Experimental Study on the Solid-Liquid Separation of Sugar Mud

Yanhui Chen, Xinjie Zhang and Linfeng Zhang
School of Mechanical Engineering, Guangxi University of Science and Technology, Liuzhou, China
gxut_jx@163.com, 930243857@qq.com, 838492376@qq.com

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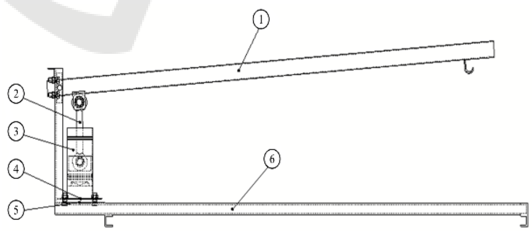
Abstract: In order to research the relevant dehydration properties of sugar mud deeply. The paper carry out the compression dehydration experiment with sugar mud as the raw material which using the piston type dehydration device of self-designed. The effect of the mass and the pressure on the dehydration rate of the sugar mud was analysed according to the relationship between the time and the filtrate volume. Thus, the type of the compression filter of the sugar mud was determined. Finally, the corresponding mathematical formula was derived from the theory of one dimensional squeezing and dewatering.

1 INTRODUCTION

Biomass energy refers to some of the wastes produced by agriculture, forestry and animal husbandry. The conversion of solar energy into internal energy and aggregated into organisms mainly through photosynthesis in plants. Theoretically, it belongs to renewable energy (Ma, 2012) (Chen, 2010). Sugar cane was one of the sources of biomass energy. Sugar making plants use sugar cane to process sugar. Most of the sugar was used to produce white sugar. But a small portion of the sugar was carried away by the by-products produced in the sugar process. If the sugar sludge was disposed of arbitrarily or discarded, it could easily cause deterioration, decay and pollution. On the other hand, it was also a serious waste of resources. Comprehensive development of effective utilization of the sugar mud, not only reduces the waste of resources, the raw materials were provided for the production of other products, the corresponding environmental problems were solved, and also brought some social and economic benefits. However, the comprehensive utilization of sugar mud were based on the dehydration and the drying. Therefore, the study on the properties of sugar mud dehydration has very important practical significance.

2 EXPERIMENT EQUIPMENT AND METHODS

The experiment device for the compression and the dehydration of sugar mud as shown in Figure 1. It was mainly composed of pressure bar, piston, cylinder, fixed plate and filter panel. The filter panel was evenly distributed with dehydration micro-pores about 2 mm. 300 mesh nylon filter cloth was selected as the filter medium according to the previous experiment.



1. Pressure bar; 2. Piston; 3. Cylinder; 4. Fixed plate; 5. Filter panel; 6. Body bracket

Figure 1: The schematic diagram of experiment device.

Experiment method: Firstly, clean and dry the beaker with sugar mud. Then weigh it and record the mass as m_1. Secondly, get the sugar mud back to the normal temperature and pour into the beaker. And weighed and recorded as m_2 to ensure the mass of the sugar mud taken as the experiment.

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Finally, the 400 g, 500 g, 600g and 700g of sugar mud gained from the weighing were poured into the cylinder. And the dehydration experiments under the pressure of 0.08 MPa, 0.23 MPa, 0.38 MPa, 0.53 MPa and 0.68 MPa were carried out respectively. Meanwhile, recorded the filter time and the corresponding amount of filtrate.

3 EXPERIMENT RESULTS AND ANALYSIS

According to the above experiment method, the sugar mud was compressed and dehydrated, and the experiment data of time and filter were arranged as shown in the Figure 2.

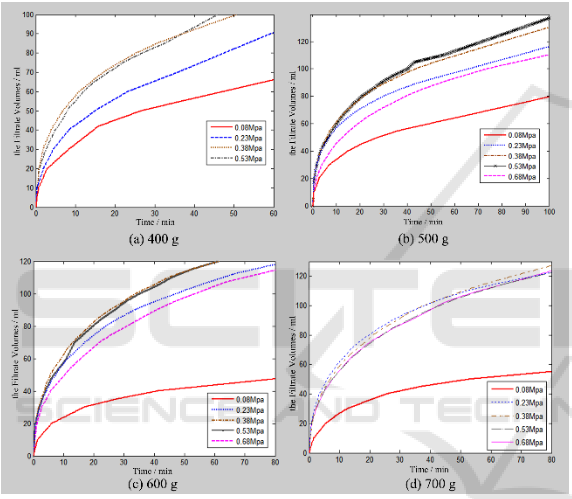

Figure 2: The relationship between time and filter of sugar mud under different pressures

