Predicting Particle Flow in Bulk Handling Applications





Granular Materials



- Granular material is defined as
 - Collection of macroscopic individual (discrete) particles
 - Particles interact through physical contact associated with energy dissipation
- Granular materials are everywhere in nature, and are second to water, the most used resource on earth [1]
- The handling and processing consumes 10% of the energy that we produce on earth [2]
- It is estimated that we waste 40% of the capacity of many of our industrial plants due to problems related to the handling of granular materials, and a poor understanding of their behaviour [3].



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A Typical Working Day















































Can we model granular materials?





Continuum-based Models

Material Point Method (MPM)

Open pit mine wall failure

• Mohr-Coulomb material



- Young's modulus 1e7 N/m²
- Poisson's ratio 0.3
- Friction 30°
- Dilation 5°
- Density 2600 kg/m³





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Discrete-based Models



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Screening

Discrete-based Models

Discrete Element Method (DEM)

- DEM models discrete particles
- Contact models based on overlap-force relation



Discrete particles





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Time cycling

Calibration of parameter values





- Perform laboratory experiment
- Repeat experiment in DEM
- Adjust the contact parameter values to match the bulk response
- Combination of experiments needed for the multi-parameter set
- Experiments: small, sensitive to material properties
- Developed experiments and methodologies over 20 years



Calibration of parameter values

Particle size and shape







Calibration of parameter values

Shear testing



Acrylic cell diameters 110 x 240 mm



Ring (Rotational) Shear Testing of Corn



Direct (Translational) Shear Testing of Coal









Calibration of parameter values

Angle of repose and mass flow rate





Calibration of parameter values

Static angle of repose



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Calibration of parameter values

Dynamic angle of repose





Calibration of parameter values

Centrifuge testing



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Applications

Applications Silo/bin/hopper discharge



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Applications Rotary valve





Applications Mixing and blending





Applications Tumbling mill





Applications Soil-tool interaction



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Dragline bucket filling

Soil tillage

Applications Conveyor transfer modelling



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Laboratory recirculating conveyor

DEM modelling

Cohesive material

Applications Conveyor transfer scale testing







Applications Fertiliser spreading



Title: Stellenbosch University - Fertilizer Spreader 7b: Time = 5.00106106073e-003 s





Title: Stellenbosch University - Fertilizer Spreader - Reflector 2b: Time = 5.00106106073e-003 s





Applications Rock fall protection







Applications Postharvest handling of fruit (soft particles)



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Destemming of grape berries

Apple packaging

Apple water conveyor









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[1] Richard, P., Nicodemi, M., Delannay, R., Ribiere, P., Bideau, D., 2005, Slow relaxation and compaction of granular systems, Nat. Matter, 4(2), 121

[2] Duran, J., 2000, Sands, Powders, and Grains: An Introduction to the Physics of Granular Materials. Partially Ordered Systems. Springer, New York

[3] Ennis, B.J., Green, J., Davies, R., 1994, Particle technology: The legacy of neglect in the U.S., Chemical Engineering Progress, 90, 32–43