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Studies of Granular Flow Down An Inclined Chute

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Progress Report:

The dynamics of flowing granular material has been previously observed in inclined chutes (e.g. Savage, 1979; Johnson et. al, 1990; Ahn et. al, 1991). One of the questions arising from previous work regards the existence of fully developed, steady flows. Depending upon the friction or bumpiness of the chute base, experiments have indicated that under some conditions the flow appears to be steady and fully developed. While a truly fully developed flow can never be proven to exist in an experimental apparatus because of its finite length, apparent fully developed flows are observed to within reasonable experimental accuracy's. The present series of experiments focuses on the existence of steady, fully developed flows over a low friction, bumpy base.

Experimental Apparatus

The inclined chute is 4 meters long, with an adjustable width set to 15 cm. A belt conveyer provides material recirculation that allows for continuous operation. The granular material used in these experiments are medium quality glass spheres with diameters of approximately three millimeters. The angle of inclination is variable; for these experiments the angle is varied between 19 and 28 degrees. The base of the chute is removable and exchangeable; in these experiments the base consists of 3 mm glass spheres fixed in a closely spaced hexagonal pattern. For the data to be shown below, the separation between base grain centers is 4 mm.

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A series of flow-trapping gates has been developed to measure the mass hold-up in six sections along the chute. These gates fall under the influence of gravity when holding pins are simultaneously removed by a solenoid driven piston. The mass hold-up can be combined with flow thickness measurements and discharge measurements in order to calculate the average volume fraction and velocity in each of the six sections.

Results and Discussion

A variety of flow regimes are observed in the chute. The flows exhibit distinctive characteristics that relate to the inclination of the chute, the nature of the base of the chute, and the entrance/exit conditions. The flow is frequently observed to have constant mass flux and constant flow thickness along the chute. However, the volume fraction and velocity of these flows generally changes with position along the chute. It is found that fully developed flows exist only over a small range of inclinations (with all other variables constant).

An example of a steady, fully developed flow is shown in Figure 1. The angle of chute inclination for this flow was 23.4 degrees. The volume fraction, velocity, mass hold-up, and flow thickness are all nearly constant along the chute.

A technique to measure the structure of the velocity and concentration fields is under development. These quantities are estimated from high speed images transmitted through a 5 mm diameter boroscopic lens. The lens is inserted into the side wall to be flush with the wall, or the lens may be inserted thorough the side wall into the flow. In the latter case, some disturbance to the flow is likely, but not yet quantified. Preliminary analyses of some images indicate a nearly linear velocity profile with slip at the base and an abrupt concentration gradient (interface) at the top of the flow.

In conclusion, we have observed steady, fully developed flows of glass spheres in an inclined chute. These flows seem to exist over a range of inclination angles of a few degrees.

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