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Selection and mathematical modelling of high efficiency air classifiers

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ABSTRACT

Air classification is a method used to classify feed material according to the shape, specific gravity and size of the particles and preferred where water interaction is avoided. Since it is widely used by many of the industries, this study contributes to the literature related with high efficiency air classification by considering the design and modelling aspects for cement industry. In this context, various types of high efficiency classifiers operated at cement grinding circuits were sampled at the same cement quality then mass balancing studies were carried out. After all, the variation of rotor size and air amount parameters with the capacity of the classification process was investigated. Moreover, a mathematical model for high efficiency air classifiers was developed by applying the efficiency curve approach. In contrast to previous studies, the sharpness parameter (α) was found to be dependent on the capacity of the separation process and the diameter of the classification chamber which made the model structure unique.

1. Introduction

Air classification is a process employed to control or adjust the final product fineness of the grinding circuit where water interaction with the material is avoided. This technology was developed early in the 19th century to meet the demand of cement industry where tube mills with high capacities were employed. High milling capacities and the need for fine particle classification had driven the technology. Up to now, various types of air classifiers have been developed to be used in different industries, i.e., pharmaceutical, food, pigment, coal, and cement.

Air classifiers can be grouped as static classifiers and dynamic classifiers. Static classifiers have no moving parts and the target size is adjusted by changing magnitude and direction of the air flow. Vane-type [1] and V-separators [2] are the two examples for these types of classifiers. Dynamic air classifier technology has been evolving since 1885 and nowadays their classification range changes between 300 μm and sub-micron (<10 μm) with a specific type of classifiers [3]. Typically, dynamic classifiers have a rotating plate on which the material is poured and dispersed with the aid of centrifugal force. As the particles are thrown towards the separator wall, air is introduced into the separation chamber where final classification is carried out [4]. Following the first generation technology, second and third generation air classifiers were developed. The second generation classifiers are operated with cyclones in order to increase the fine collection efficiency; additionally, fan is mounted outside of the separator body so as to supply air for the classification. Third generation (high efficiency separator) classifier was unveiled in the 1980s. In these classifiers fineness is adjusted by changing either rotor speed or air flow [5]. As the rotor speed increases, the product gets finer; on the other hand, increasing the air flow rate makes the product coarser [4,6–8]. High efficiency separators are demanded mostly by cement industry and some of the studies reported that it was achievable to decrease the bypass percentage of the classification process down to 5–10% [9] and increase the overall production rate of the grinding circuit by 15–35% at the same cement quality [10]. High efficiency separators are also found applications in integrated grinding systems such as vertical roller mill [11], air classifier mill [12] and air jet mills [13] where classification down to fine sizes is performed.

The performance of an air classifier is evaluated by drawing the "actual efficiency curve" or "Tromp curve" that explains what portion of the material in the feed subjects to the underflow or overflow streams at a given size fraction [7,14]. The *x*-axis of the curve denotes to particle size and the *y*-axis denotes to the probability for being separated as fines and coarse. Fig. 1 illustrates an observed efficiency curve of an air classifier. Because the classification process is not 100% efficient, in actual cases, the *y*-axis does not reach to 0%. This portion of the curve is named as the bypass fraction and is defined as the fine material not appearing in the fines but circulating back to the mill with the reject stream for re-grinding [7,15,16]. The bypass fraction is mainly influenced by the solid air concentration (dust loading) of the separator feed [4,5,7]. In addition, poor feed dispersion and fine agglomeration are thought to be effective on the amount of bypass fraction [16,17]. The d_{50} is denoted as the cut size where the forces equally affect the particles; hence, they have 50% probability either subject to underflow or overflow streams. The sharpness of the curve is another performance indicator for the classification process. The steeper the curve,

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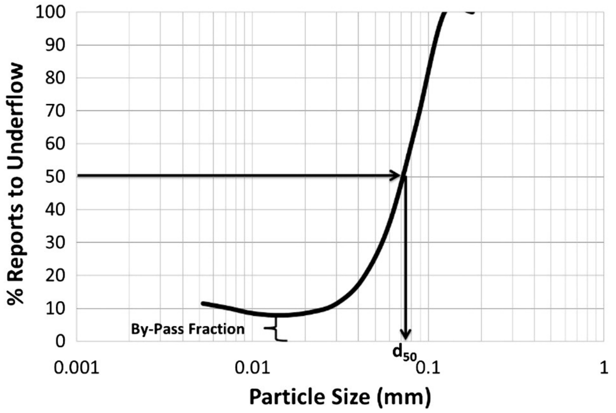

Fig. 1. Actual efficiency curve (Tromp curve) of an air classifier.

