Powder Technology 213 (2011) 48–54

Contents lists available at ScienceDirect

Powder Technology

journal homepage: www.elsevier.com/locate/powtec

Development of a novel high performance filtration system — Application for various hardly filterable materials

Hiroshi Satone [a,*], Takahisa Katsuoka [b], Kazuki Asai [b], Takahiro Yamada [b], Takamasa Mori [b], JunIchiro Tsubaki [b]

[a] Department of Mechanical and System Engineering, Graduate School of Engineering, University of Hyogo, 2167 Shosha, Himeji, Hyogo 671-2280, Japan
[b] Department of Molecular Design and Engineering, Graduate School of Engineering, Nagoya University, B2-3 (611), Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan

ARTICLE INFO

Article history:
Received 9 December 2010
Received in revised form 3 June 2011
Accepted 6 July 2011
Available online 18 July 2011

Keywords:
Environment
Cake-less filtration
Design
Concentration
Slurries

ABSTRACT

A new filtration method that a slurry is prepared in a well-dispersed state and filtered by a ceramic tube with a spiral guide rod has been developed in our previous paper. In this study, we attempted to concentrate various hardly filterable materials by using this new system. The sample slurries used were sericite, iron oxide, algal suspension and activated sludge of the excrement of farm animals. Their respective concentrations were 57, 74, 1.1, and 7.55 mass%. The concentrated slurry of all samples exhibited good flowability. In addition, to apply this system to real industrial processes, we attempted to calculate the required number of ceramic filters from the relationship between the filtration flux and the slurry concentration. Thus, the size of this system is expected to be significantly compact. Furthermore, in this system, there is a case that the batch operation is more effective than the continuous operation.

1. Introduction

In dead-end filtration, a cake forms continuously on a filter media and the filtration flux gradually decreases because of the progressive increase in the cake resistance. In order to reduce the resistance, flocculants are usually added to the feed slurry. Therefore, development of more effective flocculants has been extensively researched [1–3]. However, because of the addition of flocculants, the packing fraction of the cake is always relatively low. Moreover, the solids deposited on the filter media cannot flow. Thus, the cake has to be scraped mechanically, which increases the size, complexity, and maintenance cost of the system.

Due to these disadvantages, many researchers are investigating cake-less filtration types such as cross-flow filtration [4–8] and rotating disk filtration [9–14]. In cross-flow filtration, fouling increases energy consumption and cleaning frequency, which in turn increases the production cost. Therefore, many studies have focused on determining operating parameters that minimize fouling or analyzing the mechanism of fouling [15–20]. In rotating disk filtration, fouling-prone slurries can be concentrated; however, it requires high power consumption. On the other hand, several advancements in reducing energy consumption have been reported [6,21,22]. This type of filtration system is relatively more complex than others complicated because of existing the moving parts and mechanical seals associated with its filter rotation in this method.

It was reported that a well-dispersed slurry can retain flowability if it is concentrated [23,24]. Furthermore, we have successfully developed novel gravity filtration [25] and rotating disk filtration [26] systems, in which the dense slurry can be collected continuously without using a scraping device. Unfortunately, the ability to scale-up these systems is limited. Thus, in our previous report [27], a new filtration system using a ceramic tube filter with an internal spiral guide rod was developed. Fig. 1 shows the schematic representation and the internal features of the filtration system. Although similar designs were previously reported [28–31], they were only tested with dilute feed slurries. The following points prove the novelty of the new system: (1) this system has the ability to process a high concentration slurry, (2) the slurry concentration achieved by this system is equal or higher than that of conventional systems, (3) the concentrated slurry has good flowability, and (4) the structure of the system is simple. We previously reported the optimization of operating parameters including the use of the spiral guide rod, pitch of the spiral guide rod, filtration pressure, and circulation flow rate. When sericite slurry was filtrated by this system, it was shown that the filtration flux was dramatically improved (about 30 times) compared with that of the conventional cross-flow filtration system as shown in Fig. 2 [27]. It was also shown that fouled particles could be removed easily, and the filtration flux could be recovered to its initial level by ultrasonication. However, neither the ability of the system to handle various hardly filterable materials nor the scale-up of the system was investigated.

Thus, this study aims to evaluate the new filtration system's ability to process hardly filterable materials and discuss the scale-up of the system. Slurries of sericite, iron oxide, algal suspension, and activated

* Corresponding author. Tel./fax: +81 79 267 4842.
E-mail address: satone@eng.u-hyogo.ac.jp (H. Satone).

0032-5910/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.powtec.2011.07.004

