Parameter Identification for Soil Simulation based on the Discrete Element Method and Application to Small Scale Shallow Penetration Tests

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ABSTRACT

In recent years, the Fraunhofer ITWM has developed and implemented a software solution entitled GRAnular Physics Engine (GRAPE) for modeling and simulating soil and soil-tool interaction based on investigations in [1, 2, 3]. GRAPE is founded on the Discrete Element Method (DEM) with a focus on the accurate prediction of reaction forces. The particles are represented by three-dimensional rigid spheres with three translational degrees of freedom and scale-invariant linear particle interaction forces. In particular, GRAPE is validated in real application scenarios in cooperation with Volvo Construction Equipment, cf. [4, 5].

The parametrization of a GRAPE model is based on a triaxial test as described in [1], and implies the appropriate choice of the most influencing simulation parameters like the particle size distribution (that may represent a scaling of the real grain-size distribution due to the scale-invariant force law), the porosity n, the normal stiffness k_N and damping d_N, the tangential stiffness k_T and damping d_T, or the friction coefficient μ. The parameters of the virtual experiment are determined to reflect the soil's characteristic strain-stress behavior in the corresponding real experiment performed in the soil mechanics laboratory.

In this presentation, we illustrate the parameter identification process for two types of soil, namely a poorly graded sand (A) and a well graded sand-silt mixture (B) with mean grain diameter $d_{50}(\mathrm{A}) = 0.290$ mm and $d_{50}(\mathrm{B}) = 0.036$ mm, respectively. The material is characterized according to the pertinent classification code. We determine the respective soil and particle interaction parameter sets $\mathcal{P}(\mathrm{A})$ and $\mathcal{P}(\mathrm{B})$ to match the observed behavior in the soil triaxial test. Subsequently, we discuss the applicability of these identified parameter sets – that reflect the triaxial test – to reproduce small scale shallow penetration tests performed in the soil mechanics laboratory, cf. [6]. The tests are carried out in a cylindrical container of a diameter of 300 mm and a height of 200 mm with a steel rod penetrometer of 10 mm diameter with a flat base. During the tests the penetration force and the corresponding displacement are measured for a total depth of 30 mm. We generate appropriate virtual soil samples for A and B with interaction parameters $\mathcal{P}(\mathrm{A})$ and $\mathcal{P}(\mathrm{B})$, simulate the corresponding penetration tests and compare the resulting particle reaction forces on the penetrator with the measured reaction forces in the experiment performed in the soil mechanics laboratory.

The procedure outlined in this presentation delivers a calibrated set of parameters that is validated on a boundary value problem. Subsequently, the model can be utilized for parametric analyses of soil-tool interactions for design and optimization procedures in terramechanical applications.

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