Granular flow and design studies in flighted rotating drums

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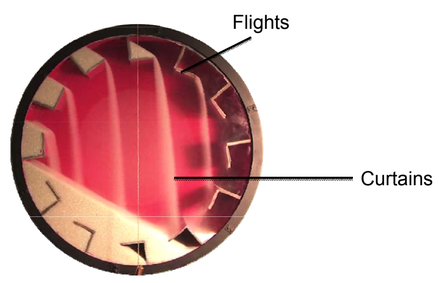
Introduction

• Flighted Rotary drums (FRD) are one of the most commonly used devices to dry granular or particulate material due to its ability to handle wide range of feed stocks providing large throughputs. The size of these drums can vary up to 120 m in length and 6 m in diameter.

• Flights lift the solid material up to certain distance to shower them across the free gas stream by developing a series of curtains.



Problem Definition

• Design of the flights is one of the major problem during the drum design which determines the effectiveness of the drum.

•Entrainment and dust formation during the operation can lead the drum to be impotent.

Objectives

• To develop a geometrical model for the flight discharge characterisitics
• To model the micro level particle-to-particle-interactions in the dryers
• To scale up the drum to 6m in diameter (Macro level)

Cooperation

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Geometrical Model

Assumptions

• Drum is operated either in design or over loaded

• Negligible cascading layer

• Continuous discharge of the flight

Kinetic angle of repose

$$\tan\gamma = \frac{\mu\cdot\cos\alpha + Fr\cdot\left(\frac{r_H}{R}\right)\cdot(\cos\delta - \mu\cdot\sin\delta)}{\cos\alpha - Fr\cdot\left(\frac{r_H}{R}\right)\cdot(\sin\delta + \mu\cdot\cos\delta)}$$

Flight unloading rate

$$\frac{\dot{m}_{A,i}(\delta)}{\rho_S\cdot\omega\cdot\pi\cdot R^2\cdot L} = -\frac{df_{H,i}(\delta)}{d\delta}$$

$f_{H,i}(\delta)$ is the flight filling degree for RI, RII, and RIII

Total particle surface area

$$\frac{A_{CS,i}}{L\cdot R} = 3\pi\cdot\left(\frac{\rho_b}{\rho_s}\right)\cdot\left(\frac{D}{d_p}\right)\cdot f_{CS,i}(\delta)$$

$$f_{CS,i}(\delta) = \sqrt{2\cdot Fr\cdot\left(\frac{h_F}{R}\right)}\cdot\left[-\frac{df_{H,i}}{d\delta}\right]$$

