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Discrete Element Modelling of Moisture-Dependent Grain Bulk Behaviour under Compressive Loading

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Abstract

Appropriate conception and construction of the in-storage bins are of great importance to the safety of stored grains. In this regard, a major problem to address is the substantial decrease in the bulk porosity imposed by the compressive stresses caused by the dead weight of bulk in the storage bins. The decreasing rate of porosity is mainly attributed to the mechanical deformation of grains and depends on their physical and viscoelastic properties, the aggregate stored mass as well as the bin properties. For practical purposes, the misestimation of the porosity contributes to ineffective aeration strategies and likely grain deterioration. Thus, this study aimed to investigate the bulk behavior of wheat (Pioneer A, DSV AG) during compression under controlled conditions. As the computational approach, the discrete element method (DEM) was used to analyse in detail the grain behaviour at alike conditions. The compression tests were carried out at two different moisture contents, explicitly 12.39 and 25.41 % w.b. The physical properties, such as dimensions, mass, solid density, Poisson's ratio, Shear modulus and Young's modulus were measured via laboratory experiments. The interaction properties of wheat, such as the coefficient of restitution, static and rolling friction, were empirically determined. A coherent set of yield normal stress from 0 to 300 kPa at a displacement rate of $1.25\,\mathrm{mm\,min^{-1}}$ was imposed under experimental and simulation frameworks. The increase of moisture content contributed to significant differences in physical properties and bulk compressibility at $p \leq 0.05$. A good agreement amongst the simulation and experimental results at different compressive loadings, in terms of stress, volumetric strain, and bulk density was observed. The spatial and ephemeral variations in particle-scale were modeled and compared to the real bulk formations, revealing a high potential of DEM for the design and optimisation of post-harvest handling processes.

Keywords: Calibration tests, mechanical properties, multi-sphere method, particle, physical properties, simulation, three-dimensional

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