tensile test).

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