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Title: A Parametric Study of Axial Segregation in a Rotating Cylinder

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Abstract for the viewgraph presentation entitled "A Parametric Study of Axial Segregation in a Rotating Cylinder"

When a cylindrical container, partially filled with a binary granular mixture of particles that differ in size or density, is rotated around its axis, a spontaneous segregation of the two granular components may occur. In order to better understand this phenomena, we have carried out an experimental study probing the effect of average particle size and relative size difference between particles on the onset of segregation. The experimental study is followed by a novel scaling analysis that relates the deterministic, convective driving force for particle segregation to the randomizing diffusional driving force present in these systems through the definition of an axial granular Péclet number. This Péclet number based approach will forgo some of the difficulties inherent in full-scale dynamic simulations, but will still allow us to determine the effects of system parameters on the final steady-state that is achieved. Values of this granular Péclet number are shown to successfully correlate with segregation behavior in the present experiment results, as well as in comparable results present in the literature.

A Parametric Study of Axial Segregation in a Rotating Cylinder

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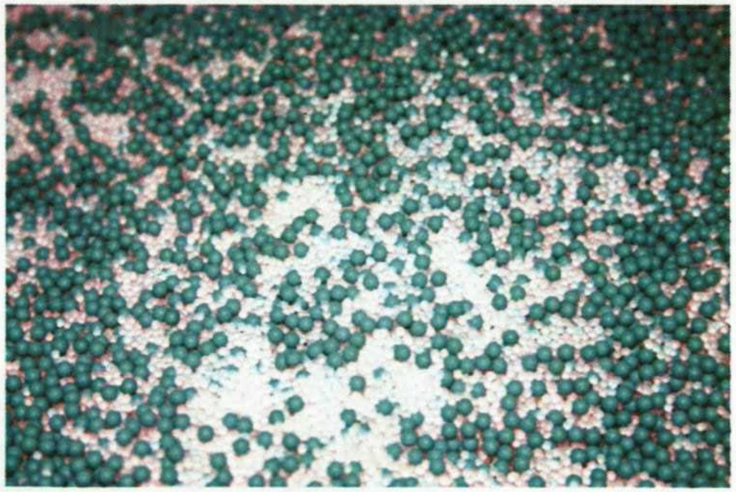
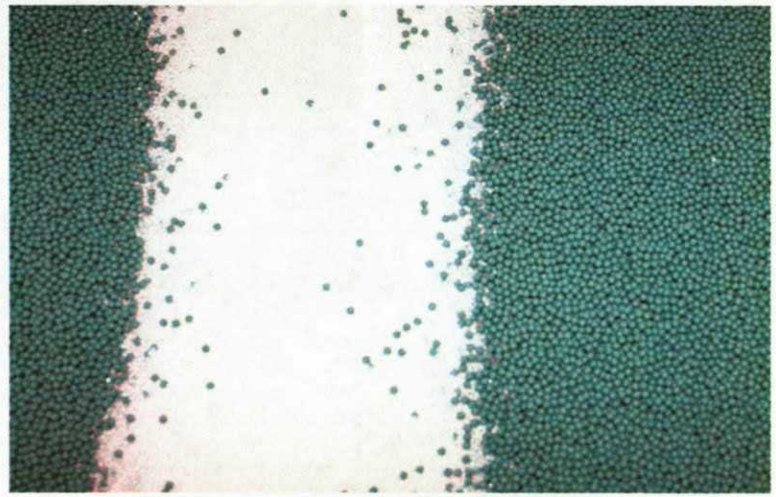
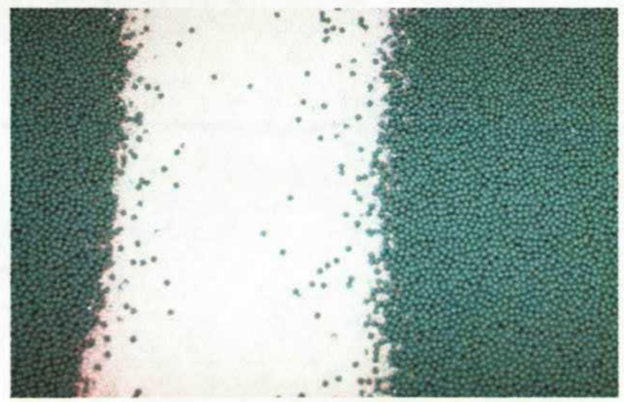




