Discrete Element Modeling of a Vibratory Subsoiler

by

Jaco van der Linde

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

Department of Mechanical and Mechatronics Engineering,
University of Stellenbosch,
Private Bag X1, Matieland 7602, South Africa.

Supervisor: Mr. D.N.J. Els

December 2007

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: ....

Abstract

Discrete Element Modeling of a Vibratory Subsoiler

J. van der Linde

Department of Mechanical and Mechatronics Engineering,
University of Stellenbosch,
Private Bag X1, Matieland 7602, South Africa.

Thesis: MScEng (Mech)

December 2007

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 Modellering van 'n Vibrerende Skeurploeg

("Discrete Element Modeling of a Vibratory Subsoiler")

J. van der Linde

Departement Meganiese en Megatroniese Ingenieurswese,
Universiteit van Stellenbosch,
Privaatsak X1, Matieland 7602, Suid Afrika.

Tesis: MScIng (Meg)

Desember 2007

Om 'n tand implement te vibreer is 'n effektiewe manier om die trekkrag, wat benodig 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 the modelleer, te evalueer, en om die oorsaak van die krag vermindering te ondersoek.

Die DEM model was geïvalueer teen data ...

Acknowledgements

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

Dedications

Hierdie tesis word opgedra aan …

Contents

List of Figures

List of Tables

Nomenclature

Constants

$\pi =$	3.141 592 654	
$\mathrm{e} =$	2.718 281 828	

Variables

Re_{D}	Reynolds number (diameter)	[ ]
x	Coordinate	[m]
$\ddot{x}$	Acceleration	[m/s^2]
θ	Rotation angle	[rad]
τ	Moment	[N·m]

Vectors and Tensors

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

Subscripts

a	Adiabatic
a	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 $\mathrm{d}V$ 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,

$$m = \int_{\text{body}} \rho \, \mathrm{d}V \tag{A.1.1}$$

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)

$$m_i = \tfrac{4}{3}\pi\rho_i \, R_i^3. \tag{A.1.2}$$

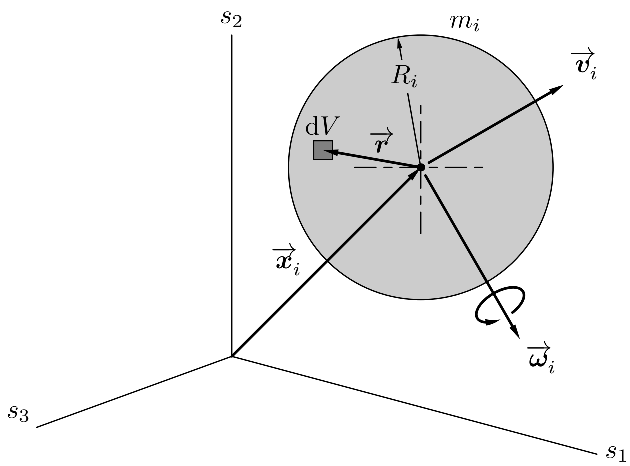

Figure A.1: Ball Element Parameters

List of References

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

Luding, S. (1994). *Models and Simulations of Granular Materials.* PhD, Universität Freiburg.

Luding, S. (2004). Molecular dynamics simulations of granular materials. In: Hinrichsen, H. and Wolf, D. (eds.), *The Physics of Granular Media*, pp. 299–324. Wiley-VCH, Weinheim.