Table 1
Technical specifications of the classifiers sampled and number of surveys performed.

	Rotor diameter (m)	Rotor circumferential area (m^2)	No. of surveys
SEPOL®	2	3.14	3
	2.15	3.63	14
	2.5	4.91	6
	2.9	6.61	6
	3.1	7.55	5
SEPAX®	1.77	2.46	4
	1.9	2.84	4
	2.24	3.94	15
	2.53	5.03	4
SEPMASTER®	2.68	5.64	2

the sharper the separation. Developments in air classification technology allowed performing sharper classification operations [18].

Air classification process has attracted interests of researchers as it is widely used in dry processing, particularly in cement grinding area. Its selection and efficient operation are of crucial importance for the plants. Within the scope of the study, a methodology for selecting high efficiency separators was developed and then the modelling studies were performed by using the data obtained from cement grinding circuits. In this context, sampling campaigns around high efficiency separators were conducted initially. Operational parameters, i.e., feed tonnage, product tonnage and air flow rate, were correlated with the design of the rotor. The obtained results from the sampling campaigns were then used in modelling studies so as to develop a software that could be used in simulating closed circuit cement grinding operations accurately. In this context, the efficiency curve approach was applied and all the parameters in the equation were correlated with the operating conditions and design variables. The novelty of the model structure with respect to previous modelling studies is;

- The development of the correlations with the sharpness of separation parameter. This parameter was assumed as constant in the previous modelling works; however, it was found to have a correlation with the design and operating parameters of the classifier.

In the following sections, the findings obtained are discussed in details with the literature related to modelling of air classifiers.

2. Materials and methods

2.1. Sampling campaigns

In this study, several sampling campaigns were arranged around different brands of high efficiency air classifiers. All of the sampling studies were conducted at the same cement type (CEM I 42.5R) having the final product fineness (% retained on 45 μm sieve) ranging between 6.4% and 7.24%. Table 1 summarizes the technical specifications of the classifiers sampled. As can be seen from the table, the performances of Sepol®, Sepax® and Sepmaster® classifiers were evaluated within the scope of the study. The details on the operating principles of the classifiers are reported in the literature [7,19–21].

Prior to performing a sampling survey around a classifier, steady state conditions were provided that is, minimum fluctuations were observed in power draws of the mill discharge elevator (that feeds the classifier), rotor and product conveying systems. In other words, what came into the grinding circuit came out from the final product stream equally. Simplified representation of a classifier with the sampled streams and control room trends is illustrated in Fig. 2.

2.2. Experimental and mass balancing studies

The collected samples from sampling surveys were subjected to the size characterization studies. Sympatek Laser Sizer was used to determine the whole size distribution of the material starting from the top size, down to 1.8 μm. Fig. 3 shows obtained cumulative particle size distribution curves by mass around a high efficiency separator. Similar trends were observed for each of the sampling campaign and Table 2 gives the ranges of the d_{50} and d_{80} values of the classifiers sampled. As can be understood, although the sampling campaigns were performed at the same cement quality and cement type, the variations in raw material properties result in obtaining different product size distributions. Within the study it was observed that $d_{50,3}$ of the final product varied between 12 and 15 μm.

The measured particle size distributions were then used to perform mass balancing studies in order to calculate the flow rates of each

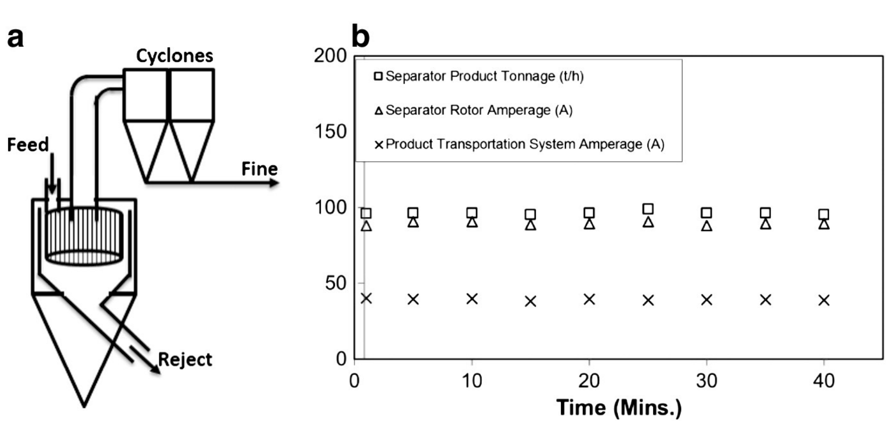

Fig. 2. Sampling points (a) and typical control room trends (b) of a high efficiency classifier.