Development of a novel high performance continuous cake-less filtration system

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Abstract

A new cake-less continuous filtration system has been developed for large-scale treatment. Sericite slurries prepared by adding water glass as dispersant were filtered by the developed filtration system. It was shown that a spiral guide rod inserted into a ceramic tube filter is very effective for the cake-less continuous filtration. This system achieves much higher filtration rate compared to a conventional cross-flow filtration and we can collect much denser concentrate continuously without any cake formation.
Keywords: dispersant, dynamic cross-flow filtration, purification, solid-liquid separation, suspension, thickening, washing.

1 Introduction

Cake filtration is widely used in many industries to separate solid particles from liquid. In cake filtration, a cake grows continuously on a filter media and the filtration rate gradually decreases due to progressive increase in the cake resistance. In order to reduce the resistance, flocculants are usually added in a slurry. By adding flocculants, the filtration rate can be increased because the formed cake has looser porous structure, therefore many researches have been done to develop more effective flocculants. However, because of adding flocculants, the packing fraction of the formed cake is always relatively low. This means that the cake contains much water and the more time and cost are spent for drying after filtration. In addition, the formed cake on the filter media has to be scraped mechanically, which makes the system operate by batch process.

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In order to overcome these problems, we developed a novel filtration system, in which a dispersant is added instead of a flocculant and the concentrate can be collected continuously without any scraper because the concentrate still has fluidity [1]. However, in our previous system, it is difficult to scale up due to its structure [2]. Therefore, the aim of this work is to develop a new cake-less continuous filtration system which can be applied for large-scale treatment.

2 Experiments

2.1 Filtration system

Figure 1 shows the schematic illustration of the filtration system developed in this work. The filter media was a ceramic tube distributed by Noritake Co. Ltd., Japan. The pore size was 1.5 μm and the inner diameter, outer diameter and length were 9, 12, and 300 mm, respectively. We introduced the spiral guide rod in the ceramic tube because of following reasons. First, the shear force acting on a concentrate in the tube increases and this helps the concentrate to be eliminated from the filter surface easily, which means that the filtration resistance can be reduced and the filtration rate becomes higher. Secondly, the particle concentration in the tube becomes homogeneous while the concentration distribution of the radial direction is formed in a conventional cross-flow filtration.

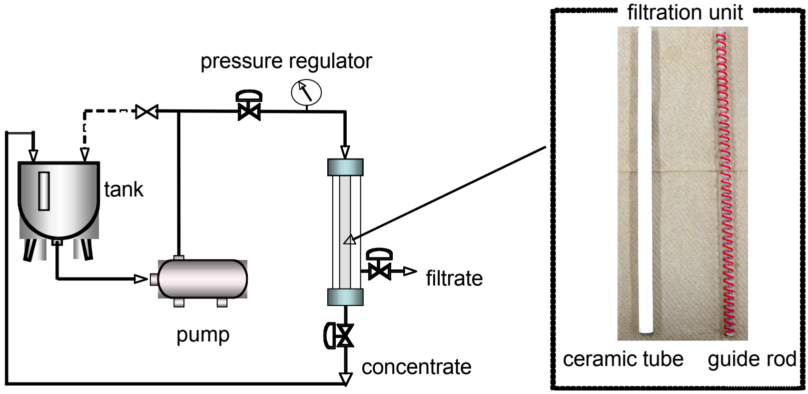

Figure 1: Schematic illustration of the developed filtration system.

2.2 Effect of spiral guide on filtration

The raw material was sericite powder. Sample powder was dispersed in tap water using water glass as dispersant. The prepared slurry was filtered by this system as shown Fig.1. The slurry was also filtered by the ceramic tube without the spiral guide rod (that is, a conventional cross-flow filtration) and filtration rate was compared to this system. Solid concentration of the feed slurry was 1.5 vol%. In order to keep the particle concentration in the filtration unit constant, the filtrate and the concentrate were returned to the tank. The filtration pressure was 0.4 MPa and the flow rate of the concentrate was 2.8 kg min^{-1}.

2.3 Effects of filtration pressure and flow rate

Sericite slurries with the particle concentration of 1 vol% were filtered by changing the filtration pressure from 0.1 to 0.8 MPa, and the flow rate of concentrate from 0.4 to 4.4 kg min^{-1}. Filtration rates in each filtration condition were compared to discuss the effects of filtration pressure and flow rate of the concentrate on the filtration rate for this system.

2.4 Effect of the pitch of spiral guide rod

The pitch of spiral guide rod was changed from 1.9 to 40 mm in order to optimize the shape of spiral guide rod. Sericite slurries were filtered at the filtration pressures of 0.1 and 0.4 MPa, and the filtration rates were compared in various pitches of the spiral guide.

