A Model for the Shear Thickening Effect of Raking Systems on Red Mud.

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Abstract

Raking systems are commonly installed in settlers used in the mining industry. They contribute to the thickening of the mud and to its displacement towards the underflow. These effects have been known for many years, but the understanding of the compaction mechanisms is incomplete. A better understanding of these mechanisms would facilitate rake design improvements and would allow for a more accurate assessment of their efficiency. Several software suppliers propose commercial codes that simulate fluid flow, but unfortunately, no software application has been identified to simulate the compaction of mud by the shearing action of a rotating rake. Red mud compaction by shear action has been measured in our laboratory using a novel and unique experimental set-up. The observed data agree well with a semi-empirical mathematical model that we have established based on shear strain. This model has been incorporated as a compaction module into the ANSYS FLUENT fluid flow software to simulate the mud compaction by a rotating rake. The compacting performance of rake systems under various operational conditions can therefore be investigated.

Keywords: Red mud; shear strain thickening; compaction; rake.

1. Introduction

In the Bayer process, settlers are used for clarification and thickening of the bauxite residue. Thickener rakes contribute to the thickening of the slurry and to its displacement towards the underflow. Although the thickening action of a rake is a key issue, the understanding of the rake compaction mechanisms is still incomplete today. Buscall and White [1] have indicated that the permeability and the compressive yield stress of a concentrated suspension are factors contributing to its thickening. Usher and Scales [2] used fundamental theoretical models to predict the compressive dewaterability of thickener suspensions, based on the suspension compressive yield stress and hindered settling function. Discrepancies between predicted thickener performance and actual performance were attributed to shear processes such as raking. Farrow *et al*. [3] investigated the relative importance of compression and shear for dewatering of kaolin suspensions. They concluded that rake action, not compression, was the dominant dewatering mechanism. Du *et al*. [4] studied the effect of raking on the structure of a flocculated kaolinite suspension, and stated that:
"While forming this self-supporting structure resisting the self-weight compression, this network structure is also fragile to additional applied shear stress, evidence showed by the results from Malvern Mastersizer".

Simulation is another efficient tool available to study the efficiency of gravity thickeners. In this way Bürger *et al*. [5] and Martin [6] have studies the settling behavior of flocculated suspensions in clarifier-thickeners. Rake action was neglected in their analysis. Sutalo *et al*. [7] and Rudman *et al*. [8] have carried out Computational Fluid Dynamic (CFD) analysis of the rake transport in thickeners. Thickening by the shearing action of the rake was not included in their analysis. Shear thickening is usually excluded from most analyses because, to our knowledge, no simple relation between solid fraction and shear is available.

In this paper a novel experimental set-up that allows the solid fraction of sheared red mud to be measured as a function of an applied shear strain and a simple semi-empirical relation between solid fraction and shear strain are presented. Finally this mathematical relation has been incorporated as a compaction module into the ANSYS FLUENT fluid flow software to validate our measuring procedure of the mud shear strain and to simulate the mud compaction by a rake blade.

2. Experimental

2.1. Experimental set-up

The design of the experimental set-up used to study shear thickening requires that two major difficulties be solved: eliminate tractive rods emerging form the mud bed and establish a procedure to measure mud displacement. Tractive rods must be eliminated because they may act as dewatering pickets complicating the analysis of the data.

The experimental set-up consists of two nonmagnetic concentric cylinders, delimiting between them a circular channel. The cylinders rest on a nonmagnetic table. The outer cylinder is made of Plexiglas, so that the mud movement may be observed. A ruler tape is fixed as a length reference on the outer cylinder. A second set of such cylinders, may be added above the first set, increasing the mud capacity to study the effect of the height of the mud bed. Up to four metallic spheres or half spheres, may be symmetrically inserted on the channel bottom. They are used as magnetic rotors to shear the mud. Four electromagnets are symmetrically located on a rotating circular arc under the table. They provide the magnetic traction moving the rotors around the channel without traction rods. The speed of the rotating arc may be varied and is chosen to be representative of the typical translational speed of rakes in industrial settlers. Figure 1 shows this experimental set-up. A digital camera is placed directly in front of the apparatus to record the transits of the rotors.

Bauxite residue obtained from the Rio Tinto Vaudreuil alumina refinery was used to prepare a suspension by diluting to 75 g/L with a 20 g/L caustic solution and then flocculated in a 10 L cylinder with 60 g/t of ALT780VHM flocculant. After resting for a few hours, the supernatant liquid is removed and the remaining suspension is gently poured into the circular channel.

All the tests are carried at room temperature and a typical test lasted two hours. The effect of the speed of the rotors, of their number (1,2 or 4) and of their shape (half or complete sphere) and the effect of the mud bed height have been investigated. At intervals of ten minutes during the test, the rotors were stopped; two samples were collected in front and behind a rotor to measure their solid mass fraction by conventional means. The average of the two values was considered to be the solid mass fraction of the mud bed at the rotor position. A rheometer could be used *in situ* to measure directly the yield stress and the viscosity of the mud in the channel. After these manipulations the rotors were set into motion again.

The effect of dewatering rods could be examined by fixing such a vertical rod on the top of the rotors used in our experimental set-up. Moreover, extra work is required to relate the empirical constants from the mathematical relationship to the rheological properties of the red mud.

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