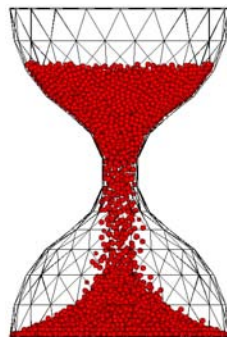




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Granular Materials Research Group



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1 Introduction

1.1 Background

The flow and behaviour of granular material is an ongoing research subject for many years because of its importance in industrial processes such as bulk materials handling, comminution, mixing, consolidation, etc. A great wealth of information exists in these fields but most of the information is in the form of empirical formulas and curve fits. Soil mechanics and earthmoving are two of the historic research areas where much work was done. The empirical behaviour of soils and rocks is well documented and various numerical models were developed.

In recent years, research into the behaviour of granular materials shifted towards numerical simulation models, such as the discrete element method (DEM) and specialised continuum models. The exponential growth in the computing capability of modern computers makes it possible today to model fairly complex granular flows. The largest part of the research effort in this field is still in the optimisation of algorithms and development of contact constitutive models.

1.2 History of Research at Stellenbosch

The research into granular flow at the Department of Mechanical and Mechatronic Engineering of the University of Stellenbosch started off with a request from industry for the optimisation of dragline buckets. During the research it was realised that the interaction between granular material and the engagement tools is very poorly understood.

The granular materials research group was established with the aim to investigate the optimisation of earthmoving, mining and agricultural equipment. With financial support from industry, a three-dimensional discrete element method (DEM) simulation software package was purchased. A continuum based simulation model was also developed for granular flows using the material point method (MPM), a meshless finite element method.

Over time, through undergraduate and postgraduate projects, a range of support test equipment was developed to obtain material properties for numerical simulations. This includes a large scale shear tester. The testing facilities at the Civil Engineering department were also extensively used for material classification and small scale shear tests.

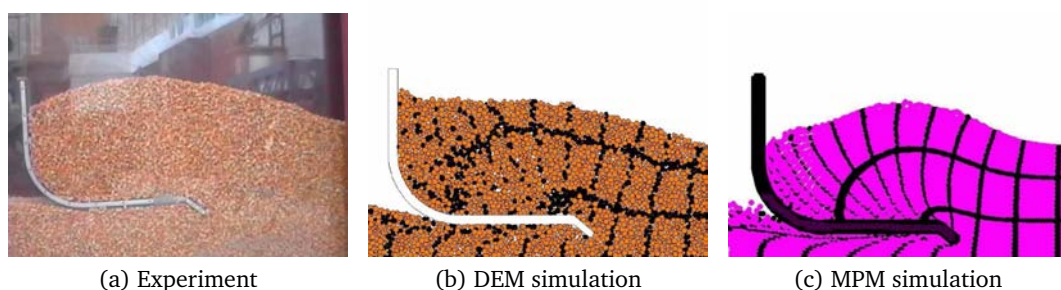


Figure 1: Excavator bucket filling

2 Stellenbosch Granular Materials Research Group

2.1 Expertise

The Granular Materials Research Group in the Department of Mechanical and Mechatronic Engineering, Stellenbosch University, has established expertise and software to conduct research and investigations into a variety of granular flow problems, through:

- Simulation of granular flow using the discrete element method (DEM).
- Simulation of granular flow using the material point method (MPM), a meshless finite element method.
- Experimental calibration of simulation parameters for material properties.
- Experimental verification of granular flow simulations.

2.2 Objectives

The objectives of the research group are to:

- Establish and broaden the expertise in the modelling of granular materials.
- Provide consulting services to industry to solve their granular flow problems.
- Train engineers equipped with the necessary skills and knowledge to contribute to the field of granular materials research as well as to serve the industry as specialists in the field.

2.3 Software and equipment

Discrete Element Method computer code: The group uses the commercial PFC3D software from Itasca. It was successfully used for a wide range of research. The group has an indepth knowledge and expertise in the use of DEM software.

Material Point Method computer code: The group developed an in-house Material Point Method computer code. This code, based on a meshless finite element method, can model applications where large deformation and displacements are present. It has been successfully used to model anchor pull-out and excavator bucket filling.

3 Research projects

3.1 Mining and excavations

Dragline bucket optimization: This research was undertaken for VR Steel as a THRIIP/TIPTOP project. The aim was to model the filling process of a dragline bucket using DEM and predicting the bucket motion, the filling rate and the drag forces.

