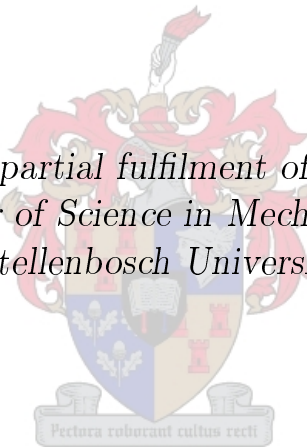


Discrete Element Modeling of a Vibratory Subsoiler

by

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*Thesis presented in partial fulfilment of the requirements for
the degree of Master of Science in Mechanical Engineering at
Stellenbosch University*



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Declaration

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Abstract

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Vibrating a tillage tool is an effective way of reducing the draft force required to pull it through the soil. The degree of draft force reduction is dependent on the combination of operating parameters and soil conditions. It is thus necessary to optimize the vibratory implement for different conditions.

Numerical modelling is more flexible than experimental testing and analytical models, and less costly than experimental testing. The Discrete Element Method (DEM) was specifically developed for granular materials such as soils and can be used to model a vibrating tillage tool for its design and optimization. The goal was thus to evaluate the ability of DEM to model a vibratory subsoiler and to investigate the cause of the draft force reduction.

The DEM model was evaluated against data ...

Uittreksel

Diskrete Element Modelling van 'n Vibrerende Skeurploeg

(“Discrete Element Modeling of a Vibratory Subsoiler”)

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Om 'n tand implement te vibreer is 'n effektiewe manier om die trekkrag, wat nodig word om dit deur die grond te trek, te verminder. Die graad van krag vermindering is afhanklik van die kombinasie van werks parameters en die grond toestand. Dus is dit nodig om die vibrerende implement te optimeer vir verskillende omstandighede.

Numeriese modulering is meer buigsaam en goedkoper as eksperimentele opstellings en analitiese modelle. Die Diskrete Element Metode (DEM) was spesifiek vir korrelrige materiaal, soos grond, ontwikkel en kan gebruik word vir die modellering van 'n vibrerende implement vir die ontwerp en optimering daarvan. Die doel was dus om die vermoë van DEM om 'n vibrerende skeurploeg te modelleer, te evalueer, en om die oorsaak van die krag vermindering te ondersoek.

Die DEM model was geëvalueer teen data ...

Acknowledgements

I would like to express my sincere gratitude to the following people and organisations ...

Dedications

Hierdie tesis word opgedra aan ...

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Nomenclature

Constants

$$\pi = 3.141\,592\,654$$

$$e = 2.718\,281\,828$$

Variables

$$Re_D \quad \text{Reynolds number (diameter)} \quad \dots \quad [\quad]$$

$$x \quad \text{Coordinate} \quad \dots \quad [\text{m}]$$

$$\ddot{x} \quad \text{Acceleration} \quad \dots \quad [\text{m/s}^2]$$

$$\theta \quad \text{Rotation angle} \quad \dots \quad [\text{rad}]$$

$$\tau \quad \text{Moment} \quad \dots \quad [\text{N}\cdot\text{m}]$$

Vectors and Tensors

$$\overrightarrow{v} \quad \text{Physical vector, see equation ...}$$

Subscripts

$$a \quad \text{Adiabatic}$$

$$a \quad \text{Coordinate}$$

Chapter 1

Discrete Element Method

1.1 Introduction

In granular or particle flow simulations with Discrete Element Method (DEM), the mechanical behavior of a system of particles are simulated. The basic building blocks of DEM are finite sized particles and walls. It is generally classified into two basically different approaches.

The first is the “hard sphere”, event-driven method (e.g. Luding, 1994, 2004), where particles are assumed to be perfectly rigid and they follow an undisturbed motion until a collision occurs. Due to the rigidity of the interaction, the collisions occur instantaneously with accompanying momentum transfer. It is mainly used for collisional, dissipative granular gases.

The second is the so-called “soft particle” molecular dynamics pioneered by Cundall and Strack (1979), where the particles are allowed to overlap or penetrate each other. Constrains on the physical space that a particle can occupy at a specific time is included with contact or penalty forces related to the amount of overlap and contact velocity between particles or between particles and walls. The motion of the system is modelled by the integration of Newton-Euler equations for motion of every individual particle.

Appendices

Appendix A

Discrete Element Method Theory

A.1 Ball elements

A.1.1 Ball mass and inertia parameters

Consider a volume element dV with respect to a static base S of an arbitrary solid body with density ρ . The mass of the body is obtained by integrating over the volume of the body,

$$m = \int_{\text{body}} \rho dV \quad (\text{A.1.1})$$

In figure A.1, a ball with radius R_i and uniform density ρ_i is depicted. The mass of the ball is after integration of equation (A.1.1)

$$m_i = \frac{4}{3}\pi\rho_i R_i^3. \quad (\text{A.1.2})$$

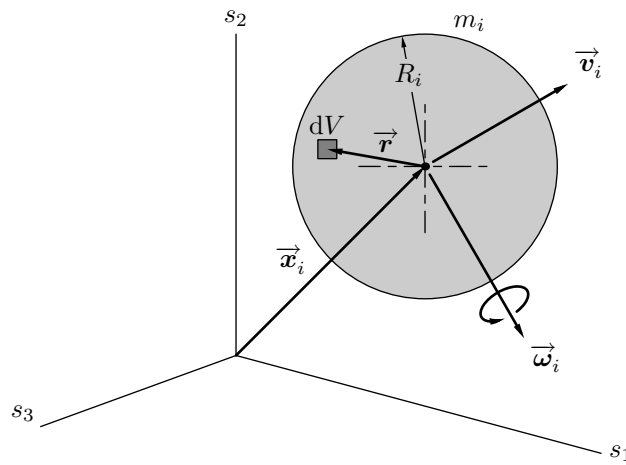


Figure A.1: Ball Element Parameters

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- Cundall, P.A. and Strack, O.D.L. (1979). A discrete numerical model for granular assemblies. *Géotechnique*, vol. 29, no. 1, pp. 47–65.
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