SEPARATION AND DEWATERING OF BIOLOGICAL MICROPARTICLES FROM LOW CONCENTRATED SUSPENSIONS BY USING THE ENERGY EFFICIENT THIN FILM FILTRATION

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ABSTRACT

The cake filtration is considered to be a low cost process for the continuous separation of inorganic and organic particles and also provides a very gentle product treatment. The continuous sedimentation in the centrifugal field or the precoat filtration on a vacuum drum filter is currently used for the separation of biological microparticles. Separation in a centrifugal field with a low density difference between the particles and the continuous phase requires a high centrifugal force to achieve the desired separation efficiency. Therefore a large amount of energy is required to accelerate the suspension. An alternative separation method for biological microparticles would be the cake filtration, but this method however causes a high filter cake resistance.

The aim of this project is to develop a continuous thin film filtration method for the cake filtration. In order to realize this, microporous membranes with pore diameters ranging from 0.1-1 µm will be used. Besides the advantage of a particle free filtrate, using these semipermeable membranes will result in a filtration without any gas flow rate. These semipermeable membranes are permeable for liquids but will block the gas flow. Concerning this the characterization of the pore size distribution and the capillary pressure of those membranes are necessary. To determine the cake filtration resistance and the filter medium resistance at different pressures and different concentrations of particles in the suspension, a pressure filter device will be used. Measuring the dry mass can provide information about the dewatering efficiency of this process and allows a comparison of the different membranes at various experimental conditions and filtration resistances.

KEYWORDS

Cake filtration, thin film filtration, membrane filtration, biological microparticles, algae, yeast

The concept of the cake filtration is based on the layer of the particles which build a bridge above a pore of the filter cloth. The following particles in the suspension cannot pass this layer and the following particles start to build higher layers [1]. However the use of filter cloths can have negative effects. The large pore sizes of the filter cloths allow a high gas flow, which will reduce the efficiency of this process since the vacuum pump will need to maintain the pressure for the filtration. Furthermore the use of filter cloths will also lead to a product loss. Before building a particle bridge the particles in the suspension can easily pass the pores. Only after building a stable particle bridge above the pore the particles will be hindered and the filtrate will become clear. As an alternative, membranes can be installed, which will stop the gas flow (Figure 1). Once hydrophilic membranes are wetted with water they will only be permeable for liquids unless a larger pressure than the capillary pressure of the largest pore of the membrane is applied.

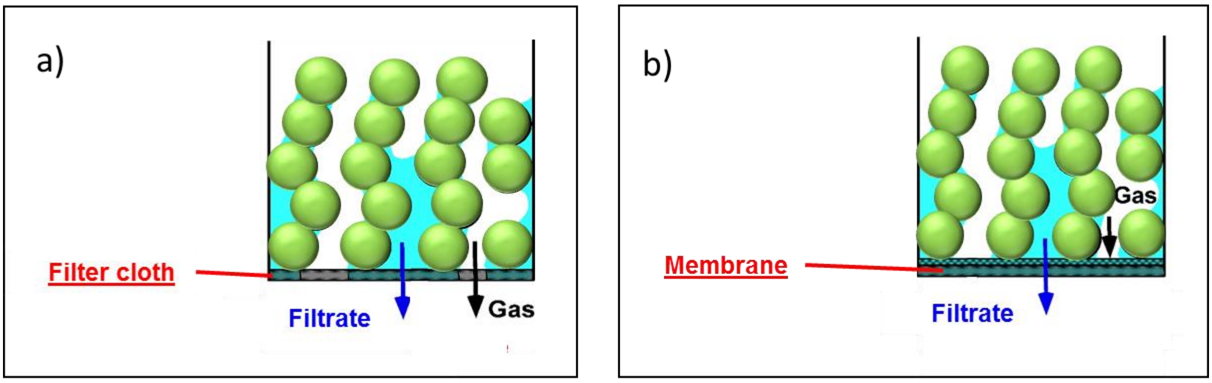

Figure 1: a) Gas permeable filter cloth; b) hydrophilic and semi-permeable membrane

To determine the applicability of the different membranes for the cake filtration, the capillary pressures (bubble point) and the pore size distribution will be measured. A porosimeter can test the bubble point as well as the pore size distribution of the membrane. By doing so it can be ensured that there is no gas flow during the filtration process.