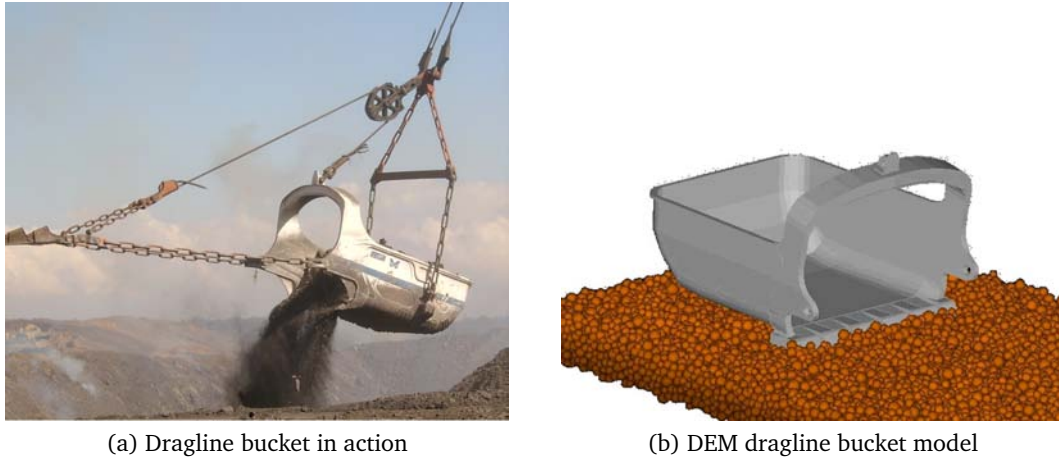


Figure 2: Dragline bucket filling

Conveyor transfer point: This was a research/demonstration project for Anglo American. The aim of the research was to model a conveyor material transfer point using DEM. It was used for a newly designed transfer point where platinum ore is transferred from one conveyor to another conveyor via a chute to predict material flow rates.

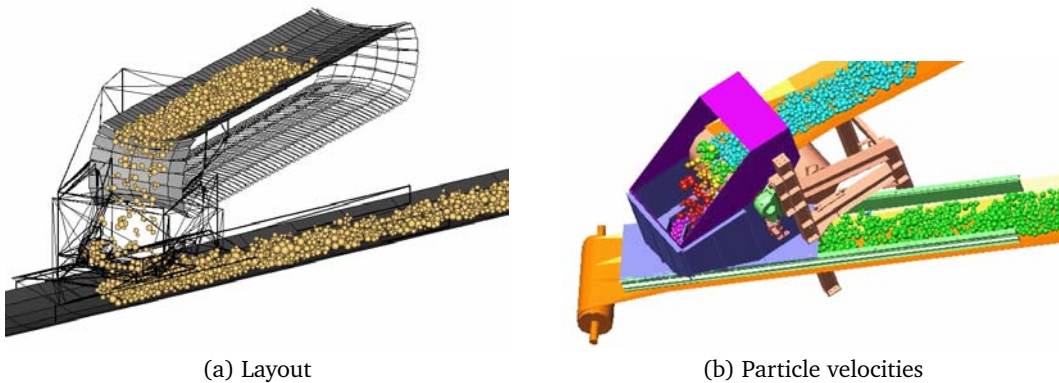


Figure 3: DEM simulation of conveyor transfer point

Material calibration: This is a research project for Anglo American and THRIIP for the development of material calibration procedures for DEM applications. This includes determining particle size and shape, density, contact stiffness and friction values (ongoing research).

3.2 Agricultural

Vibrating subsoiler: This was an in-house research project to investigate the draft force reductions encountered by vibrating ploughs. The aim was to obtain a better understanding of the phenomena and to optimize the performance of such implements.



Figure 4: Vibrating subsoiler

Centrifugal fertiliser spreader: There a great need in the soft fruit industry for fertiliser spreaders that can deliver the fertiliser in a specific pattern to minimize wastage. This in-house project was undertaken to investigate the performance and optimize the design of centrifugal fertiliser spreaders. This is an ongoing project.

Mechanical handling of soft fruit: This new project was undertaken to model the handling of grapes with the focus on the de-stemming process (the removal of the berries from the stems). It includes experiments and DEM simulations.