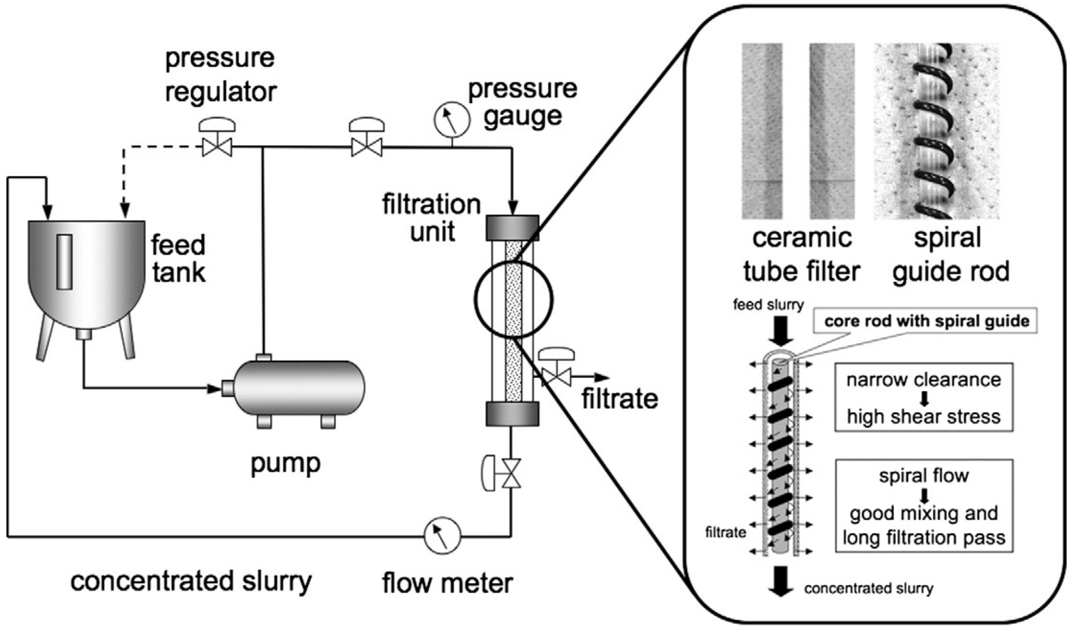

Fig. 1. Schematic representation indicating the internal features of the new filtration system.

sludge of the excrement of farm animals were selected as sample slurries. In current industrial processes, these materials are concentrated by filter press or sun drying. However, there is a demand for more efficient methods. We attempted to use the new system to concentrate these slurries and compared the final concentrations with those of current filtration systems. In addition, we attempted to calculate the number of ceramic filters that was necessary to achieve the target concentration and volume throughput. Moreover, we compared the batch and continuous operation efficiencies of the new system.

2. Concentration test of hardly filterable materials

2.1. Filtration units

The slurry in the feed tank was fed into the filter assembly via a pump and a pressure regulator system as shown in Fig. 1. The filter media was a ceramic tube with a pore size of 1.5 μm. The inner diameter, the outer diameter, and the length were 9, 12, and 300 mm, respectively. The spiral guide rod was fixed concentrically in the ceramic tube. This internal baffle consisted of a 1.5-mm-diameter lead wire wound helically with a pitch of 10 mm around a 6-mm-diameter cylindrical acrylic core. In order to concentrate the slurry up to a target concentration, the slurry was circulated in the system. The filtration pressure and the circulation flow rate were controlled by the pressure regulator and the valve at the outlet of the filter and measured by a pressure gage and flow meter, respectively. The filtration flux was calculated by measuring the filtrate mass at corresponding time intervals. A minimum volume load of 4 L was necessary to maintain circulation. Therefore, this system was limited to a 10-fold increase in concentration because the volume of the feed tank was 40 L.

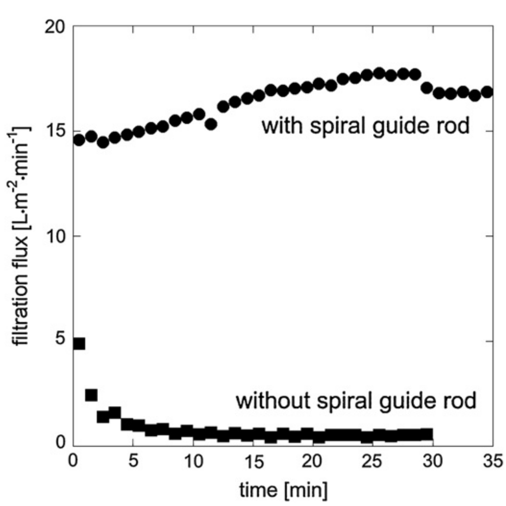

Fig. 2. Advantage of the new filtration system.

2.2. Concentration of sericite slurry

The raw material used was sericite powder (average particle size of 4 μm, density of 2.8 g cm^{-3}; Sanshin Mining Co., Ltd., Japan). This sericite powder is used as a cosmetic raw material and its shape is squamous; therefore, it is difficult to filter. Now, in the fabrication plant, the slurry with an initial concentration of 2.8 mass% (1 vol.%) is concentrated up to 55 mass% (30 vol.%) using a filter press.

In order to prepare the slurry at a target concentration, sample powder and tap water were weighed beforehand. Afterwards, sample powder was dispersed in tap water. Water-glass (Kanto Kagaku Co., Ltd., Japan) was added as a dispersant at a mass fraction of 0.3 mg g^{-1} relative to sericite solids. The sericite slurry was prepared at concentrations of 2.8, 24, 41 mass% (1, 10, 20 vol.%, respectively). These slurries were concentrated using the new system, which was operated at a filtration pressure of 0.4 MPa and a circulation flow rate of 16.8 L min^{-1}.

2.3. Concentration of iron oxide slurry

The iron oxide slurry (density of 5.2 g cm^{-3}) was supplied by JFE Chemical Co. Ltd. The initial concentration was 32 mass% (8.3 vol.%). Now, in the fabrication plant, this slurry is concentrated up to 70 mass% (31 vol.%) using a filter press.

This slurry was attempted to concentrate by the new system. This iron oxide slurry, obtained as a residual product from the ironworks, originally contained ammonium sulfate as a flocculant. Therefore, water glass having an additive amount of 2.4 mg g^{-1} relative to iron oxide solids was added as a dispersant. 40 L of the iron oxide slurry