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Development of new deliquoring method with bypass discharge mechanism in centrifuge

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INTRODUCTION

Centrifugal deliquoring is used in many industrial processes (e.g., chemical, food, pharmaceutical and biotechnological processes). A high driving force for solid liquid separation by a centrifuge can easily be obtained, resulting in a short processing time. However, during deliquoring of a slurry with poor filterability by a centrifuge, cake with poor permeability forms near the filter medium. Thus, such a slurry cannot be separated effectively by a conventional centrifuge.

A new deliquoring method is developed to solve this problem. A schematic drawing of the new method is shown in **Fig. 1**. In this method, a new filter medium is placed parallel to the centrifugal force. In this study, the effect of the new filter medium on the consolidation process is evaluated, and an analytical method for deliqouring process using the new filter medium is proposed.

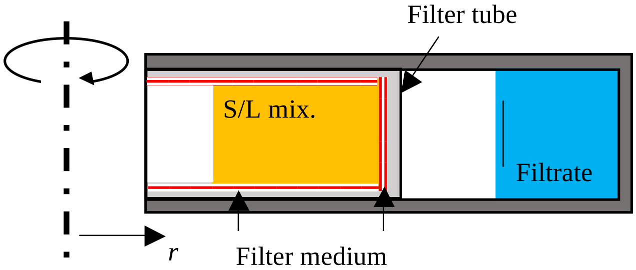

Fig. 1 Schematic diagram of the new method.

EXPERIMENTAL

The centrifugal tube with an inner diameter of 31.7 mm and height of 56.8 mm was used. In the conventional method, filter paper (Advantec; No. 5C) was set at the bottom of the tube as a filter medium. Also, a side filter medium was used in the experiments of the new method. The distance from the center of the centrifuge to the filter medium set at the bottom of the chamber was 11.9 cm. Batch-wise centrifugal deliquoring experiments were carried out using a centrifuge (Kokusan; H-26F). Soy sauce mash was used as an experimental material; the solid concentration of the mash was in a consolidation region. The density of the solid is 1530 kg/m^3. The density of the soy sauce is 1180 kg/m^3, and the viscosity is 4.14 mPa･s (25.0 ℃). At a fixed elapsed time from the beginning of centrifugation, the weight of removed liquid was measured. The centrifugal deliqouring was conducted with various combinations of total solid volume per unit cross-sectional area ω_0 and rotational speeds N. ω_0 ranged from 0.08 to 0.16 cm^3/cm^2 in the centrifugal test. Soy sauce mash was centrifuged with N = 1500~3000 rpm.

RESULTS AND DISCUSSION

Effects of the new filter medium

Fig. 2 represents the time course of the average consolidation ratio U_C during centrifugal deliquoring of the soy sauce mash. The deliquoring rate of the new method was much faster than that of conventional method.

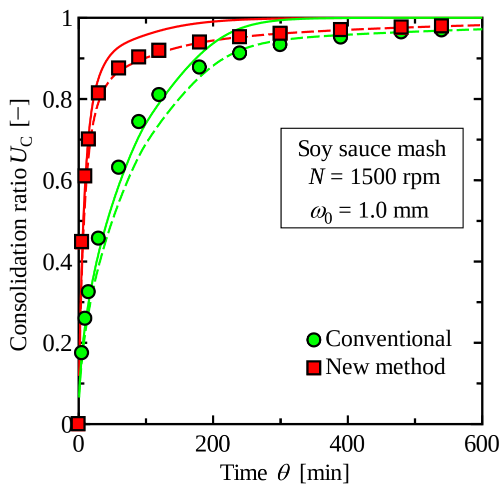

Fig. 2 Progress of deliqouring.

The dependencies of the deliquoring time θ_{50} required for attaining 50% of U_C on the total solid volume ω_0 are presented in **Fig. 3**. The dependency of θ_{50} on ω_0 using the new method is smaller than that using the conventional method.

Analytical method

Consolidation equations representing the relation between local void ratio e and local solid compressive pressure p_s during the deliquoring by the conventional method and the new method are expressed by Eqs. (1) and (2), respectively.