Figure 5: Centrifugal fertiliser spreader

3.3 Mechanical and aerospace engineering

Particle dampers: Particle dampers are basically a container filled with one or more particles (metals, ceramics, etc.). It functions by dissipating energy through inelastic impacts and friction between the particles and the walls and between the particles themselves. The main applications are aerospace, ground transportation and the high performance sporting equipment industry.

The purpose of this research was to determine the performance parameters of particle dampers under acceleration loads that can be found during a rocket launch, a banking aircraft, etc.

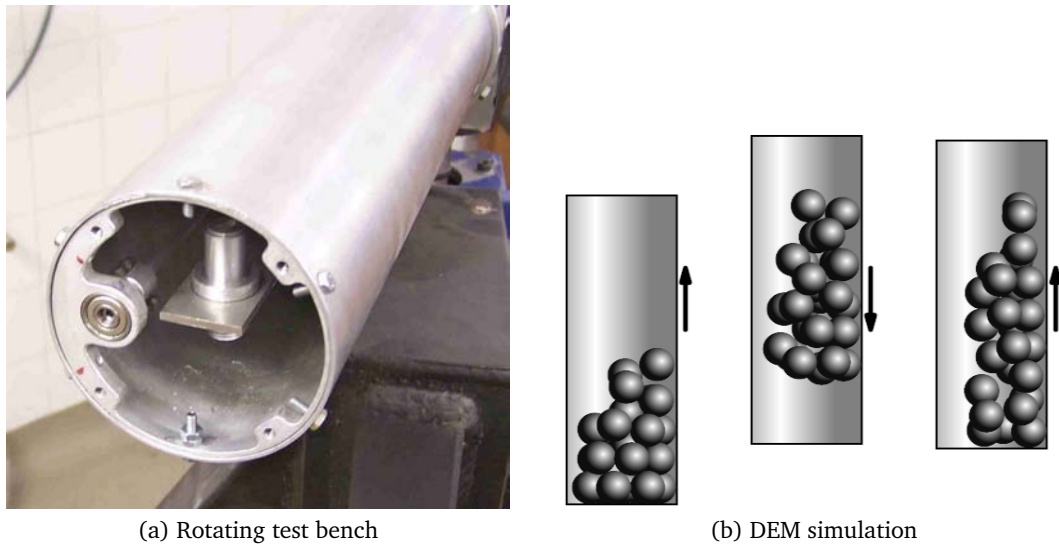


Figure 6: Particle dampers

4 Future work

There is a worldwide need for standardised tests and procedures for DEM calibrations. This is the focus of a number of international work groups made up of industry and academic institutions. At this stage there is no consensus on any standards or tests.

The major focus of our research group is the development of equipment and procedures for obtaining and calibration of material parameters for granular flow simulations. This is needed for our industrial work and to contribute towards the international effort.

5 Research outputs

5.1 Theses and dissertations

PhD's

- **Coetzee, C.J.:** *The modelling of granular flow using the particle-in-cell method*, PhD thesis, University of Stellenbosch, South Africa, 2004.
- **Els, D.N.J.:** *The Effectiveness of Particle Dampers under Centrifugal Loads*, PhD thesis, University of Stellenbosch, South Africa, 2009.

Masters

- **Crouse, P.G.:** *Modelling of Dragline Dynamics*, MSc (Mech) thesis, University of Stellenbosch, South Africa, 2000.
- **Coetzee, C.J.:** *Forced Granular Flow*, MSc (Mech) thesis, University of Stellenbosch, South Africa, 2000.
- **Dymond, G.F.D.:** *Creation, Optimization and Verification of a Three Dimensional Numerical Model to Simulate a Dragline Bucket During the Digging Cycle Using Modern DEM Software*, MSc (Mech) thesis, University of Stellenbosch, South Africa, 2007.
- **Van der Linde, J.:** *Discrete Element Modeling of a Vibratory Subsoiler*, MSc (Mech) thesis, University of Stellenbosch, South Africa, 2007.