3 Results and discussion

3.1 Effect of spiral guide rod on filtration

Figure 2 shows the time changes of filtration rate for the developed system in which the spiral guide rod was inserted into the ceramic tube, and the usual cross-flow filtration system(that is the only ceramic tube without any guide inside it). The filtration rate of this developed system was almost 30 times larger than that of the usual cross-flow filtration system. Moreover, we could not observe any cake on the filter surface after filtration in this system, while the

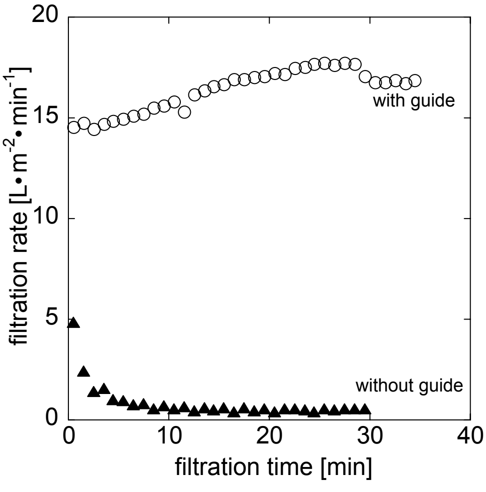

Figure 2: Effect of the spiral guide rod on filtration rate.

cake was formed slightly in the cross-flow filtration system. From these results, we can conclude that the spiral guide rod is very effective to enhance filtration performance in this system.

3.2 Effects of filtration pressure and flow rate

Figure 3 shows the effects of the flow rate on the filtration rate in various filtration pressures. From these results, the filtration rate increased with the flow rate of the concentrate and did not depend on the feed pressure. This indicates that the shear stress in the filtration unit increases with the flow rate of the concentrate, preventing fouling of smaller particles and making the filtration rate much higher.

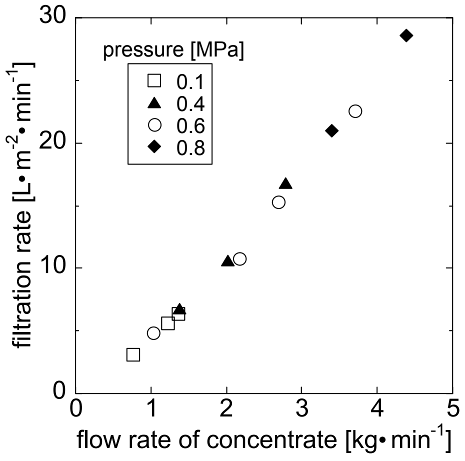

Figure 3: Effect of the flow rate of concentrate on filtration rate.

3.3 Effect of the pitch of spiral guide rod

Figure 4 shows the effect of the pitch of spiral guide rod on the filtration rate. The optimal value of the pitch which gave the maximum filtration rate was different at each feed pressure. The larger the pitch became, the smaller the flow resistance in the filtration unit became, resulting in higher filtration rate. However, if the pitch was larger than the optimal value, the shear stress became not enough to eliminate the concentrate and this is because the filtration rate decreased.

3.4 Intermittent filtration

When using this filtration system in real industrial processes, it is desirable to use the same filter as long as possible without washing even though the filtration system is operated intermittently. The effect of intermittent operation on the filtration rate was checked as following.

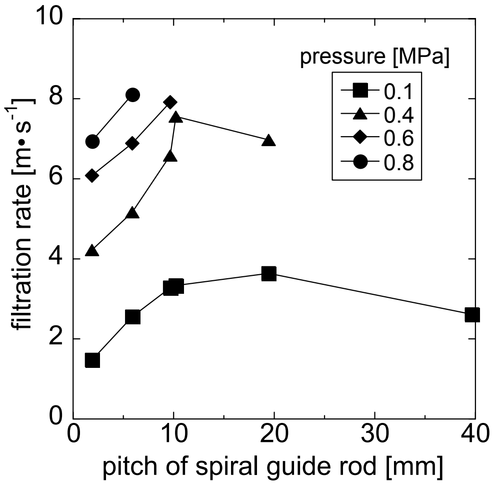

Figure 4: Effect of the pitch of spiral guide rod on filtration rate.

