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Experimental analysis of a flighted rotary drum to assess the optimum loading

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HIGHLIGHTS

- A lot of experiments are carried out on a batch rotary drum.
- The drum is designed with rectangular flights of different numbers and dimensions.
- The experiments are performed to assess the optimum loading of the rotary drum.
- Comparisons have been conducted between the results and models from literature.
- New fitting factor to modify Baker's model is proposed.

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ABSTRACT

The loading state of a rotary drum strongly affects its overall performance. Hence, assessing the optimum (design) loading of the rotary drum is a critical issue. In the present work, a lot of experiments were carried out on a 50 cm diameter and 15 cm length batch rotary drum furnished internally with rectangular flights. Different loadings were examined through image analysis processing of the recorded videos from under-loading to over-loading, including design-loading. Many solid materials (free flowing) with different particle diameters and angles of repose, varied rotational speeds (from 1 to 5 rpm), two numbers of flights (12 and 18), and two flight length ratios (0.375 and 0.75) were researched. A comparison is conducted between the experimental results and some available design loading models from literature. Based on the experimental results a new fitting factor is proposed.

1. Introduction

Rotary drums are essential in industry for the manufacturing and the processing of different granular materials with free flowing or cohesive nature (sugar, cement, limestone, sands, fertilizers, wood chips etc.). Rotary kilns, rotary dryers and rotary coolers are the most commonly used types of rotary drums within industry. A rotary drum consists of a long cylinder inclined slightly to the horizontal and have the possibility to rotate around its axis. The solid material and the processing gas pass and interact through the drum specifically in the gas-borne area, in either counter or co-current flow directions (Friedman and Marshall, 1949).

Flights are usually installed on the interior wall of the drum which lift the solid material from the bottom bed then cascade and shower it through the gas-borne area. Many configurations of flights are available; radial, rectangular (right angled), angled and circular flights are used according to the application (Revol et al., 2001; Krokida et al., 2007; Lee and Sheehan, 2010; Sunkara et al., 2013a).

The loading of a rotary drum is the total amount of solid (holdup) fed to the drum. It strongly affects the overall performance as it influences the amount and distribution behavior of the solid in both the gas-borne phase and flight-borne phase. Furthermore, it affects the residence time of transportation along the drum. As a consequence these parameters affect the exchange processes of both heat and mass (Keey, 1972; Matchett and Baker, 1987).

Three types of drum loading states can be categorized: under-loading, design loading (optimum loading), and over-loading, which are characterized based on the holdup and the discharge angle of the first unloading flight (FUF) (Matchett and Baker, 1987; Kelly, 1992; Papadakis et al., 1994; Sherritt et al., 1993; Shahhosseini et al., 2000; Britton et al., 2006; Sunkara et al., 2013b). As at the under-loading: the first unloading flight (FUF) holds less material than its capacity and its discharge angle is in the upper half of the drum lately than 0° (9 o'clock position), see Fig. 1a.