Background

- Granular materials are not liquids or solids.
- Axial segregation in rotating drums
  - The relative difference in particle sizes and rotating drum diameter have been found to be important
  - Limits exist on the size differences between particles



Experimental Technique

$$Fr = \omega^2 R / g$$
$$= 2.6 \times 10^{-3}$$

Fill Fraction = 41%

Experimental Variables

$$D^* = \frac{\text{Drum Diam}}{\text{Avg Part Diam}} \qquad \Phi = \frac{\text{Max Particle Diam}}{\text{Min Particle Diam}}$$

$$9.6 < D^* < 106.7 \qquad 1 < \Phi \le 4$$

Experimental Results

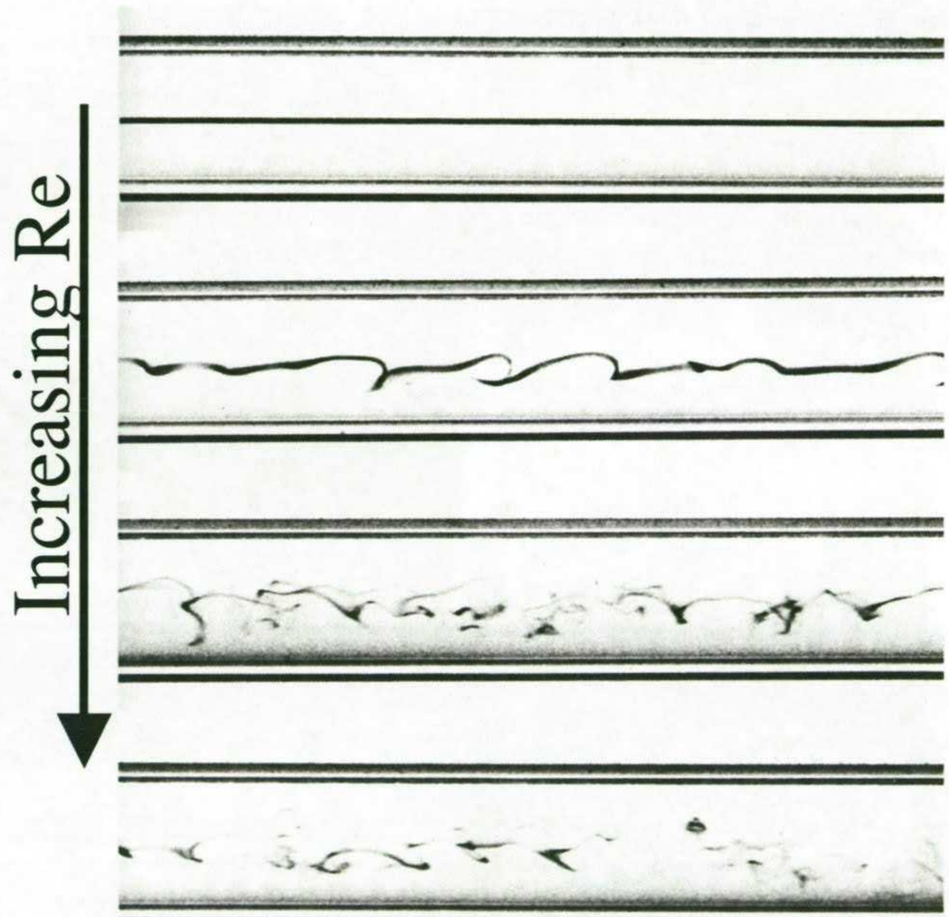
- 14 tests run
- *Larger values of Φ* had greater tendency to segregate
- *Larger values of D^** had a greater tendency to segregate

Particle Diameters (mm)		Drum Diameter (mm)	Segregation
1.6	6.4	152	Yes
3.2	12.7	152	Yes
6.4	19.1	152	No
6.4	12.7	152	No
3.2	6.4	152	No
1.6	3.2	152	Yes
12.7	19.1	152	No
1.6	6.4	254	Yes
3.2	12.7	254	Yes
6.4	19.1	254	No
1.6	3.2	254	Yes
6.4	12.7	254	No
3.2	6.4	254	Yes
12.7	19.1	254	No

Steady-State Segregation

- Turbulent behavior can be quantified by the Reynolds number (Re).