3.4.1 Intermittent filtration in short interval

We filtered the sericite slurry with a particle concentration of 1 vol% under constant concentration by returning both the filtrate and the concentrate in the tank. After filtration rate became constant, the feed slurry was replaced to the other one with a particle concentration of 20 vol% and filtered under constant concentration. We repeated these operations in short interval. Sericite slurries were filtered at the filtration pressures of 0.4 MPa. Figure 5 shows the effect of the repeated number of experiment on filtration rate. The filtration rate of the dilute slurry became lower once after having filtrated the high concentration

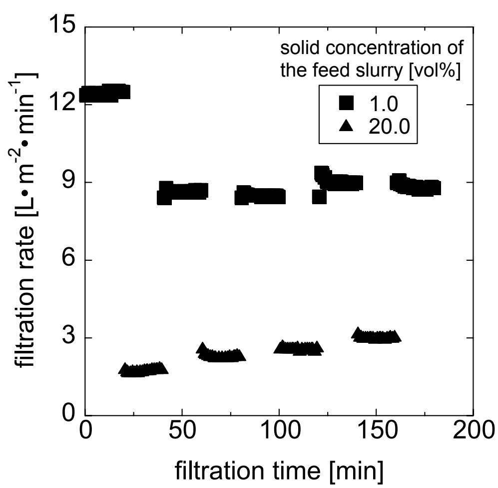

Figure 5: Effect of repeated experiment in short interval on filtration rate.

slurry. This is because the particles clogged in pores of filter and filtration resistance increased at the first filtration of the dense slurry. After the second filtration of dilute slurry, however, the filtration rate recovered instantaneously and was constant.

3.4.2 Intermittent filtration in long interval

We also checked the effect of a long interval operation on the filtration. We filtered the sericite slurry with a particle concentration of 1 vol% under constant concentration after the filtration of the other one with a particle concentration of 20 vol% under constant concentration for a long time. Figure 6 shows the time change of the filtration rate. After filtration of the high concentration slurry for a long time, the filtration rate gradually increased up to the value obtained from the repeated experiment. It seemed that the more particles clogged pores of the filter compared with the case of the short interval, however, the filtration rate of 20vol% slurry kept constant. From these experimental results, a lot of particles should be removed in order to recover the filtration rate completely.

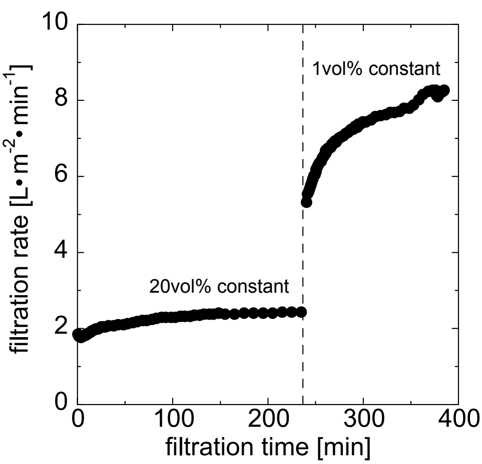

Figure 6: Effect of the long-time filtration on filtration rate.

3.5 Cleaning of used filters by ultrasonication

First, we filtered the sericite slurry with a particle concentration of 1 vol% under constant concentration using a virgin filter. Figure 7 shows the filtration rate of the virgin filter.

In order to confirm whether the particles that clogged the filter can be removed easily, we compared the filtration rate before and after ultrasonication. After 5 ours filtration of 30 vol% sericite slurry, the filtration rate of 1 vol% slurry was measured as shown Fig. 8. After cleaning by ultrasonication for one hour, again the filtration rate of 1 vol% slurry was measured as shown Fig. 8. Comparing Figs 7, 8 it is obvious that particles that clogged the filter can be removed easily, furthermore, the filtration rate can be recovered to the initial condition.

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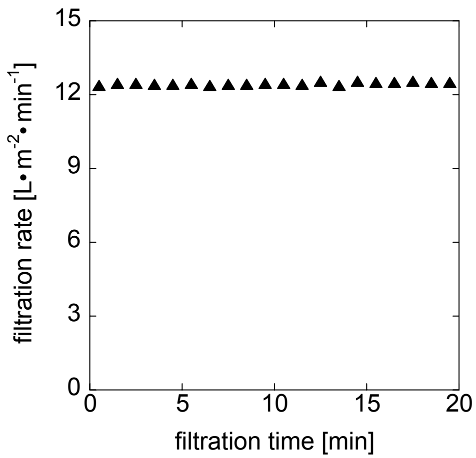

Figure 7: Filtration rate of a virgin filter filtrating 1 vol% sericite slurry.

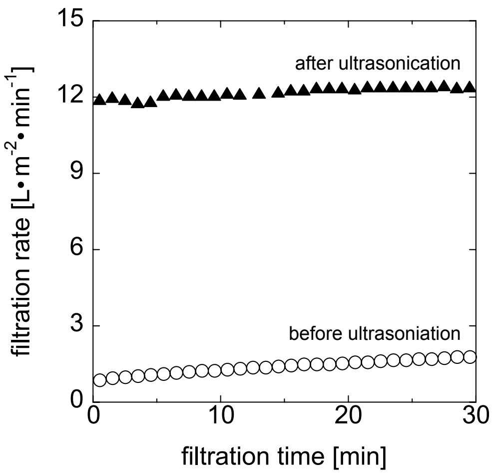

Figure 8: Effect of the ultrasonication on filtration rate.

