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Comparison of image analysis methods to determine the optimum loading of flighted rotary drums

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ABSTRACT

The loading state of a flighted rotary drum strongly affects its overall performance. Hence, assessing the optimum (design) loading needed is a critical issue. In the present work experiments were carried out to assess the optimum loading of a batch rotary drum (0.5 m diameter and 0.15 m length) furnished with rectangular flights. Different solid materials (free flowing), rotational speeds (from 1 to 5 rpm) and flight tangential/radial length ratios (0.375 and 0.75) were researched. The experimental work mainly relied on recording videos in front of the drum at different operating conditions. Then by means of image analysis tools the results were drawn. Two methods of image analysis were used and compared: manual and automated with many advantages over the methods previously found in literature. However some problems were found when applying the automated method on the current experimental work images. Indicating that a new experimental technique should be developed in the future to facilitate both manual and automated methods.

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 has 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 [1].

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 [2–5].

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 [6,7].

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) [8–13]. Typical definition for the different loading found in Sunkara et al., [13]: 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. 1(a). 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 9 o'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. 1(b). 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 overloading. In this drum the discharge of the material starts immediately as the flight tip detaches from the bed surface, see Fig. 1(c).

As a conclusion it is proved that, the best performance of a flighted drum occurs when the drum operates at design loading conditions [13,14]. Therefore, assessing the design loading of the drum is a critical issue.

The determination of the design loading of a flighted rotary drum will depend on carrying out experiments at different drum loadings.

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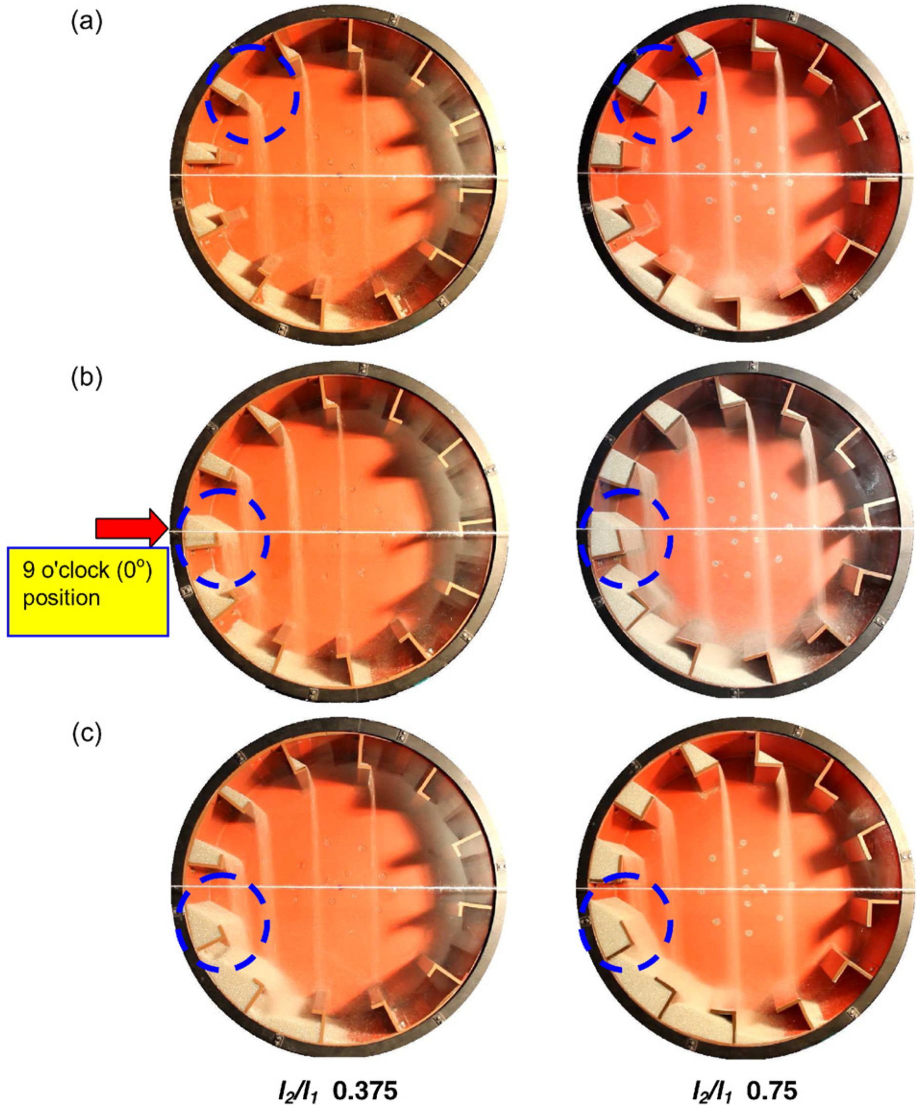

Fig. 1. Sample photos from our experimental work showing different loadings, for two flight tangential/radial length ratios of 0.375 and 0.75.

Previous studies have described the determination of the rotary drum loading (holdup) and its individual flights, using photographs of the cross sectional area at the open end of the drum [15]. These studies have used different image analysis methods for the data extractions from the photographs.

Image analysis is a powerful tool for solving different engineering problems in particle technology. It is the process of extracting important information from the image; mainly from digital images. Most of the scientific publications in image analysis have been arisen from the biological science fields with application of measuring size and counting the number of bacteria in an image. Massana et al., [16] compared two methods for measuring size and counting the number of Planktonic bacteria represented in different water bodies samples. Heffels et al., [17] studied different possibilities of changing backward light scattering for characterizing dense particle systems. Obadiat et al., [18]developed an innovative digital image analysis approach to quantify the percentages of voids in mineral aggregates of bituminous mixtures.

The digital image to be analyzed can be defined as a two dimensional array of x and y, where x and y are plane coordinates. A pixel is the smallest element of an image represented on the screen. The address of a pixel corresponds to its physical coordinates (x, y). The total number of pixels in an image depending on: the device (the camera) used for capturing the digital image or the video where the image is drawn from and the size of the image. There are four basic types of images which can be defined namely: red-green-blue (RGB or true color) image, indexed image, gray scale image and binary (black and white) image.

In the RGB image each pixel has a color which is described by the amounts of red, green, and blue in it. Each of these components can have a range of values from 0 to 255 giving a total of $255^3 = 16{,}581{,}375$ different color possibilities in the image and each pixel in an image corresponds to three values. This leads to deal with a complicated analysis process. The indexed image likes a color map and each pixel with a value does not give its color but an index to its color in the color map. The gray scale image is characterized by shades of gray and the pixel ranges from 0 for black and 255 for white. In the binary image (black and white image) the pixels are either black with value of 0 or white with value of 1. The image analysis technique is much influenced by the type of image to be processed. Where complicated analysis technique is needed for the true color images. The technique becomes easier when using gray scale images and more easier when using binary (black and white) images. Thus, gray scale and binary images are predominantly used in image analysis for engineering applications.