5.2 Journal Papers

- **Coetzee, C.J., Vermeer, P.A. and Basson, A.H.:** The Modelling of Anchors using the Material Point Method, *International Journal for Numerical and Analytical Methods in Geomechanics*, vol. 29, pp. 879-895, 2005.
- **Coetzee, C.J., Basson, A.H., Vermeer, P.A.:** Discrete and Continuum Modelling of Silo Discharge, *R&D Journal, A Publication of the South African Institution of Mechanical Engineering*, vol. 22, no. 2, 2006.
- **Coetzee, C.J., Basson, A.H. and Vermeer, P.A.:** Discrete and continuum modelling of excavator bucket filling. *Journal of Terramechanics*, vol. 44, pp. 177-186, 2006.
- **Coetzee, C.J. and Els, D.N.J.:** Calibration of discrete element parameters and the modelling of silo discharge and bucket filling, *Computers and Electronics in Agriculture*, vol. 65, no. 2, pp. 198-212, 2009.
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- **Coetzee, C.J., Els, D.N.J. and Dymond, G.F.:** Discrete element parameter calibration and the modelling of dragline bucket filling, *Journal of Terramechanics*, 2009, Doi:10.1016/j.jterra.2009.03.003
- **Coetzee, C.J. and Els, D.N.J.:** The Numerical Modelling of Excavator Bucket Filling using DEM, *Journal of Terramechanics*, Accepted June 2009.

5.3 Conference proceedings

- **Els, D.N.J. and Coetzee, C.J.:** Friction forces in a vertically pushed granular column, In: *Proceedings of the International Symposium on Reliable Flow of Particulate Solids III*, Porsgrunn, Norway, Aug 1999.
- **Crouse, P.G. and Els, D.N.J.:** A rigid Multibody dynamical description of a rope and pulley problem. In: *Proceedings of SACAM 2000*, Durban, South Africa, Jan 2000.
- **Coetzee, C.J. and Els, D.N.J.:** Modelling excavator bucket filling with DEM. In: Mang, H.A., Rammerstorfer, F.G. and Eberhardsteiner, J. (eds), *Proceedings of the Fifth World Congress on Computational Mechanics*, Vienna, Austria, 7–12 Jul 2002.
- **Beuth, L., Benz, T., Vermeer, P.A., Więckowski, Z. and Coetzee, C.J.:** Large deformation analysis using a quasi-static Material Point Method. In: *Proceedings of the 17th International Conference on Computer Methods in Mechanics*, Lodz, Poland, 2007.
- **Beuth, L., Benz, T., Vermeer, P.A., Coetzee, C.J., Bonnier, P. and Van der Berg, P.:** Formulation and validation of a quasi-static material point method. In: Pande, G.N. and Pietruszczak, S. (eds), *Proceedings of the Tenth International Symposium on Numerical Models in Geomechanics (NUMOG X)*, Rhodes, Greece, 25–27 Apr 2007.
- **Coetzee, C.J.:** The Modelling of Bulk Materials Handling using the Discrete Element Method. In: *Proceedings of the 1st African Conference on Computational Mechanics – An International Conference, AfriComp*, Sun City, South Africa, 7–11 Jan 2009.
- **Beuth, L., Więckowski, Z., Vermeer, P.A. and Coetzee, C.J.:** 2009, The Modelling of Large Deformation Geotechnics using the Material Point Method. In: *Proceedings of the 1st African Conference on Computational Mechanics – An International Conference, AfriComp*, Sun City, South Africa, 7–11 Jan 2009.
- **Els, D.N.J.:** Damping of rotating beams with particle dampers. In: *Proceedings of the 50th AIAA/ASME/ ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference*, AIAA 2009-2688, Palm Springs, California, 4–7 May 2009.
- **Jassim, I. and Coetzee, C.J.:** A Contact Algorithm for Non-Structured MPM Meshes, In: *Proceedings of the 18th International Conference on Computer Methods in Mechanics, CMM 2009*, Zielona Gora, Poland, 18-21 May 2009.

5.4 Other research Publications

- **Vogler, U., Coetzee, C.J. and Vermeer, P.A.:** Simulation of Field Model Tests by two different Numerical Approaches. *DGGK, AK 1.6 “Numerik in der Geotechnik”:* *Workshop: Nachweise für Böschungen und Baugruben mit numerischen Methoden*, S. 37-46, Weimar, 2003.
- **Coetzee, C.:** Calibration of Discrete Element Parameters and the Modelling of Bulk Materials Handling, *Conveyors and Bulk Materials Conference*, Midrand, South Africa, 6–7 August 2008