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Challenges and opportunities of hydrocyclone-thickener dewatering circuit: A pilot scale study

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ABSTRACT

Hydrocyclone-thickener circuit is a promising solution to enhance the dewatering efficiency in mineral industries. The major challenge in the circuit is reducing particle size in the thickener feed and the opportunity is a rise in the residence time of sediments. In this work, the effect of particle size, bed depth and residence time on the pilot thickener performance were investigated. Furthermore, the influence of residence time was differentiated due to the variations in the bed depth and settling flux. Moreover, a new approach was introduced to estimate solids residence time in the thickener. Results indicated that a significant drop in the thickener performance was observed by reducing the particle size. Additionally, it was found that longer residence time and deeper bed increased the thickener performance while the bed depth had a stronger effect.

1. Introduction

Thickeners are widely utilized in mineral industries to recycle tailings and concentrate water content. During the last decade, the scarcity of global water resources became more serious. Employing a hydrocyclone-thickener circuit is a potential remedy to enhance the dewatering efficiency of thickeners (Garmsiri, 2008). In this circuit, suspension is introduced to the dewatering hydrocyclone. The thickened suspension is discharged from hydrocyclone underflow while overflow containing a major fraction of water and fines is fed to the thickener for further dewatering. In this circumstance, thickener feed fine fraction increases which may be a challenge during thickening. Moreover, the residence time of the sediments in the thickener increases due to a lower feed flow rate which may be beneficial.

Hydrocyclone is well known as a classifier, whereas it could be used as a dewatering tool (Rizk et al., 2010). The efficiency of a dewatering hydrocyclone is affected by spigot and vortex finder sizes (Firth, 2003) as well as inlet pressure (Pasquier and Cilliers, 2000).

Tao et al. (2010) mentioned that thickener performance increased linearly with residence time while Jiao et al. (2013) reported this relationship is non-linear and affected by flocculant. Note that flocculants are used to enhance the thickener performance (Garmsiri and Haji Amin Shirazi, 2014). The residence time of material in the thickener could be affected by settling flux or bed depth while as the authors are aware, this difference has never been differentiated in the literature.

Particle size affects the thickener capacity and compressibility of suspension in the bed (Garmsiri and Haji Amin Shirazi, 2018). Shear yield stress is a rheological property which has been used to assess the compressibility of suspension (Garmsiri et al., 2015). It was found that shear yield stress of suspensions increases with a fine fraction (Tangsathitkulchai, 2003) while the details need to be studied.

Since copper concentrators are the largest producers of tailings in mineral industries, an improvement in the dewatering efficiency is essential. To achieve this, the hydrocyclone-thickener circuit may be promising for both existing and future concentrators. The main objective of this research is investigating the effect of particle size and residence time of sediments on the performance of a pilot scale thickener.

2. Material and methods

2.1. Material characterization

Tests were conducted using the flotation tailings of Sarcheshmeh and Shahrebabak copper concentrators in Iran. A high molecular weight anionic polymer, with the commercial name CU43U was utilized to induce flocculated suspension. Stock flocculant solution (3 wt.%) was prepared for an hour and then diluted to 0.3 wt.% before application. Flocculant dosage was about 20 g/t during the experiments.