It can be seen that with the increase of pressure on 400 g sugar mud, the filtrate volumes gradually increased, when squeezing 500 g sugar mud, the filtrate volumes first increased and then decreased, mainly due to excessive pressure so that the medium surface cake layer to accelerate the formation. Resulting in increased filtration resistance, and the dehydration rate decreased. When the pressure of 0.68 MPa in 600 g sugar mud, the filtrate volumes increased more than 500 g, then the formation of filter cake layer slowly. The mass increased to 700 g, the four curves approximate coincidence. Increasing the pressure has little effect, and only when the pressure was large enough to obtain more the filtrate volumes. However, there was a certain limit to dewatering and dehydration.

3.1 Filtration Resistance and Compressibility Factor

The filtration resistance shows the resistance of the unit mass of material in unit filtration area (Wan, 2007). The data was obtained by the relationship of t/v and v in Cartesian coordinates. The constant pressure filtration coefficient was obtained by linear fitting, and the specific filtration resistance was calculated by formula as shown in Table 1.

$$\alpha_{av} = \frac{2\Delta P(1-ms)}{\mu \rho s K} \quad (1)$$

In the Equation (1): v - the filtrate volume of the unit filtration area; K - the filtration coefficient of constant pressure; ΔP - pressure difference, pa ; m - wet dry ratio of filter cake; s - the concentration of solid mass; ρ - the density of filtrate, $\mathrm{g/cm^3}$; μ - the viscosity of filtrate, $pa \cdot s$;

Table 1: The filtration resistance of sugar mud under different pressures

Filtration resistance	0.23 MPa	0.38 MPa	0.53 MPa	0.68 MPa
400 g	$4.20*10^{15}$	$9.99*10^{15}$	$6.48*10^{15}$	——
500 g	$4.41*10^{15}$	$6.99*10^{15}$	$8.95*10^{15}$	$2.28*10^{15}$
600 g	$4.50*10^{15}$	$5.80*10^{15}$	$8.44*10^{15}$	$1.26*10^{15}$
700 g	$2.87*10^{15}$	$4.85*10^{15}$	$1.99*10^{15}$	$8.55*10^{15}$

The filtration ratio of the sugar mud filter cake was in the order of about $10^{15} \sim 10^{16}$, and it was a kind of difficult to filter materials. Besides, it was mainly due to the existence of sugar substance, which makes the solid particles of sugar mud exist the larger force.

Compressibility coefficient that the material under the action of external force volume changes easily, according to the size of the compressibility factor was divided into high-compression, medium-compression, low-compression and incompressibility of materials. According to the relationship between the pressure and the average filter, the logarithmic was obtained (Rushton, 2005).

$$\log \alpha_{av} = \log \alpha_0 + n \log \Delta P \quad (2)$$

In the Equation (2), the relationship between $\log \alpha_{av}$ and $\log \Delta P$ was obtained in Cartesian coordinates, and the compressibility coefficient was obtained by straight line fitting as shown in Table 2.

Table 2: The compressibility coefficient of different masses mud under different pressures

Mass/ g	400	500	600	700
Compressibility factor/ n	1.48	1.37	0.93	0.58

The compression coefficient of the sugar mud was more than 0.5, which belongs to the high-compression shrinkage material. Therefore, the sugar mud was a kind of material which was easy to be compressed but difficult to be filtered. So, the pretreatment may be appropriately performed in order to improve the dehydration rate of sugar mud.

