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Discrete element modeling of moisture-dependent grain bulk behavior under compressive loading

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Introduction

- During in-bin storage, cereal grains are subject to burden stresses exerted by the dead weight of the bulk, resulting in self-compaction.
- The main objective of this study was to investigate the bulk behavior of wheat grains during compression under controlled conditions.

Material and Methods

- The wheat grains (*Pioneer A, DSV AG*) at moisture contents of 12.39 and 25.41 % w.b was used as a reference product.
- Physical, mechanical and interaction properties of grains have been experimentally assessed.
- An in-house apparatus (Fig.1) with yield stress ranging from 0 to 300 kPa at a constant displacement rate of 1.25 mm·min^{-1} was applied for the compression tests.
- Discrete Element Method (DEM) was used for modeling purposes.

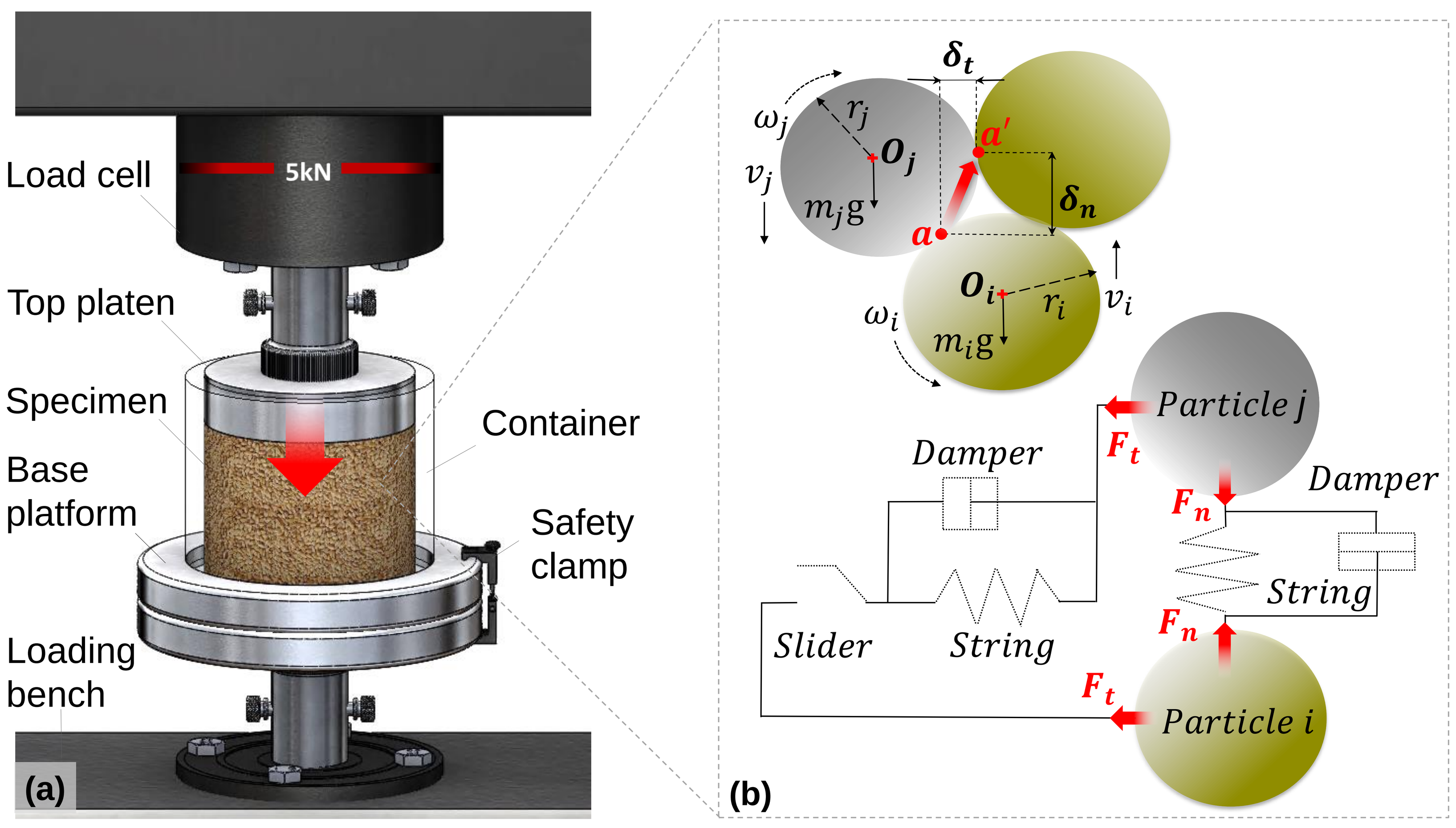

Fig. 1. (a) Configuration of the compression apparatus, (b) the illustration scheme of the contact model used for DEM simulations.

