ABSTRACT

Continuum-scale finite element simulations of powder flow and processes require calibrated constitutive models. The modified Drucker-Prager Cap (mDPC) model, a commonly used constitutive model, has parameters for common pharmaceutical powders obtained from die compaction tests at high relative densities and high plastic volumetric strains [1, 2]. This work presents an experimental calibration of the mDPC model for microcrystalline cellulose MCC PH-101 using a conventional triaxial tester at low confining pressures (50-100 kPa) to supplement existing data at high confinement pressure regimes allowing accurate finite element method (FEM) simulations across a broader range of plastic volumetric strains.

The bulk modulus K is measured from elastic unload-reload cycles during pure hydrostatic compaction and is shown to follow a quadratic dependence on both confining pressure and plastic volumetric strain, consistent with prior die compaction observations. The cap hardening law $p_b(\varepsilon_{v,p})$ is calibrated from the hydrostatic yield stress at each pressure level.

Consolidated-drained triaxial compression tests are performed on 35 specimens at confining pressures of 50-100 kPa. A unified fitting procedure is developed in which the shear yield line parameters (friction angle β, cohesion d) and cap eccentricity R are determined simultaneously by minimizing a single cost function that combines cap-riding and shear failure residuals. The friction angle decreases linearly with plastic volumetric strain, the cap eccentricity increases linearly, and the cohesion is constant over the investigated density range.

Uncertainty in all calibrated parameters is quantified through parametric bootstrapping, in which measured stresses and strains are perturbed within their propagated instrument uncertainties and the fits are repeated over 2000 iterations. The resulting 95% confidence intervals provide an estimate of how measurement noise propagates into the constitutive model parameters. All parameters and their uncertainties are reported as functions of plastic volumetric strain for direct input into finite element simulations.