MODELLING OF SNOW AVALANCHE DYNAMICS USING NUMERICAL TECHINQUE AND SNOW CHUTE EXPERIMENTATION

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by

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To my beloved parents,
and mostly to my wife Swagatika

CERTIFICATE

This is to certify that the thesis entitled "**Modelling of Snow Avalanche Dynamics Using Numerical Technique and Snow Chute Experimentation**" being submitted by Mr. **Deba Prakash Satapathy** to the ***Indian Institute of Technology Delhi*** for the award of the degree of ***Doctor of Philosophy*** *is* a bonafide record of research work carried out by him under my guidance and supervision. The thesis work in my opinion, has reached the requisite standard, fulfilling the requirements for the said degree.

The results contained in this thesis have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

A one-dimensional numerical model incorporating variable density is developed for studying snow avalanche dynamics.The density of snow is taken as a variable. It varies along the depth of the avalanche flow as well as with time. In real life field conditions, it varies according to temperature, compaction due to the weight of the overlaying snow, and as a result of metamorphic changes in the structure of the snow cover. The model considers the motion of an avalanche over a general terrain from initiation to runout. It incorporates vertical density and velocity distributions, and is based on the depth averaged mass and momentum equations assuming snow density as variable. The model considers the snow rheology as Newtonian fluid (NF) or Criminale- Ericksen- Filbey fluid (CEFF) for accounting the effect of vertical distributions of snow density and velocity. The density stratification can be taken with the vertical velocity distribution to obtain the mass and momentum flux distribution factors for the NF and CEFF models. By applying the principals of conservation of mass and momentum, a system of hyperbolic partial differential equations has been develop that completely describes the flow, which is assumed to be fluid-like and follow the basic laws of fluid mechanics. The model accounts for the sliding friction, internal viscous friction, and gravitational forces, to capture the basic properties of snow avalanches. The model is numerically solved using TVD Lax-Friedrichs (TVDLF) finite difference scheme. The developed model can be used to predict avalanche runout distance, flow velocity and flow depth over the general terrain. It resolves many deficiencies of Vollemy- Salm model, the Norwegian NIS (Norem-Irgens-Schieldrop) model and the depth integrated constant Saint- Venant equations based models. The parameterizations are obtained for density and velocity

distributions along the flow depth in terms of mass and momentum distribution factors. Two types of constitutive relationships as described for Newtonian and Criminale-Ericksen-Filby fluids are considered. The avalanche flow experiments were carried out in an inclined snow chute of 61 m long, 2 m wide and 1 m deep, constructed at Dhundhi, Manali, India for a number of flows characterizing different release depth and varying snow density. The CCD cameras connected with the digital video recorder (DVR) are used to visualize and capture the motion of moving snow mass in the chute and to measure the velocity and the depth of flow. Based on the experimental observations, generalized mass and momentum distribution factors were computed for the two NF and CEFF models using the derived parameterization schemes for different density stratification. The obtained distribution factors are used in the density varying model. The comparison of results obtained with the developed numerical model with the experimentally measured values indicates that flow variables, namely velocity and runout distance are simulated well by the model. The optimum values of model parameters, namely dynamic friction coefficient (μ) and turbulent friction coefficient (ξ) are required to simulate velocity and runout distance of an avalanche event. The optimal values of μ and ξ to simulate runout distance are 0.25 and 800, respectively, and the values of these parameters to simulate velocity 0.3 and 1000, respectively. The sensitivity analysis is also carried out to investigate the effect of variation in friction parameters on flow velocity and runout distance. The temporal variations of snow parameters are also discussed. The variation of front velocity and flow depth along the chute are also discussed. Results presented for the interaction between obstacle and avalanche flow are limited to only experimental study, the developed model does not have the capacity to simulate these effect.

Contents