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Dynamic model for a dense medium drum separator in coal beneficiation

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ABSTRACT

Dense medium drum (DMD) separators are unit processes that are typically used to beneficiate coal, iron ore and other minerals by making use of density separation. Some coal dense medium separation plants typically include a DMD separator. The operational management of this unit process is often limited to localised control of medium density and feed mass flow rate. Dynamic models for coal dense medium separation have been developed by the authors with the intention of using them for dynamic control.

A suitable dynamic model for a DMD separator could not been found in the available literature. This paper shows how the dynamic model for a dense medium cyclone has been applied to a DMD separator. The model parameters were determined and the performance of the model is evaluated using actual plant data from a Wemco drum. Coal washability and drum partitioning behaviour are used to estimate the grade of the product for model grade simulation and validation.

1. Introduction

This work is based on Meyer and Craig (2010) which details the development of dynamic models for a dense medium separation process in coal processing. These dynamic models were developed using first principles and include models for screening, medium make-up and dense medium separation through cyclones. As far as the authors are aware, a dynamic model for a dense medium drum (DMD) separator is not available in the open literature. Since a drum separator is an integral unit process required in coal beneficiation (King, 1999) it is necessary that a dynamic model be generated for this unit process such that a process controller can be implemented.

The dynamic model for the drum separator is developed from first principles where the conservation of mass and mass of components are used (Stephanopoulos, 1984). The dense medium cyclone (DMC) dynamic model of Meyer and Craig (2010) is applied to the drum separator. However, certain assumptions are modified to cater for the different mechanisms of separation between a cyclone model and a drum separator model. The validation of the dynamic drum separator model requires a steady-state model, similar to that of Meyer and Craig (2011).

This paper initially describes the metallurgy of minerals processing regarding the operation of DMD separators in Section 2. It highlights the process models available for drum separation. A high level description of the process to be used to obtain the dynamic model of the drum separator is also given. A detailed description of how the dynamic drum separator model is determined is given in Section 3. The simulation results are shown in Section 4, and detail the throughput, steady-state partition curve and grade output. A conclusion and summary of the paper is presented in Section 5.

2. Dense medium drum process and process model

The process flow diagram in Fig. 1 shows a typical DMD circuit which is normally used for separation of large particle sizes (+15 mm to −100 mm) (Hayes, 2003). A magnetite medium ferrofluid is used to facilitate the separation of the coal from discard through density separation. The medium is circulated in a closed circuit and recovered by making use of a magnetic separator. The medium is usually collected in a sump and a density controller is used to correct the density of the medium that is added to the crushed ore. Screening is used to classify the ore before the density separation stage such that smaller sized coal feed can be separated using a DMC circuit.

Drum separators operate on the principle of float and sink separation where particles of different densities to the medium can either float or sink in the medium due to gravity. Coal feed is mixed with the medium and processed through a relatively static container. England et al. (2002) describe two main horizontal drum separators used in industry being the Wemco or Teska drum. Although the principle of operation is similar for each type of drum

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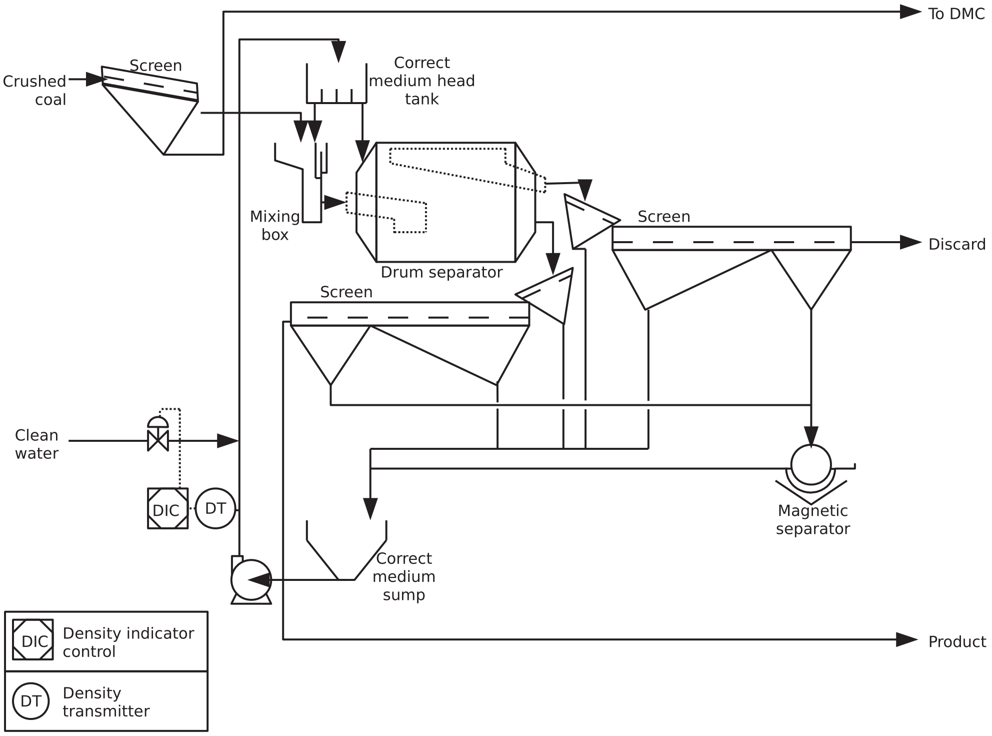