Can a similar approach yield insight into axial segregation in granular systems?



Picture taken from M. Van Dyke *An Album of Fluid Motion* (Parabolic Press, Stanford 1982).

The Peclet Number

$$Pe = \frac{\text{Deterministic, Convective Motion}}{\text{Randomizing, Diffusive Motion}}$$

Binary Mass Transfer: $Pe = \dfrac{XU}{D_{AB}}$

Suspension Rheology: $Pe = \dfrac{a(a\dot{\gamma})}{kT/(6\pi\mu a)}$

Goal: Determine "convective" and "diffusive" scales for this granular system

Convective and Diffusive Scales

Convective Velocity

$$U \propto \omega R \cdot f\,(\text{particle property differences})$$

$$f \propto \frac{d_A - d_B}{d_{Avg}}$$

Convective Length

$$X \propto d_{Avg}$$

Diffusivity[2]

$$D \propto g(Fr)\, d_{Avg}^2\, \omega$$

$$Pe_{Fr=const.} \propto \frac{(d_A - d_B)R}{d_{Avg}^2}$$

2. S.B. Savage in *Disorder and Granular Media*, edited by D. Bideau and A Hansen (Elsevier, Amsterdam 1993).

Experimental Validation

- High *Pe* dominated by convective sorting
- Low *Pe* dominated by diffusive mixing

Data Sets

1. Current Experiments
2. K.M Hill and J. Kakalios, Phys. Rev. E **52** 4393 (1995).

Particle Diameters (mm)		Φ	Drum Diameter (mm)	Pe	Segregation	Source
12.7	19.1	1.5	152	3.9	No	*
12.7	19.1	1.5	254	6.4	No	*
6.4	12.7	2.0	152	10.7	No	*
6.4	19.1	3.0	152	11.9	No	*
3.1	4.8	1.5	127	13.1	No	Hill
6.4	12.7	2.0	254	17.8	No	*
6.4	19.1	3.0	254	19.8	No	*
3.2	6.4	2.0	152	21.3	No	*
3.2	12.7	4.0	152	23.0	Yes	*
1.0	1.2	1.2	127	23.4	Yes	Hill
3.2	6.4	2.0	254	35.6	Yes	*
3.2	12.7	4.0	254	38.4	Yes	*
1.6	3.2	2.0	152	42.7	Yes	*
1.6	6.4	4.0	152	46.1	Yes	*
1.2	4.8	4.0	127	48.0	Yes	Hill
1.2	3.1	2.6	127	49.3	Yes	Hill
1.0	4.8	4.9	127	55.2	Yes	Hill
1.0	3.1	3.2	127	61.7	Yes	Hill
0.7	4.8	6.9	127	65.1	Yes	Hill
0.7	1.2	1.7	127	66.5	Yes	Hill
1.6	3.2	2.0	254	71.1	Yes	*
1.6	6.4	4.0	254	76.8	Yes	*
0.7	3.1	4.4	127	79.8	Yes	Hill
0.4	0.7	1.7	127	107.1	Yes	Hill
0.4	1.2	2.9	127	142.7	Yes	Hill

Summary/Discussion

- Current/Available data suggests segregation depends upon both Φ and D^*
- Peclet number based analysis allows for explicit representation of this dependence

$$Pe \propto \frac{(d_{A-} - d_B)R}{d_{Avg}^2} = \frac{(1-\Phi)}{(1+\Phi)} D^*$$

- An extension to polydisperse systems is underway