The largest pore size of the membrane can be calculated by using the equation from Young-Laplace (Eq. 1). The pore size D of the Young-Laplace equation is derived from the interfacial tension γ, the contact angle θ and the porosimeter intrusion pressure Δp.

$$D = \frac{4 \cdot \gamma \cdot \cos(\theta)}{\Delta p} \qquad \text{(Eq.1)}$$

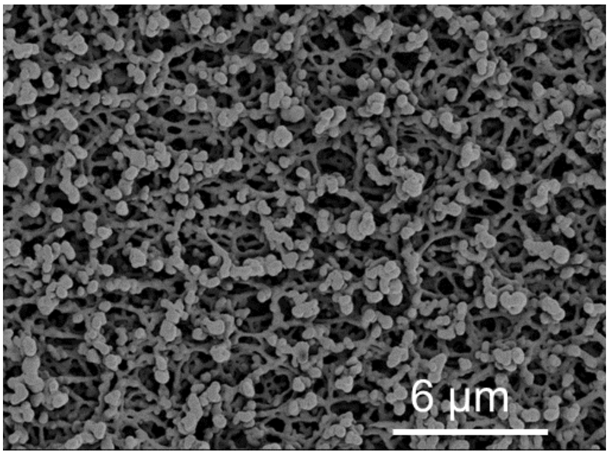

Figure 2: SEM picture of the 0,2 µm polyethersulfone membrane.

In Figure 3 the bubble points of the different polymer membranes are shown. Following the Young-Laplace equation (Eq. 1) the bubble point pressure is higher when the pore size is smaller. For the vacuum filtration a bubble point of 80 kPa would be enough to prevent the gas flow. As in Figure 3 can be seen all membranes which are smaller than the mean pore size of 450 nanometers have a bubble point higher than 80 kPa. So regarding the bubble point all these membranes with a mean pore size of at least 450 nm would be suitable for vacuum filtration.

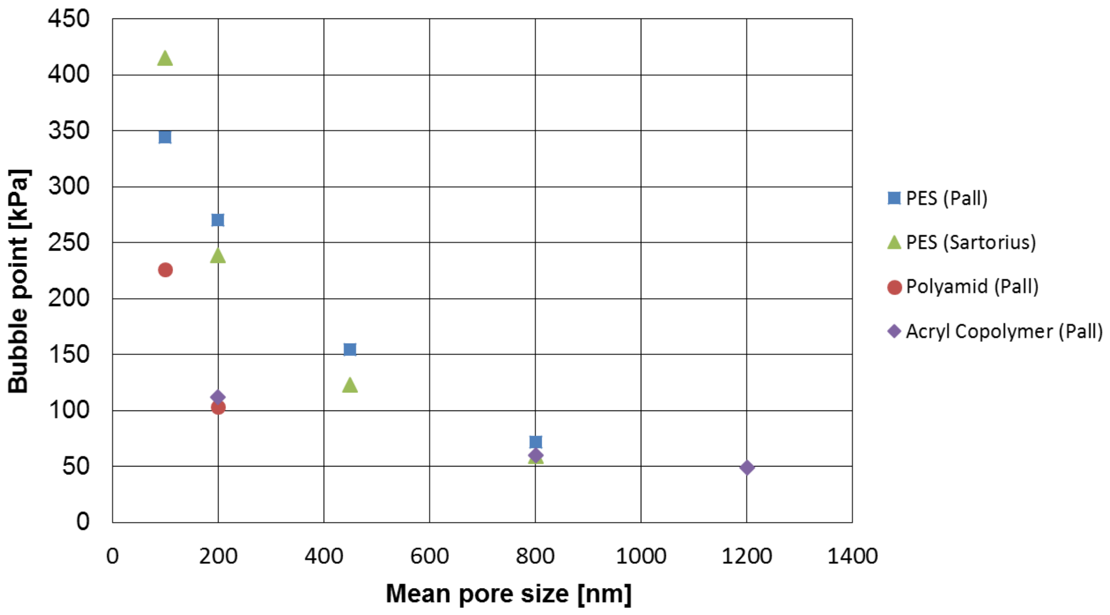

Figure 3: Bubble points of different membranes.

Another aspect for the cake filtration using membranes is the comparison of the filter medium resistance between filter cloths and membranes. If the water permeability of the filter cloth and the membrane is compared, the result will show that the water permeability of the filter cloths is much higher than the water permeability of the membranes due to their larger pores. But once the transition resistance during the cake filtration is compared, both have similar resistances, since the transition resistances depend on the particles in the suspension. Moreover the main resistance during the cake filtration is the cake itself and not the filter medium, so that the filter medium can be neglected once the cake reaches a particular height.

In this work the focus will be on the filtration of biological microparticles like for example micro algae or yeast cells. The main challenge for the cake filtration is the high filter cake resistance of these biological microparticles. To determine the filter cake resistance, the filter membrane resistance and dewatering time of the cake, a pressure filter will be used as shown below in Figure 4. Additionally different system parameters which affect the filter cake resistance like pressure, concentration of the suspension can be measured. Other system parameters like salt concentration or pH of the suspension were also investigated. After each filtration the residual moisture of the filter cake was measured by drying it in the oven.