2.2. Dewatering hydrocyclone tests

A hydrocyclone with the diameter of 50 cm was employed to have a

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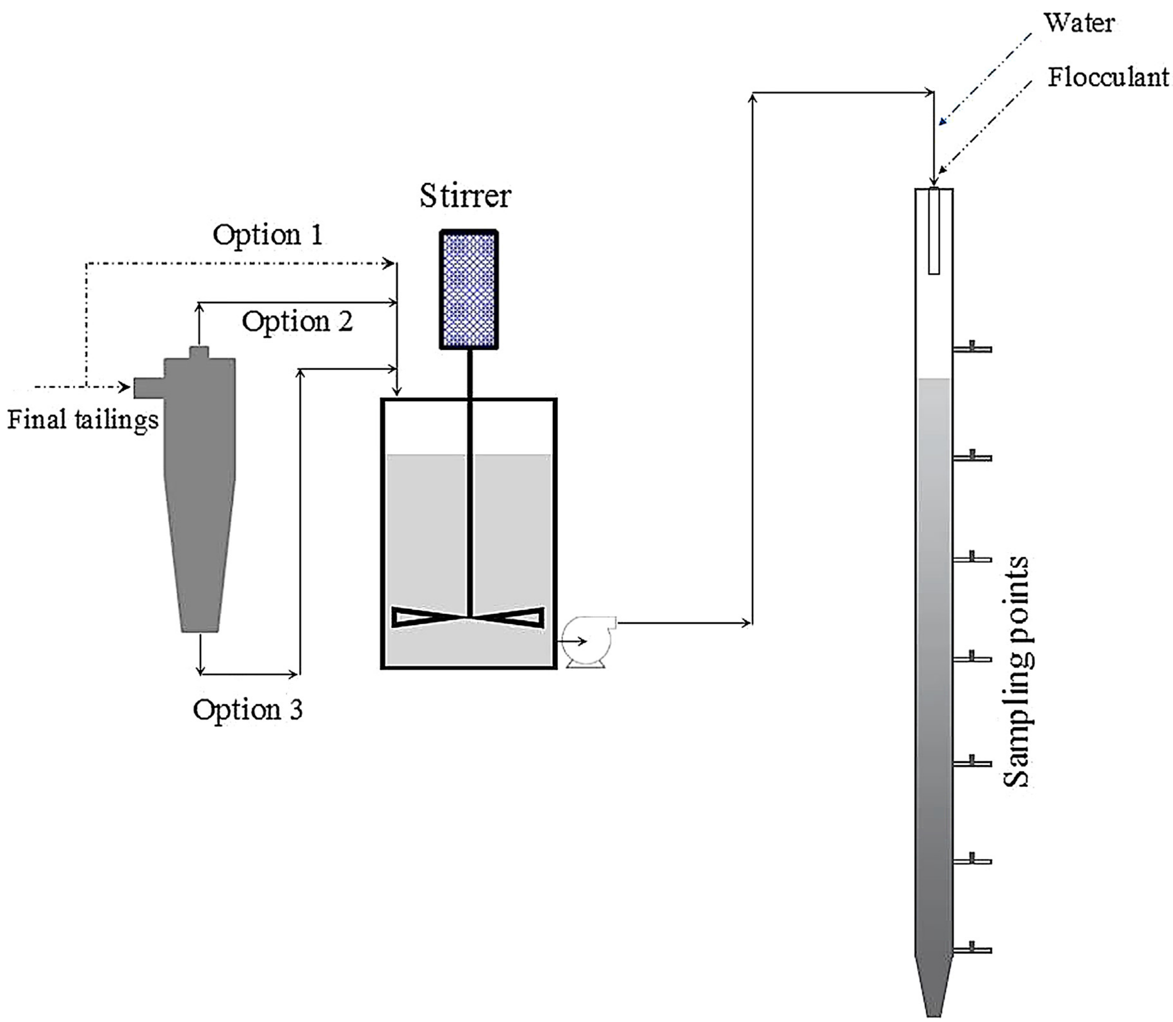

Fig. 1. Schematic view of the pilot thickener circuit.

rough estimate of dewatering hydrocyclone performance. Hydrocyclone was mounted with an inclination of 45 degrees and the dimension of spigot as well as operational pressure were modified to enhance the dewatering efficiency. Hydrocyclone tests were conducted to have a rough estimation of solids and water recovery in the underflow.

2.3. Pilot thickener circuit

A column with the dimensions of 4 and 0.2 m was employed in this work (Fig. 1). To investigate the effect of particle size, the hydrocyclone feed (i.e. unclassified flotation tailing), overflow or underflow was reported to the thickener, individually. During the tests, flocculation was carried out in the presence of diluted suspension (12 wt%) and flocculant in the feedwell. The bed level was adjusted by controlling the discharge valve. The column was operated until steady state was achieved. Samples were taken from thickener discharge and sampling points which were located down the column with the distance of 50 cm (Fig. 1). During the tests, settling flux was considered according to the full-scale data equal to 20 t/m^2 × day. Then, it was manipulated to investigate the effect of residence time due to variations in the settling flux.

2.4. Estimation of residence time

Estimating the residence time of sediments in the thickener is complicated due to the water recovery in the bed. In this work, a new approach was introduced to estimate the residence time. Assuming the entire feed solids content is reported to the discharge, mean residence time of material in the thickener bed could be calculated using Eq. (1).

$$t = \sum_{i=1}^{n} t_i = \frac{B_{Vm}}{Q_{sus\ i}} = \frac{B_{Vm}}{Q_{solids\ i} + Q_{water\ i}} \quad (1)$$

where t is the mean residence time of material (min), t_i is the residence time of material in the i^{th} element of the bed (each element is 0.5 m of bed). B_{Vm} is the volume of an element and $Q_{sus\ i}$ is the suspension flow rate in i^{th} element of the bed. $Q_{solids\ i}$ and $Q_{water\ i}$ are the solids and water volumetric flow rates in i^{th} element of the bed, respectively. It is notable that water flow rate in Eq. (1) could be calculated using solids rate and mean solids concentration in i^{th} element of the bed.

3. Results and discussion

3.1. The performance of dewatering hydrocyclone

Number of samples were collected from hydrocyclone feed and discharges. Results indicated that the average solids concentration in the hydrocyclone underflow was 66 wt% that is significantly higher than the discharge of a paste thickener in the same conditions. Furthermore, it was found that the average of solids recovery in hydrocyclone underflow was 46%. This result indicates that dewatering hydrocyclone could produce a reasonably thick suspension.