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Motion Control of a Hexapod Robot Over Uneven Terrain Using Signed Distance Fields

by

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Thesis presented in partial fulfilment of the requirements for the degree of Master of Engineering (Electronic) in the Faculty of 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 ...

Acknowledgments

Dedication

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Constants

$L_0 =$	300 mm

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

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

Subscripts

a	Adiabatic
a	Coordinate

Abreviations

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):

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

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

$$e^{i\pi} + 1 = 0, \tag{3.2}$$

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:

`\num{1.23e3}`	$\rightarrow$	1.23×10^3
`\ang{30}`	$\rightarrow$	30°
`\qty{20}{N.m}`	$\rightarrow$	$20\,\mathrm{N \cdot m}$

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

Table 3.1: Standard ISO paper sizes

Paper	Sizes	
	W [mm]	H [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.

$$e^{i\theta} = \cos\theta + i\sin\theta \tag{A.1}$$

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

$$e^{i\pi} + 1 = 0 \tag{A.2}$$

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:

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_j}\left[\rho u_j\right] = 0 \tag{A.3a}$$

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

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

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.