Fig. 1. Dense medium drum circuit (Adapted from England et al. (2002)).

separator, this paper will apply the dynamic model to a Wemco drum as this is the industrial unit that was available for the research.

The Wemco drum (Fig. 2) consists of a steel shell with a tyre and collar construction (Wilkes, 2006) where the drum operates in a longitudinal position. The drum shell rotates using a drive chain. During rotation, medium is added to the feed chute and sinks launder. Sinks are collected by sink lifters and discharged into the sinks launder. Floats exit through the lower exit of the drum.

2.1. Partition curve

Napier-Munn (1991) referenced a process model for a DMD separator. Sedimentation theory (Scott and Lyman, 1987) was used to detail the separation cutpoint (relative density where a particle has an equal chance of reporting to the float or sink). The partition factor (Baguley and Napier-Munn, 1996) for the drum separator is described as,

$$Y = \left[1-(v_{100}-v_t)^2\right]^{\left(\frac{A_{drm}}{d^2+B_{drm}}\right)}, \tag{1}$$

where v_{100} is the terminal velocity, which allows for sinks to be recovered 100%, v_t is the terminal velocity of the particle and A_{drm} and B_{drm} are constants that need to be estimated. The particle size is represented by d.

Using the terminal speed $v_t = \sqrt{\frac{2F_g}{C\rho_{d,i,med}A}}$ from Halliday et al. (2001) where F_g is the downward gravitational force on the ore particle, C is the drag coefficient for the ore particle, $\rho_{d,i,med}$ is the medium density displacing the ore particle mass per volume and A is the effective cross-sectional area of the ore particle, the steady-state partition factor (Eq. (1)) can be made a function of medium density ($\rho_{d,i,med}$). By assigning parameters $p_1 = v_{100}$, $p_2 = \frac{2F_g}{CA}$ and $p_3 = \frac{A_{drm}}{d^2} + B_{drm}$, a parametric equation for the partition factor can be derived as follows,

$$Y(\rho_{d,i,med}) = \left[1-\left(p_1-\sqrt{\frac{p_2}{\rho_{d,i,med}}}\right)^2\right]^{p_3}. \tag{2}$$

Similar results could possibly be obtained by using the terminal velocity correlation published by Concha and Almendra (1979), with an adjustment for shape factor.

Fig. 3 shows an example of a typical partition curve or efficiency curve taken from England et al. (2002). The ideal partition curve is a step function allowing for perfect separation. However, since unit processes such as the DMD do not separate perfectly, the real efficiency curve is typically an S-shaped curve of a cumulative probability distribution. In this example the probability of particles reporting as floats is shown. The location of the curve is described by the separation cutpoint (the specific relative density where a particle can have an equal chance of reporting to a float or sink) and is described as ρ_{50}. The écart probable moyen (EPM) is an empirical measure of inefficiency. This separation efficiency is typically calculated as follows:

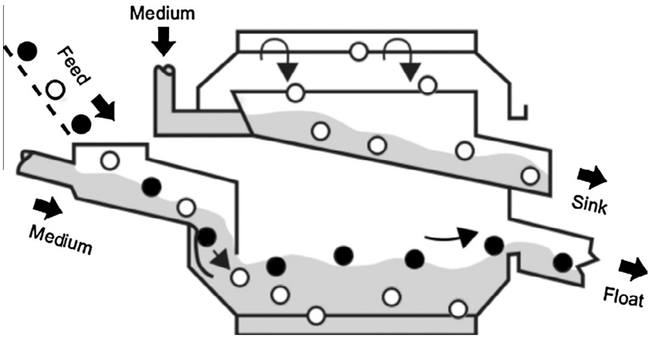

Fig. 2. The Wemco drum (Wilkes, 2006). Black particles represent coal while white particles represent discard.