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Studies of Granular Flow Down An Inclined Chute

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Quarterly Technical Progress Report
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ACQUISITION & ASSISTANCE DIV.

Contract Number: DE-AC22-91PC90182

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US/DOE patent clearance in not required prior to the publication of this document.

Progress Report:

The primary focus in the Granular Flow project this quarter has been the study of a new closer packed bumpy chute bed.

Qualitative experiments were performed to map out the flow characteristics for a range of angles and gate heights. For chute inclinations from 16.0 to 24.5 with 0.5 degree increments and gate heights of 0.5, 1.0, 1.5, 2.0 and infinity, the following physical data was collected: flow thickness, mass in chute sections, and mass in belt. A grid was placed on the side wall of one chute section and the profile of particles accumulated on one of the gates was recorded on Hi-8 video. This information may be used to compare with flow rates and velocities in the future. Hi-8 video was also taken of the side of the flow. Video was shot for all angles and gate heights covered above.

The above information was used to determine what conditions created steady flow. These initial studies have indicated that steady flow for this bumpy chute bed were found at chute inclinations of 20.5 to 21.5 degrees and 22.5 to 23.5 degrees. The next studies which are currently under way, involve intensive studies of conditions which produce steady flows. This will involve high speed imaging of side and top flow surfaces, from which velocity profiles will be calculated. Fiber optic data will also be taken to calculate side, center, and quarter flow velocity profiles. The fiber optic data acquisition system was modified from digital signal analysis to analog. This modification improved our velocity approximations. Currently we are evaluating two methods to approximate particle velocities based on fiber data. The first method is the method used previously, correlation coefficients. The second method is based on cross-spectrum analysis.

Another focus of the project was the development of an entrance vibration chamber. This project has been completed and is currently being tested. The chamber consists of a vertically vibrating plate powered by a DC motor. The amplitude range is 0.0 - 5.0 mm and frequency range is 2.0 - 20.0 Hz. The vibrating plate is set at an angle of 16.0 degrees and protrudes slightly into the chute. The chamber was designed for variable plate surfaces.

An uncertainty analysis was performed on all data and can be seen in the following tables. The first table shows the accuracy of all measured quantities associated with the experiments. The second table shows the uncertainty associated with manual particle tracking. The third table shows the error approximated through error propagation analysis for calculated values.

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TABLE 1. This table shows the precision and accuracy of the measured and constant values associated with the chute.

Quantity	Typical Values	Flow	Flow Rate	Flow Rate	Flow Rate
Flow thickness	3.3 cm	0-30 cm	0.1 cm	0.1 cm	3.03%
Mass in Chute Section	2340 g	0-8000 g	5.0 g	10.0 g	0.43%
Mass in Belt	4645 g	0-8000 g	5.0 g	10.0 g	0.22%
Gate Height	5.08 cm	0-30 cm	0.15 cm	0.15 cm	2.95%
Humidity	53%	30-80 %	1%	2%	3.77%
Air Temperature	78 F	60-90 F	0.5 F	1.0 F	1.28%
Chute Inclination	17.00 deg 22.5 deg	0.00-19.99 20.0-28.0	0.01 deg 0.1 deg	0.01 deg 0.1 deg	0.06% 0.44%
Mass of Beads in System	150E3 g	0-150E3 g	1 g	4500 g	3.00%
Chute Bed Length	365.8 cm	365.8 cm	0.15 cm	0.15 cm	0.04%
Chute Bed Width	15.24 cm	15.24 cm	0.15 cm	0.15 cm	0.98%
Section Length	50.2 cm	50.2 cm	0.15 cm	0.30 cm	0.60%

TABLE 2. This table shows the uncertainty associated with manual particle tracking in high speed video analysis. x and z are particle displacements measured in pixels. A typical grain diameter is 50 pixels.

Particle	x	y	x	y	z	z
11o	19.00	9.00	19.00	11.00	0.00	2.00
	19.00	9.00	20.00	11.00	1.00	2.00
11j	19.00	9.00	19.00	11.00	0.00	2.00
11u	13.00	19.00	14.00	19.00	1.00	0.00
10y	15.00	24.00	17.00	25.00	2.00	1.00
10x	13.00	19.00	14.00	19.00	1.00	0.00
	15.00	24.00	15.00	24.00	0.00	0.00
	Average				0.71	1.00

TABLE 3. This table shows the average percent error for calculated quantities. The values were estimated through error propagation analysis. X_{vel} and Z_{vel} are uncertainties of velocities estimated through manual particle tracking. These values are non-dimensional unless otherwise stated.

Quantity	Value	Uncertainty
Average Bulk Velocity	3.90	6.0
Mass Hold-up	4.00	7.0
Volume Fraction	0.38	4.4
Mass Flow Rate	15.8	0.24

Quantity	Value	Uncertainty	Value
Individual Grain, X_{vel} (cm/s)	25	11	34
Individual Grain, Z_{vel} (cm/s)	3	35	4

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