Electrokinetic Response of Solid-Liquid Mixture during Mechanical Expression

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INTRODUCTION

Expression is one of solid-liquid separation methods and widely used in many practical fields such as food, fermentation, and chemical industries and various wastewater treatments. The expression process is divided into two periods, filtration period and consolidation period. It is essential to determine the transition point from the filtration to consolidation periods for effective operation. In the filter press which is a solid-liquid separation apparatus, the losses of work time and product recovery frequently occur by missing the optimal switching time from the filtration process to compression process. If we can monitor the state of the cake formation in the filter chamber and determine the transition point correctly between the two periods, it is possible to reduce such losses and to improve the production efficiency. However, a simple and practical determination method for this transition does not exist.

In this study, "monitoring of the expression process" was discussed from the electrokinetic point of view; the time course of electric potential difference between filter media has been measured.

EXPERIMENTAL

Materials

Aqueous suspensions of zinc oxide (Nacalai Tesque), kaolin (Nacalai Tesque) and KC Flock (Nippon Paper) and sake mash (Yabuta Industries Co., Ltd.) were used as experimental materials. A KCl aqueous solution was added to the aqueous suspensions of zinc oxide and KC Flock to keep the ionic strength constant. The KCl concentration of the final mixture was 0.1 mM.

Apparatus and Procedure

The experimental apparatus is schematically shown in **Fig. 1**. It consists essentially of a stainless steel piston and an acrylic cylinder of 60 mm diameter. The prepared sample was inserted into this consolidation cell and expressed at a constant pressure of 55.6 kPa. The change in thickness of the sample with time θ was measured by dial gauge fitted on the cylinder. Also, the change in the electric potential difference between filter media with time θ was measured by a digital multimeter.

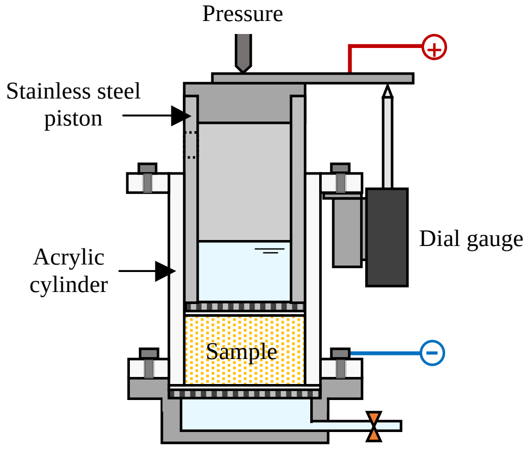

Fig. 1 Schematic diagram of experimental apparatus.

ANALYSIS

Based on Ruth's constant pressure filtration theory, the following equation holds in the filtration period.

$$-\frac{\mathrm{d}L}{\mathrm{d}(\theta+\theta_\mathrm{m})^{1/2}} = iK^{1/2} \tag{1}$$

where L is the sample thickness, θ is time, θ_m is the fictitious filtration time accounting for the filter medium resistance, i is the number of drainage surfaces, and K is Ruth's filtration coefficient. Because i and K are constant for constant-pressure filtration, $-\Delta L/\Delta\sqrt{\theta+\theta_\mathrm{m}}$ is constant. The transition from the filtration to consolidation periods can be determined as the point at which the value of $-\Delta L/\Delta\sqrt{\theta+\theta_\mathrm{m}}$ begins to decrease.

In this study, based on the transition point determined by the above conventional method, the responses of the electric potential difference and the electric potential gradient were discussed.

RESULTS AND DISCUSSION

In **Figs. 2** to **5**, the red circles are the relation between $-\Delta L/\Delta\sqrt{\theta+\theta_m}$ and θ described above. The solid lines represent the time course of the electric potential difference (ΔE) between the filter media or the electric potential gradient ($\Delta E/L$). Here, L is the sample thickness.

The result of the experiment using zinc oxide as a sample is shown in Fig. 2. It was observed that the time when ΔE suddenly began to rise coincided with the time when the filtration period ended. Further, the time attaining the second minimum value of ΔE after the transition point seems to correspond to the time when the consolidation period ends.

The result of the experiment using kaolin as a sample is shown in Fig. 3. In the case of kaolin, contrary to zinc oxide, ΔE began to decrease near the end of filtration period, and it was found that $\Delta E/L$ took a maximum value at the transition point.