Results

- The change of moisture content resulted in significant differences of physical, mechanical and interaction properties at $p \le 0.05$.

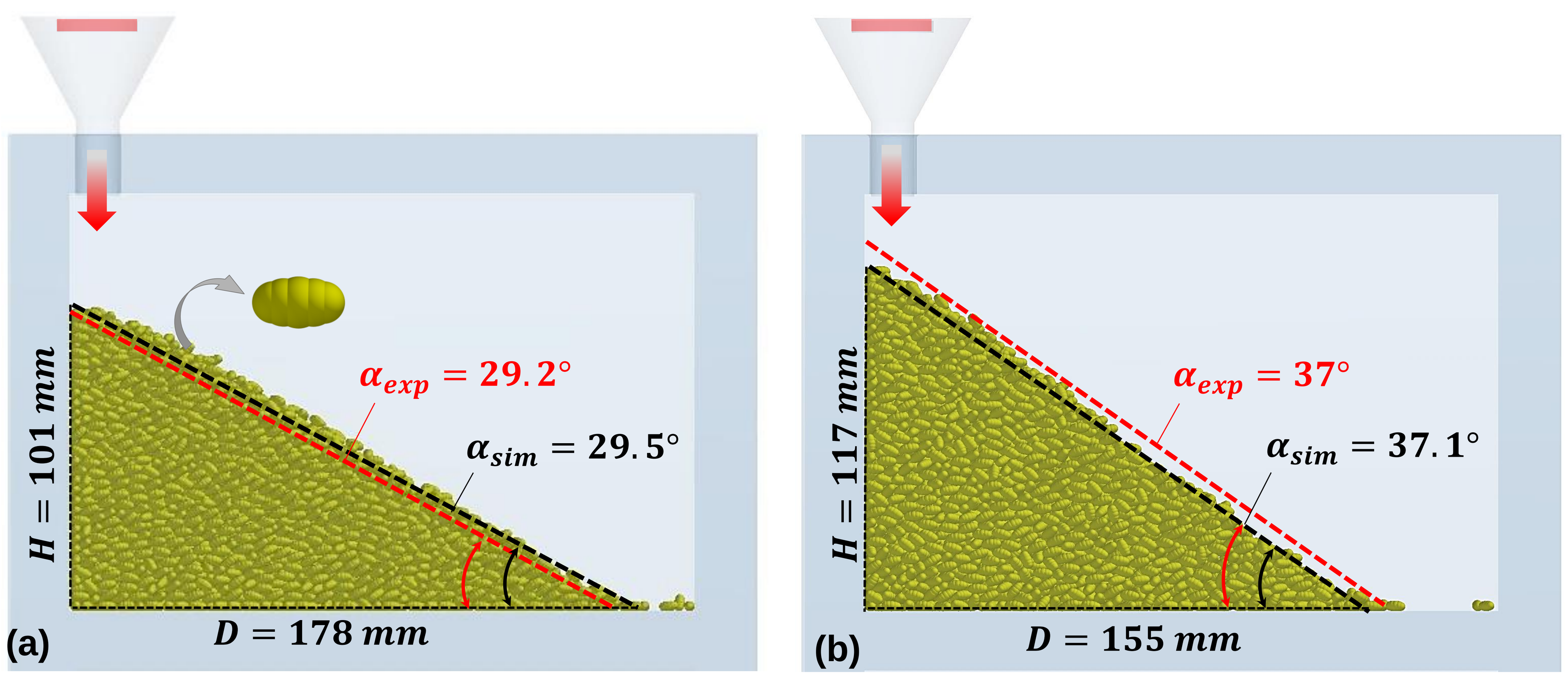

Fig. 2. The virtual experiment of the static angle of repose (α) during piling up test at moisture contents of (a) 12.39 and (b) 25.41 % w.b; Simulated (--) and measured (--) results.