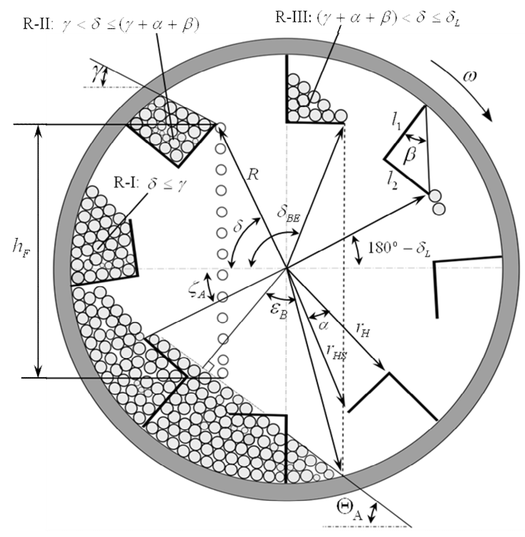


Figure 1. Schematic diagram of FRD

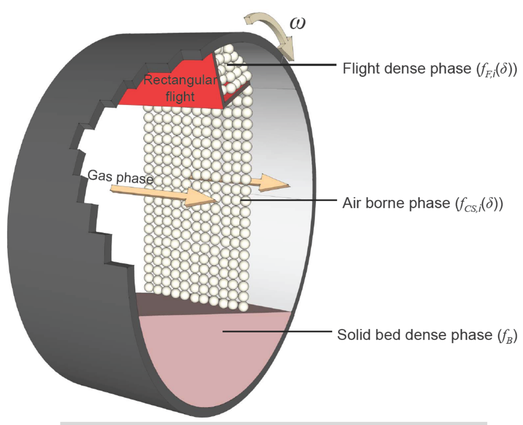


Figure 2. Various phases of the drum

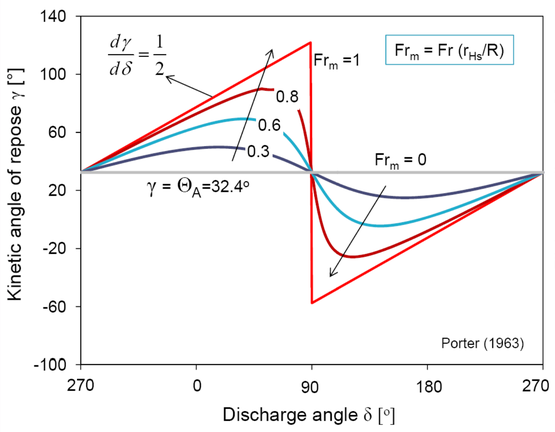


Figure 3. Kinetic angle against the position of the flight

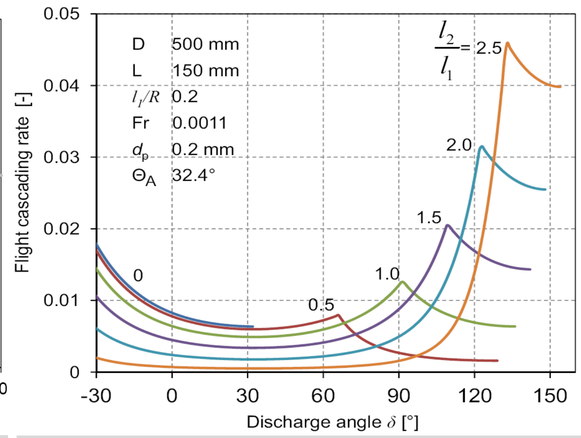
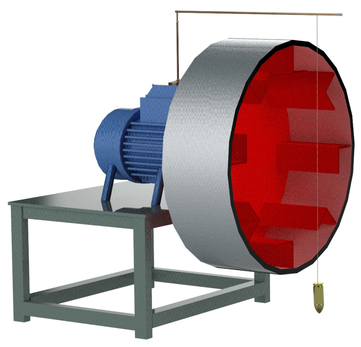


Figure 4. Flight cascading rate depending on discharge angle.

Experimental Setup



Parameter	Value
Diameter, D	0.5 m, 1 m
L/D	0.3
l_1/R	0.2
l_2/l_1	1.0, 0.75, 0.375,0
n	2-12 rpm
f_D	0.05-0.3
n_F	12, 18

Figure 5. Experimental setup of FRD

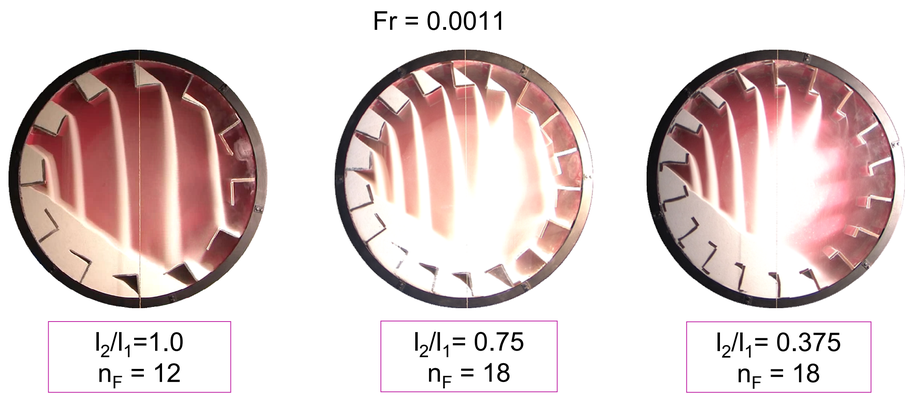


Figure 6. Experimental images if the drum at various l_2/l_1 ratios

The entrained air is recirculated upwards in counter current direction, thus influencing the falling curtains in turn.

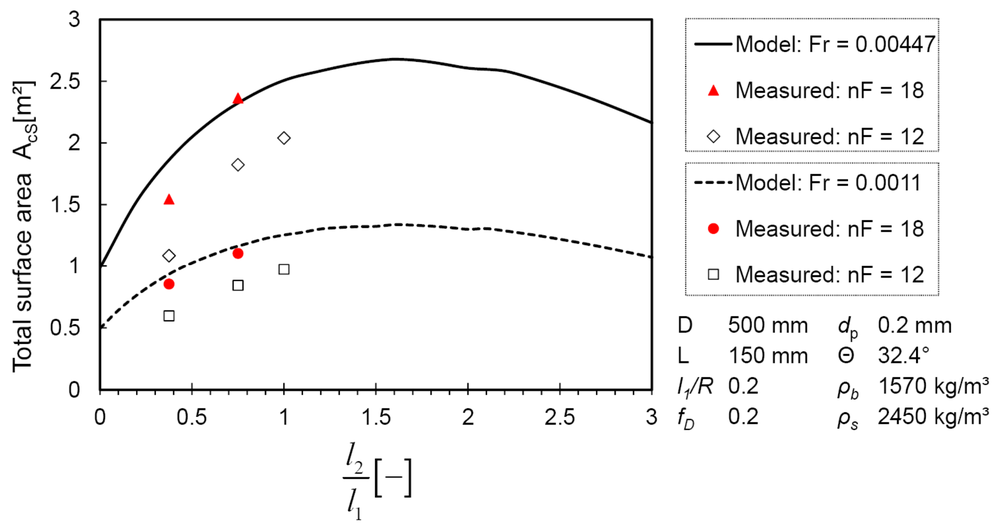


Figure 7. Total particle surface area independence on the flight length ratio for quartz sand

Results and Discussion

•Powder technology. 234, 107-116, 2013

•Chemical engineering science. 90,101-109, 2013.

•ASME/JSME 2011 8th Thermal Engineering Joint Conference, AJTEC, Honolulu, Hawaii, USA, 2011.

•5th Asian particle symposium, National university of Singapore, Singapore 2012.

•XXVI International Mineral Processing Congress, New Delhi, India, 2012.

Conclusions

• The geometrical model is able to simulate the discharge characteristics of the flight succesfully.

•Results of this model can be used for designing the industrial dryers successfully.

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