3.6 Apply to algal suspension

We tried to apply to other hardly filterable materials, such as an algal suspension.

3.6.1 Dead-end filtration

First, we filtered the algal suspension with a particle concentration of 0.3 mass% by usual dead-end filtration. Figure 9 shows the relationship between the filtration rate and filtration time. Just after starting filtration, the filtration rate rapidly decreased because the particles clogged the filter. After about 300 minutes, the filter completely clogged and the filtration stopped. From this result, the algal suspension slurry be hardly filtered.

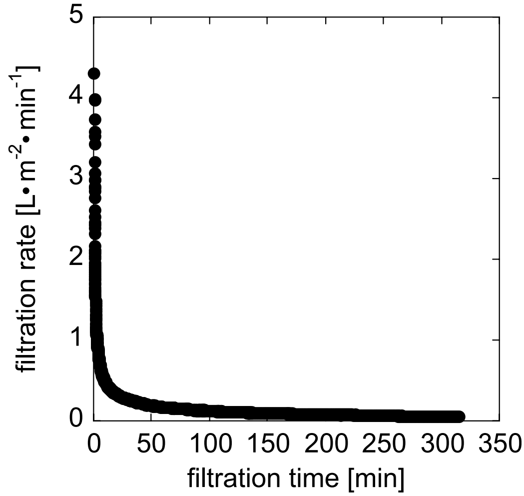

Figure 9: Relationship between filtration rate and filtration time in case of dead-end filtration.

3.6.2 Concentration of the algal suspension slurry by the novel system

Figure 10 shows the relationship between the filtration rate and filtration time and Figure 11 shows the relationship between the filtration rate and slurry concentration. As shown in Figs. 10, 11, it was able to concentrate the algal suspension without clogging unlike the dead end filtration. In this experiment the filtration test had to stop at 1.1 mass% (about 3.2 times) of the concentrate because of shortage of the feed suspension, however, it seems that the

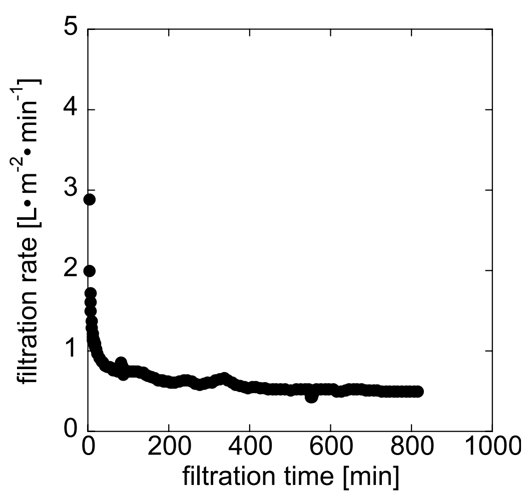

Figure 10: Relationship between filtration rate and filtration time in case of our system.

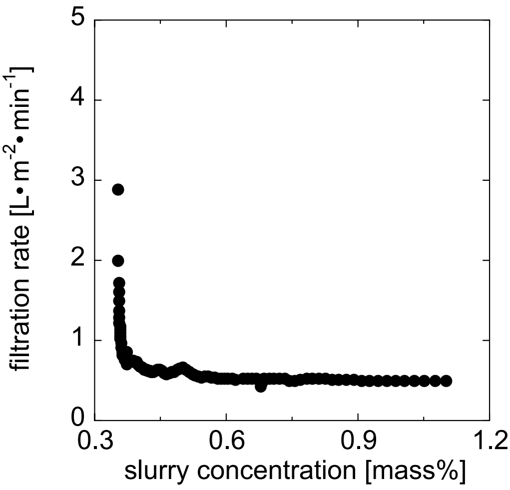

Figure 11: Relationship between filtration rate and slurry concentration in case of our system.

concentration can continue because of the following reasons. First, there were not concentration layer on the spiral guide rod after end of concentration. Second, the concentrate had enough flowability to continue the concentration.

4 Conclusions

We developed a kind of cross flow tubular ceramic filter inserted a core rod with spiral guide. It was shown that the spiral guide rod dramatically improved the filtration rate compared to the conventional cross flow filtration system. In this system the filtration rate increased with the flow rate of the concentrate and did not depend on the filtration pressure. It was also shown that the optimal value of the pitch which gave the maximum filtration rate was different at each feed pressure. If the particles clog the filter during filtration, particles can be removed easily and the filtration rate can be recovered to the initial condition by ultrasonication. Furthermore, we showed that this system was available for some hardly filterable materials.

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