$$\frac{\partial e}{\partial \theta}=\frac{\partial}{\partial \omega}\left[\frac{1}{\mu\alpha\rho_s}\left\{-(\rho_s-\rho)r\Omega^2-\frac{\partial p_s}{\partial \omega}\right\}\right] \tag{1}$$

$$\frac{\partial e}{\partial \theta}=\frac{\partial}{\partial \omega}\left[\frac{1}{\mu\alpha\rho_s}\left\{-(\rho_s-\rho)r\Omega^2-\frac{\partial p_s}{\partial \omega}\right\}\right]-\frac{4q_b}{D(1-\varepsilon)} \tag{2}$$

where θ is the deliquoring time; ω, the net solid volume per unit cross-sectional area extending from the drainage surface up to an arbitrary position in the material; μ, the viscosity of liquid; α, the hydraulic specific resistance; ρ_s, the density of solid; ρ, the density of liquid; r, the distance from the center of the centrifuge; Ω, the angular velocity; D, the inner diameter of side filter medium; and ε, the local porosity. q_b in Eq. (2) is the apparent liquid velocity through the side filter medium defined by

$$q_b=\frac{\Delta p_L}{\mu R_m} \tag{3}$$

Here, Δp_L is the liquid pressure difference across the side filter medium, and R_m is the filter medium resistance.

The solid lines in Fig. 2 represent the results calculated from Eqs. (1) and (2) considering only the primary consolidation. The agreement between calculated and experimental U_C is fairly good in the early stage of deliquoring. However, the calculated values approached final values faster than the empirical ones.

If the creep deformation of the material is considered, the rate of decrease of the local void ratio e is expressed by the following equation. [1]

$$\frac{\partial e}{\partial \theta}=\left(\frac{\partial e}{\partial p_s}\right)_\theta\left(\frac{\partial p_s}{\partial \theta}\right)_\omega+\left(\frac{\partial e}{\partial \theta}\right)_{p_s} \tag{4}$$

The first term on the right-hand side of Eq. (4) indicates the change in e due to the primary consolidation, while the second term is that of the secondary consolidation. [1]

The consolidation equations considering the secondary consolidation for the conventional method and the new method are obtained by combining Eq. (4) with Eqs. (1) and (2), respectively.

If the primary consolidation rate is much larger than the secondary consolidation rate, U_C becomes approximately the following equation for $\theta >> 0$.[1]

$$U_C \approx 1-B\exp(-\eta\theta) \tag{7}$$

Here B is an empirical constant and represents the ratio of creep deformation to the total deformation. η is an empirical constant and represents the ratio of the elastic coefficient of the spring in the Voigt element[1] to the viscosity of the dashpot of the Voigt element.

Fig. 4 shows that Eq. (7) holds in the later stage of deliquoring; i.e., the secondary consolidation rate is much smaller than the primary consolidation rate. Using Eq. (7), the values of both B and η can be graphically determined as shown in the figure.

The broken lines in Fig. 2 represent the calculated results considering the creep deformation of the material. Good agreement between the calculated and experimental results was obtained.

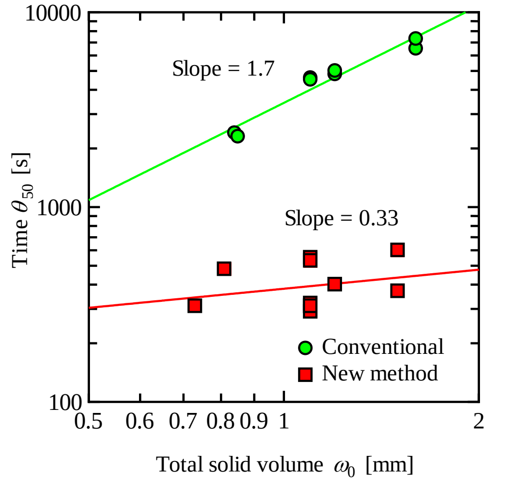

Fig. 3 Effect of ω_0 on dewatering time θ_{50} (N = 1500 rpm).

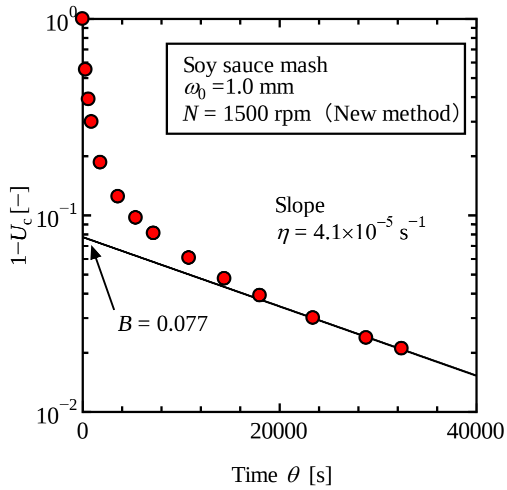

Fig. 4 Determination of B and η.

CONCLUSIONS

The process of deliquoring a slurry with poor filterability is improved dramatically using the new method. It is also shown that the effect of total solid volume on deliquoring time with the side filter medium is very small; this implies that the new method can deliquor more material in a batch than the conventional method. The agreement between calculated and experimental U_C is satisfactory when the creep deformation of the material is considered.

REFERENCE

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