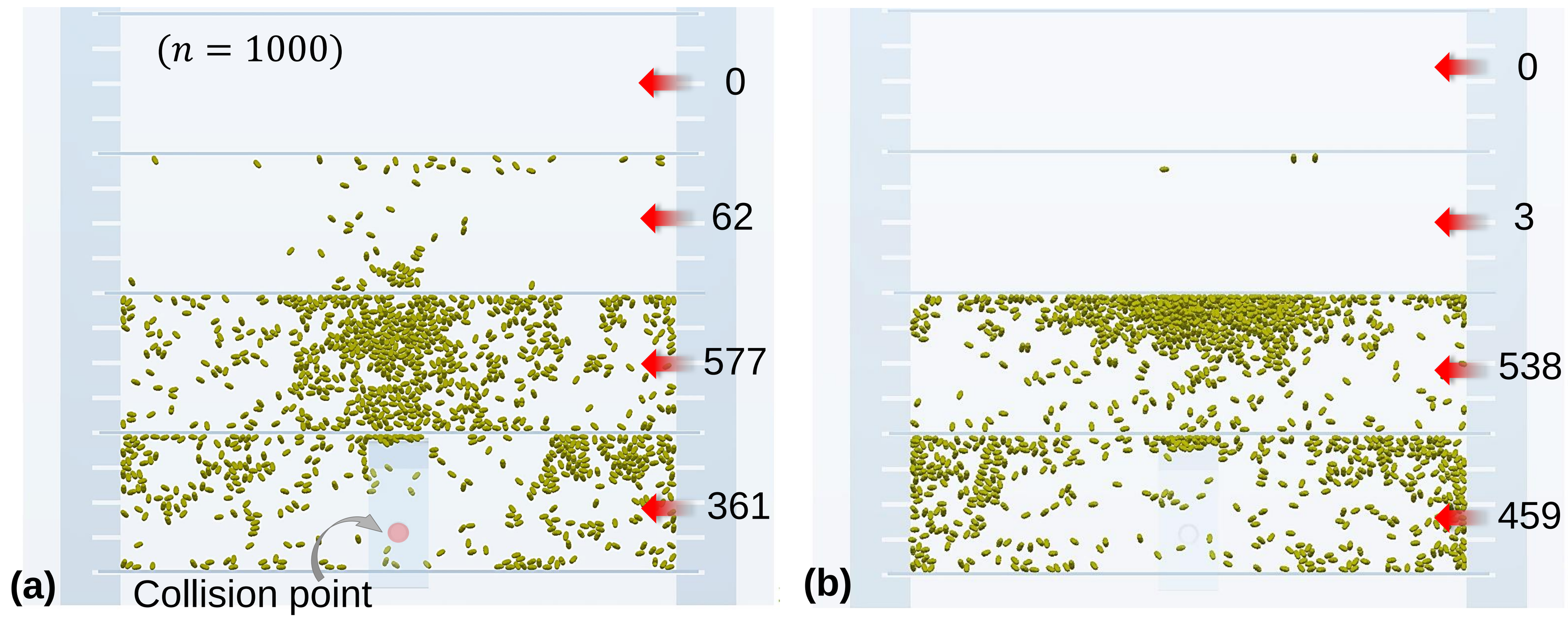

Fig. 3. Simulated results of the drop-test of wheat particles at (a) 12.39 and (b) 25.41 % w.b. An error difference of 4.6 % was found in contrast to experiments.

- The increase of moisture content resulted in higher compressibility, lower stiffness, smaller intergranular voids, and greater particle deformability.

Table 1. Interaction properties of wheat grains (*Pioneer A, DSV AG*)

MC w.b (%)	Coefficient of static friction		Coefficient of rolling friction		Coefficient of restitution	
	$\mu_{s\,(p,w)}$	$\mu_{s\,(p,p)}$	$\mu_{r\,(p,w)}$	$\mu_{r\,(p,p)}$	$e_{(p,w)}$	$e_{(p,p)}$
12.39	0.40	0.17	0.03	0.01	0.56	0.17
25.41	0.75	0.37	0.03	0.02	0.48	0.15

* (p,p) particle to particle; (p,w) particle to wall

- A good agreement was observed between the simulation and observed results at different compressive loadings, in terms of compressive stress, volumetric strain and bulk density (Fig. 4).

