



# Discrete Element Modeling of a Vibratory Subsoiler

by

John Doe

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

Supervisor: Dr. D.N.J. Els

Co-supervisor: Prof. J. Smith

March 2023



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# Abstract

## Discrete Element Modeling of a Vibratory Subsoiler

J. Doe

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

Thesis: MEng (Mech)

March 2023

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”)*

J. Doe

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

Tesis: MIng (Meg)

Maart 2023

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 buigsam 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 ...

# Acknowledgments

# Dedication

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# List of symbols

## Constants

$L_0 = 300 \text{ mm}$

## Variables

$Re_D$	Reynolds number (diameter) . . . . .	[ ]
$x$	Coordinate . . . . .	[ m ]
$\ddot{x}$	Acceleration . . . . .	[ m/s <sup>2</sup> ]
$\theta$	Rotation angle . . . . .	[ rad ]
$\tau$	Moment . . . . .	[ N·m ]

## Vectors and Tensors

$\vec{v}$  Physical vector, see equation ...

## Subscripts

$a$	Adiabatic
$a$	Coordinate

## Abbreviations

DEM	Discrete Element Method
FEA	Finite Element Analysis

# Chapter 1

## Introduction

### 1.1 Background

Starting from the big picture, gradually narrow focus down to this project and where this report fits in.

### 1.2 Objectives

The objectives of the project (in some cases the objectives of the report). If necessary describe limitations to the scope.

### 1.3 Motivation

Why this specific project/report is worthwhile.

# Chapter 2

## Literature review

### 2.1 Discrete element method

The Discrete Element Method (DEM) analysis (Cundall and Strack, 1979) uses spherical objects. Lin and Ng (1997) developed a DEM model for ellipsoids.

# Chapter 3

## Content chapter

Unless the chapter heading already makes it clear, an introductory paragraph that explains how this chapter contributes to the objectives of the report/project.

### 3.1 Heading level 2

#### 3.1.1 Heading level 3

##### 3.1.1.1 Deepest heading, only if you cannot do without it

**Equations:** An equation must read like part of the text. The solution of the quadratic equation  $ax^2 + bx + c = 0$  given by the following expression (note the full stop after the equation to indicate the end of the sentence):

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2b}. \quad (3.1)$$

In other cases the equation is in the middle of the sentence. Then the paragraph following the equation should start with a small letter. Euler's identity is

$$e^{i\pi} + 1 = 0, \quad (3.2)$$

where  $e$  is Euler's number, the base of natural logarithms.

The `amsmath` has a wealth of structure and information on formatting of mathematical equations.

**Symbols and numbers:** Symbols that represent values of properties should be printed in italics, but SI units and names of functions (e.g.  $\sin$ ,  $\cos$  and  $\tan$ ) must not be printed in italics. There must be a small hard space between a number and its unit, e.g. 120 km. Use the `siunitx` package to typeset numbers, angles and quantities with units:

$$\begin{aligned}\backslash\mathrm{num}\{1.23\mathrm{e}3\} &\rightarrow 1.23\times 10^3 \\ \backslash\mathrm{ang}\{30\} &\rightarrow 30^\circ \\ \backslash\mathrm{qty}\{20\}\{\mathrm{N.m}\} &\rightarrow 20\,\mathrm{N.m}\end{aligned}$$

**Figures and tables:** The `graphicx` package can import PDF, PNG and JPG graphic files.

Table 3.1: Standard ISO paper sizes

Paper	Sizes	
	$W$	$H$
	[mm]	[mm]
A0	841	1189
A1	594	841
A2	420	594
A3	297	420
A4	210	297
A5	148	210

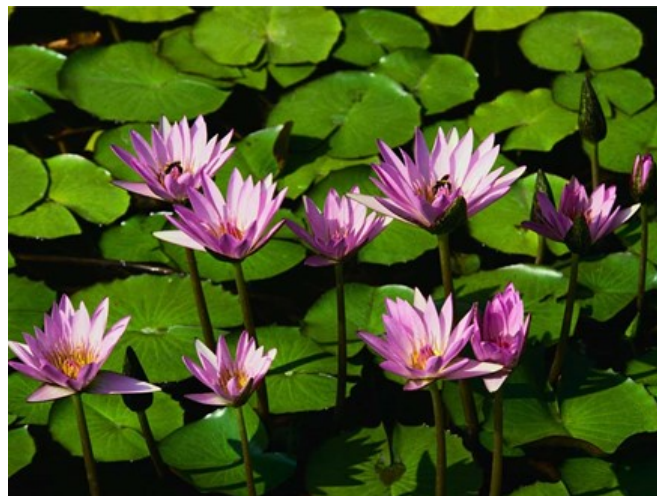


Figure 3.1: Water plants

## Chapter 4

## Conclusions

# Appendix A

## Mathematical proofs

### A.1 Euler's equation

Euler's equation gives the relationship between the trigonometric functions and the complex exponential function.

$$e^{i\theta} = \cos \theta + i \sin \theta \quad (\text{A.1})$$

Inserting  $\theta = \pi$  in (A.1) results in Euler's identity

$$e^{i\pi} + 1 = 0 \quad (\text{A.2})$$

### A.2 Navier Stokes equation

The Navier–Stokes equations mathematically express momentum balance and conservation of mass for Newtonian fluids. Navier-Stokes equations using tensor notation:

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_j} [\rho u_j] = 0 \quad (\text{A.3a})$$

$$\frac{\partial}{\partial t} (\rho u_i) + \frac{\partial}{\partial x_j} [\rho u_i u_j + p \delta_{ij} - \tau_{ji}] = 0, \quad i = 1, 2, 3 \quad (\text{A.3b})$$

$$\frac{\partial}{\partial t} (\rho e_0) + \frac{\partial}{\partial x_j} [\rho u_j e_0 + u_j p + q_j - u_i \tau_{ij}] = 0 \quad (\text{A.3c})$$



## Appendix B

### Experimental results

# 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.
- Lin, X. and Ng, T.T. (1997). A three-dimensional discrete element model using arrays of ellipsoids. *Géotechnique*, vol. 47, no. 2, pp. 319–329.