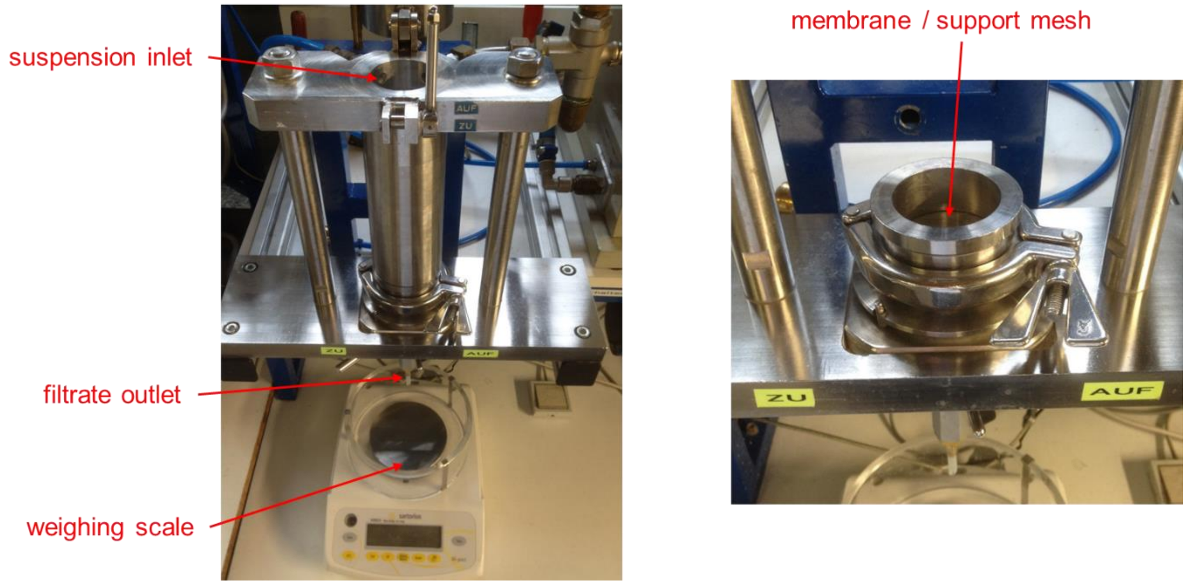

Figure 4: Pressure filter with weighing scale

One problem of the thin film filtration with membranes is the removal of the filter cake after the filtration. Since the filter cake of biological microparticles is pasty it will stick to the membrane. Using a knife to discharge the cake would be not possible since it damages the membrane. As a solution a roll will be used to remove the filter cake from the membrane. A special device that allows controlling the speed and the strength of the roll is shown below in Figure 5. A roll is pressed on the filter with weights. An electric motor rotates the roll and the filter plate can move with an adjustable speed. The filter plate is connected to a vacuum pump. During the discharge with the roll a certain vacuum can be applied to the filter plate to avoid the rewetting of the filter cake.

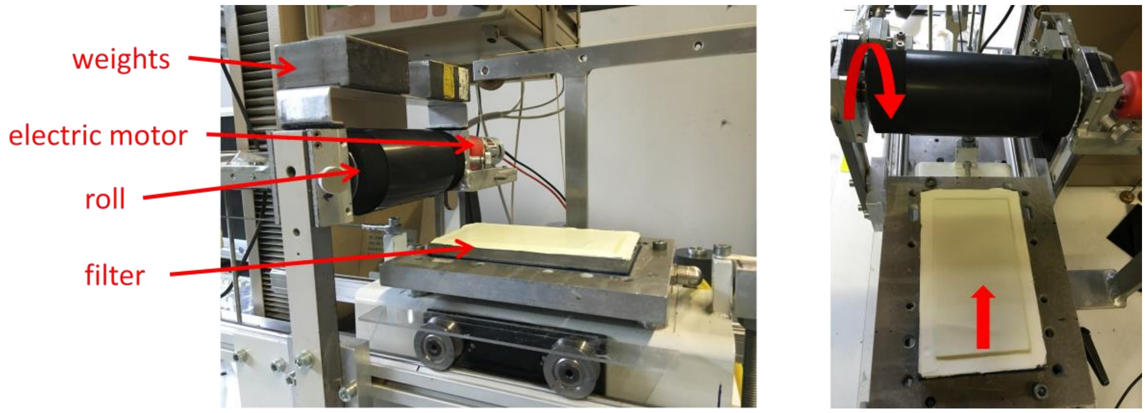

Figure 5: Roll discharge of the filter cake

The rewetting of the filter cake during the roll discharge is a problem which must be considered. If the vacuum of the filter plate is too high the filter cake cannot stick to the roll and will stay on the membrane. But if the vacuum on the filter plate is too low the rewetting of the filter cake turns the cake into a pasty consistency and thus the filter cake cannot be discharged from the membrane as well.

As a conclusion the cake filtration using membranes is a good option to separate and dewater some types of microalgae and yeast. It is suitable for particles with a high filter resistance. The use of membranes can definitely stop the gas flow at certain filtration pressures and avoid a turbid filtrate.

References

[1] T. Weigert, Haftung von Filterkuchen bei der Fest/Flüssig-Filtration. Fortschrittberichte VDI, Reihe 3, Nr. 680, VDI Verlag GmbH (2001).