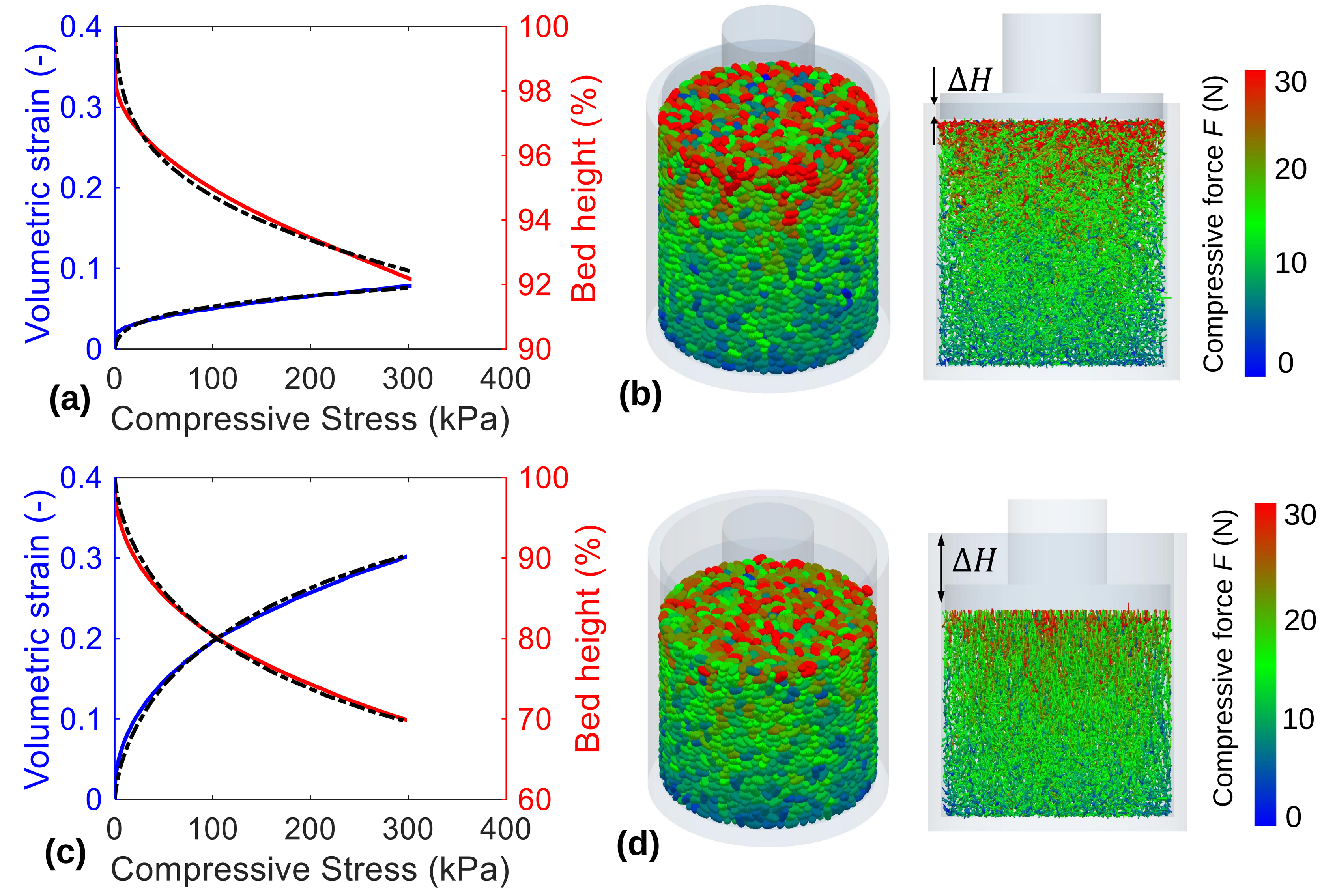

Fig. 4. Comparison of the observed (--) and simulated (=) results in terms of compressive stress, volumetric strain and bed height at (a) 12.39 and (b) 25.41 % w.b; (c, d) Particle-scale compression profiles at 300 kPa assessed by DEM.

Conclusion

- Discrete Element Method (DEM) revealed a high potential for designing and optimizing the post-harvest handling processes.

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