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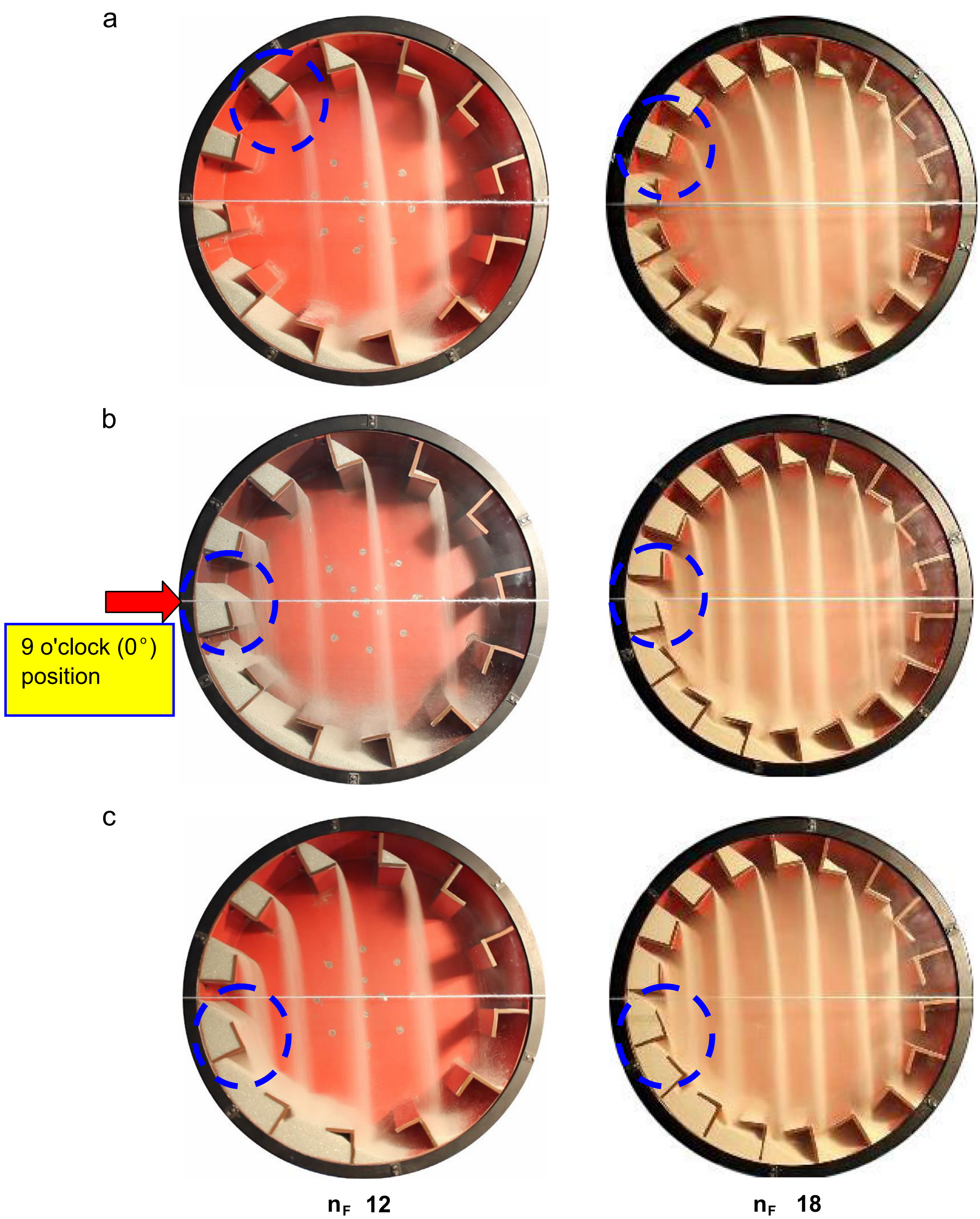

Fig. 1. Sample photos from our experimental work showing different loadings, dashed circle denoted the FUF; (a) under loading, (b) optimum design loading and (c) over loading.

Under such conditions, the time spent by the particles in the gas-borne phase is minimum, which can lead to smaller residence time than required. As the drum loading state is gradually increased, the FUF position ultimately becomes lower and the unloading starts when the flight tip is at 9o'clock position. At this point the drum is said to be at design loading. In this drum the maximum amount of material is distributed in the gas-borne phase where the particles total surface area subjected to heat and mass transfers is substantially increased, hence maximum heat and mass transfers can be expected between the solids and the gas stream, see Fig. 1b. Further increasing the feed rate does not increase the amount of gas-borne solid, but the flights are completely crowded with the material which is defined as over-loading. In this drum the discharge of the material starts immediately as the flight tip detaches from the bed surface, see Fig. 1c.

As a conclusion it is proved that, the best performance of the drum occurs when the drum operates with design loading conditions (Sheehan et al., 2005; Sunkara et al., 2013b). Therefore, assessing the design loading of the drum is a critical issue.

Recently, Ajayi and Sheehan (2012b) carried out an intensive literature survey about the design loading determination. They performed experimental work on a horizontal pilot scale rotary dryer with a diameter of 75 cm and a length of 115 cm fitted internally with angular flights. The design loading experiments