Experimental Investigations of Granular Matter Flow Regimes leading to Insight into Lahar Flow Dynamics

A thesis presented in partial fulfilment of the requirements for the

degree of

Doctor of Philosophy

in

Earth Science

at Massey University, Manawatū, New Zealand

Adam Charles Neather

2016

Abstract

The flow of granular material governs numerous natural processes including the aeolian dynamics of sand dune formation, sub-aerial and submarine mass flows, the collective dynamics of ice blocks floating on the ocean, avalanches of debris and snow, as well as volcanic granular-fluid flow processes, such as pyroclastic density currents, volcanogenic debris flows and lahars.

Lahars are a particularly important type of granular flow, in regards to its possible effect on human life; they are debris and water-based flows, initiated by volcanic processes. A fascinating aspect about granular matter is the co-existence of behaviour similar to two or all three of the classical states of matter (solid, liquid, gas) and their frequent transitions between these behaviours. Despite the ubiquity of these transitions in nature and industry, the fundamental physics of granular matter remains a mystery, to the extent that a unified theory to describe the motion and behaviour of granular matter is still absent.

This study is an attempt to simulate lahars and their erosion/deposition mechanics in the laboratory by making use of a rotating drum. A rotating drum can be treated as an analogue for a lahar because it allows for erosion and deposition to occur as an active region of material flows over a passive, erodible bed. In nature these processes are transitory and highly dynamic, but an experimental analogue allows for the processes to be observed in a steady system.

Results include detailed maps of the various regions in a flowing granular material cor-

related to the speed of rotation of the flows. The changing status of the active and passive regions allows for measurements of the erosion mechanics within the drum. Also, potentially identified are two new phenomena; high speed rotations appear to include features similar to Kelvin-Helmholtz instabilities, and enclosed regions of sub-rotation, which are referred to as self-enclosed circulation cells (SECCs).

Acknowledgements

I would like to thank my supervisors, Prof. Shane Cronin, Dr. Gert Lube and Prof. Jim Jones for their support and enthusiasm. My examiners, Prof. Ian Fuller, Dr. Stephen Tallon (Callaghan Innovation), and Prof. Indresan Govender (University of KwaZulu-Natal), should also be thanked for the useful feedback on this thesis.

I would also like to thank the engineers Clive Bardell, John Edwards, Daniel Farley, David Feek, Olaf Griewaldt, Nav Prasad (SEW Eurodrive), Ian Thomas, Anthony Wade and everyone at Triple R Engineering, Ltd. for their help designing, building, maintaining and modifying all the fun toys I got to play with during this project.

Special thanks to my family, Joan and Daniel Neather, for their continuing love and care. This thesis is dedicated to them.

Additional thanks (in no particular order) to: Shane Cronin and Debbie Sparkes for being my financial fairy god-mothers; Miles Grafton for proof-reading an embarrassingly early version of this document; Luke Fullard for the MATLAB code he wrote that greatly sped up the analysis; Eric Breard for supplying the pumice material; Anja Moebis for teaching me how the pycnometer works; Kate Arentsen, Janene de Ridder, and Julia Rayner for making sure the wheels of bureaucracy turned smoothly; Liza Haarhoff for the inexhaustible office supplies; Donald Bailey for his image processing knowledge; Mark Morris, Felicity Samuel and all the staff at the Massey Health Centre for putting Humpty Dumpty together again; Matt Hewerdine, Liam Malone, Chris Sanderson, Tom Robertson, Scott Engerbretsen, and everyone at the Manawatū Duelists for understanding the allure of tiny plastic soldiers; Jonathan Barnard for taking up the torch; Ian Furkert for being able to source any piece of scientific equipment, often at a

moment's notice; Matthew Willey for running the local Sceptics in the Pub group; Lionel Wilson and Georg Zellmer, corner-fighters; David Wiltshire for advice on how to light and film the experiments; Manuela Tost for being the world's greatest office-mate; a slightly inebriated Marco Brenna (*in vino veritas*); Wayne Treanor and Gareth Tasker of Hexanine, Palmy's greatest punk/metal band; Nick Look and Matt Irwin for working their IT voodoo; Angela Woodley for ensuring I wasn't homeless; Jonathan Proctor and Braden Walsh for letting me drive; Magret Damaschke and Gaby Gomez for looking at an active volcano and thinking "that'd be a nice place to go for a walk, let's bring Adam"; Rafael Torres-Orozco for his expertise and help in finding the ash sample; Dianne Reilly and everyone at International Student Support; The Bad Cave, Nexus Games, and Mark One Comics, for helping me scratch the itch; David Stevens and everyone at Radio Control for letting me pollute the airwaves with my taste in "music"; Thalia Evans, the world's most patient shipping agent; and all the lovely staff at the campus coffee and book shops.

Apologies to anyone who feels they should be listed here but aren't - your omission was not intentional, and should be seen as a reflection of my poor memory, rather than your lack of contribution.

Declaration

I hereby declare that this thesis is my own work and effort and that it has not been submitted anywhere for any award. Where other sources of information have been used, they have been acknowledged.

Adam Neather, August 2, 2017

Jim Jones

Shane Cronin

Gert Lube

"One can scoop up poppy seeds with a ladle as easily as if they were water and, when dipping the ladle, the seeds flow in a continuous stream."

- Titus Lucretius Carus, ca. 90 to 55 BCE

Quoted in Sands, Powders, and Grains: An Introduction to the Physics of Granular Materials *(Springer, New York, 2000) by D. Jacques.*

"If you sneeze into it, and it goes everywhere, then it's a powder."

- Dr. Marco Brenna, 28th November 2012

Quoted at the Geological Society of New Zealand annual conference BBQ.

Contents

List of Figures

List of Tables