The result of the experiment using KC flock as a sample is shown in Fig. 4. As with kaolin, ΔE began to decrease near the end of filtration period. Also, at a time when ΔE became minimum (θ = 1116 s) the consolidation of the material nearly ended; i.e. the average consolidation ratio U_c became 0.92 (not shown here). U_c indicates the progress of consolidation, which is 0 at the beginning of consolidation and unity at the end of consolidation.

The result of the experiment using sake mash as a sample is shown in Fig. 5. While there was no characteristic ΔE response (data not shown), $\Delta E/L$ changed rapidly near the end of filtration period. Also, at time when the potential gradient was maximum (θ = 193,930 s) the consolidation nearly finished (U_c = 0.98).

The reason why the characteristic potential change was observed at the transition point is due to the change of streaming potential generated in the capillary of the cake formed on the drainage surface. The time courses of ΔE and $\Delta E/L$ represent the electrokinetic responses of the materials.

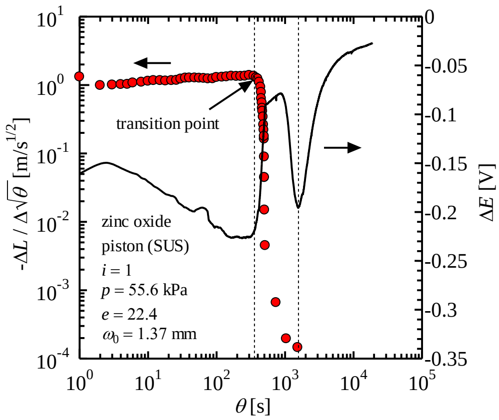

Fig. 2 Time course of overall electric potential difference of zinc oxide.

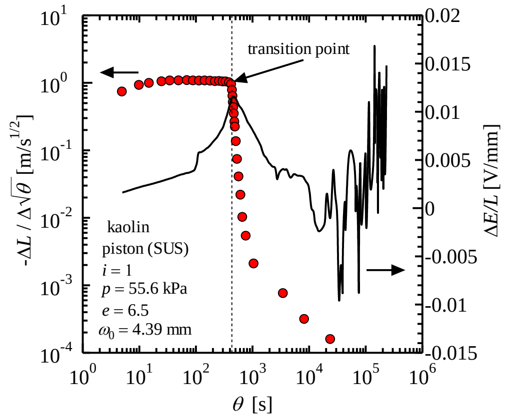

Fig. 3 Time course of overall electric potential gradient of kaolin.

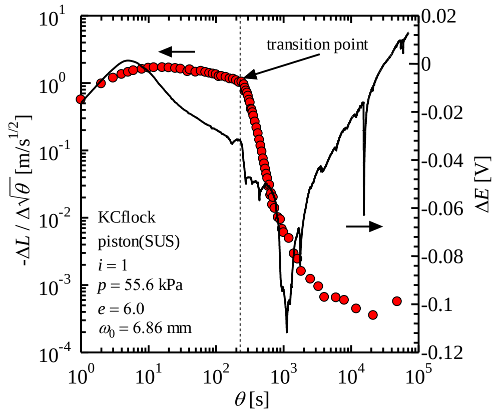

Fig. 4 Time course of overall electric potential difference of KC flock.

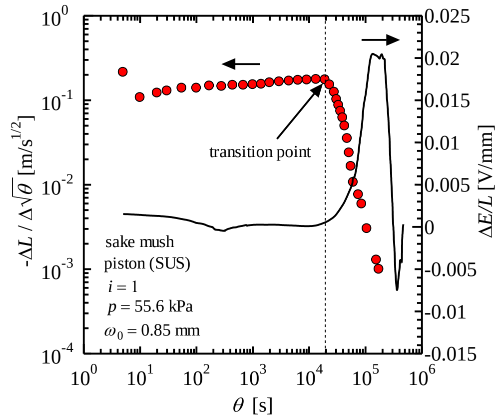

Fig. 5 Time course of overall electric potential gradient of sake mash.

CONCLUSIONS

It has been shown that the transition point could be determined by measuring the electric potential difference between filter media during expression process. In addition, the end of consolidation period seems to be determined from the electrokinetic responses of the materials.