4 THE MATHEMATICAL RELATION BETWEEN THE DEHYDRATION RATE OF SUGAR MUD WITH THE MASS AND THE PRESSURE

The Equation of Kozeny-Carman (Zhao, 2006) based on the Porseuille theory not only describes the microstructure of the filter cake, but also reveals the inherent relationships among many factors in the filtration process . The mathematical equation as

$$u = \frac{\varepsilon^3}{K_1(1-\varepsilon)^2 {S_0}^2} \cdot \frac{\Delta P}{\mu L_k} \tag{3}$$

In the Equation (3): ε - porosity; μ - average linear velocity of liquid filtration, m/s ; K_1 - the constant of Kozeny, generally taken as 5; S_0 - particle specific surface area, m^2/m^3 ; L_k - the thickness of the cake layer, m ;

In a simplified model of dehydration rate, Zhang, J. Z. (Zhang, 2015) assumed that the sugar mud was saturated material and that the solid particles were evenly distributed. The liquid phase was forced during the compression, ignoring the solid phase and the sugar mud was incompressible cake under high temperature. According to the experiment done in this paper showed that sugar mud was a highly compressible filter cake at room temperature.

Let the filter area of A, the volume of sugar mud dehydration V , the dehydration time t, the filtration rate could be expressed as

$$u = -\frac{dV}{Adt} \tag{4}$$

According to the solid phase in the filtration process remains the same principle, it was known that

$$V(1-\varepsilon) = V_0(1-\varepsilon_0) \tag{5}$$

In the Equation (5): ε_0 - the initial porosity; V_0 - the initial volume of sugar mud, m^3 ;

A differential equation with above three simultaneous equations to obtain porosity with the variation of time.

$$-\frac{d\varepsilon}{dt} = \frac{A\Delta P}{\mu K_1 {S_0}^2 (1-\varepsilon_0)V_0} \cdot \frac{\varepsilon^3}{L_k} \tag{6}$$

The porosity of the constant pressure filtration stage could be expressed as (Chen, 1993)

$$\varepsilon = 1 - \frac{M}{\rho_S A L_k} \tag{7}$$

The relationship between the mass and the volume of sugar mud in the dry state as

$$V_d = \frac{M_d}{\rho_s} = AL_0(1-\varepsilon_0) \tag{8}$$

The Equation (7) and Equation (8) were substituted the Equation (6), and got

$$-\frac{d\varepsilon}{dt} = \frac{\Delta P \rho^2{}_s A^2}{\mu K_1 {S_0}^2 m_d M} \cdot (1-\varepsilon)\varepsilon^3 \tag{9}$$

In the Equation (9): M - the mass of sugar mud, kg ; m_d - the mass of dry sugar mud, kg ; V_d - the volume of dry sugar mud, m^3 ; ρ_s - the density of the dry sugar mud, kg/cm^3 ;

The variables were solved separately.

$$\ln\frac{(1-\varepsilon)\varepsilon_0}{(1-\varepsilon_0)\varepsilon}+\frac{\varepsilon_0-\varepsilon}{\varepsilon_0\varepsilon}+\frac{\varepsilon_0^{\ 2}-\varepsilon^2}{2\varepsilon_0^{\ 2}\varepsilon^2}= \frac{\Delta P\rho^2{}_sA^2}{\mu K_1S_0^{\ 2}m_dM}t \quad (10)$$

Saturated sugar mud porosity ratio was equal to the ratio of water content, the rate of dehydration $\lambda = m_{出}/M$, then the moisture content was

$$\eta=\frac{\eta_0\frac{1}{\lambda}-1}{\frac{1}{\lambda}-1}=\frac{\eta_0-\lambda}{1-\lambda} \quad (11)$$

In the Equation (11): η - the moisture content; η_0 - the initial moisture content; $m_{出}$ - the dehydration mass of sugar mud;

After the simplification, the relationship between the dehydration rate of sugar mud and time under different mass and pressure was obtained

$$2\lambda(\eta_0-\eta_0^{\ 2})-\lambda^2(\eta_0^{\ 2}+1)= \frac{\Delta P\rho^2{}_sA^2}{\mu K_1S_0^{\ 2}m_dM}t \quad (12)$$

5 CONCLUSIONS

(1) In the pressure range of this experiment, the average filtration ratio of sugar mud filter cake was in the order of $10^{15}\sim10^{16}$. It was difficult to filter materials. And it was mainly due to the existence of sugar substance, which makes the solid particles of sugar mud exist the larger force.

(2)The coefficient of the compressibility of the sugar mud was more than 0.5, which belongs to the high-pressure shrinkage material.

(3) On the basis of reasonable assumptions, the sugar mud was determined as a high compression material. And the relationship between the dehydration rate of the sugar mud and the change of time under different mass and pressure was deduced.

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