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THE EFFECT OF MICROPARTICLES FOR THE MEMBRANE RESISTANCE

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Abstract

The aim of this study was to examine the applicability of bakelite particles for the reduced of the cake layer. Formation of a cake layer on the membrane surface has a decreasing effect on the long-term behaviour of the system. A typical cake layer shows compaction, which causes decrease in the porosity of the cake layer. One alternative approach to reduce fouling is to enhance the local shearing near the membrane surface, thereby increasing mass transfer of accumulated compounds back into the feed bulk. Ways of increasing the local shear rate near the membrane surface is use of scouring particles.

Keywords:
microfiltration, microparticles, shearing

1. INTRODUCTION

Pressure-driven membrane separation processes (microfiltration, ultrafiltration, nanofiltration and reverse osmosis) are important and attractive alternative candidates to conventional wastewater treatments for purification of wastewater and surface water [1], because of their high removal efficiencies and also because it allows reuse of the treated water or some of the valuable waste constituents [2]. The pressure-driven membrane techniques present several advantages: the permeate purified usually has a great quality, the processes are easy to operate with moderate temperatures and low energy requirements in general, no chemicals are needed, and combination with other separation processes is easy due to modular construction. In these processes, the water passes through the membrane and contaminants are removed by various mechanisms mainly depending on the pore size. Generally, microfiltration membranes have pores ranging from 0.1 to 10 μm and operate at pressures below5 bar [3]. They are useful for the removal of suspended solids, emulsified components and microorganisms larger than the pore size. Crossflow microfiltration is widely used in concentrating, purifying or separating macromolecules, colloids and suspended particles from solution.

Among the numerous applications of cross-flow microfiltration in the food processing industry. However, industrial applications of this technology meet two main problems. Permeate flux in microfiltration processes decreases with time as the retained particles accumulate on the membrane [4].

Membrane fouling is a very complicated phenomenon mainly caused by adsorption of particles, pore shrinkage and blockage, deposition of particles on the membrane surface and concentration polarization [5], and it is the irreversible alteration in the membrane caused by specific physical and/or chemical interactions between the membrane and various components [6]

The build-up of the filter cake increases the cake-layer resistance to flow, thereby it reduces the filtration flux rate, decreases the longevity of the membrane modules and increases the cost of production and limits the further industrial application to membrane microfiltration technology. Hence, how to alleviate the thickness of filter cake on the membrane surface is still a focus and key technology in membrane field and many various techniques have been suggested, such as turbulence promoting inserts, rotating. [7]. One alternative approaches to reduce fouling are discussed here. The local shear increase near the membrane surface, thereby increasing mass transfer of accumulated compounds back into the feed bulk. Ways of increasing the local shear rate near the membrane surface is use of scouring particles (bakelite) [8].

2. MATERIALS AND METHODS

Solution preparation

40 g bakelit particles were added into the 20l chulk-dust solution to prepare suspensions. We were added 125-160 μm, 160-200 μm and a 200-400 μm size bakelite. The prepared suspension was well mixed and was pumped into the cross-flow system by using a circulation pump. The suspension concentrations are 0.2, wt%.

Microfiltration experiments

The cross-flow microfiltration (MF/K1) unit used is represented in Fig. 1. It featured a tubular ceramic membrane, with the following attributes: 19 channels with an internal diameter (*d*=2.5 mm), average pore size diameter (0.45 μm), and a total effective filtration area (*A* = 0.125 m²). Temperature was controlled, using cold water circulating through a tubular heat exchanger (H). Operating temperature was adjusted to 25±2 ◦C. The cross-flow velocity was adjusted and measured by a rotameter (R). The filtration pressure was adjusted by the control valves (14,17) and was measured using the pressure indicators (PI/1, PI/2). TMPs were varied at 100, 150, 200, 250, 300 kPa to determine TMP-dependent changes in permeate recycle of cross-flow filtration. The crossflow velocities are 2, 4, 6, 8, 10, 12 in this study. The Reynolds number is about 1500–5500. The concentrated chalk-dust solutions were recycled back into the suspension tank.

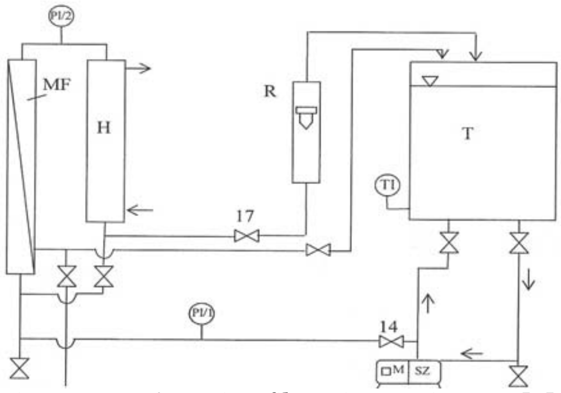

Figure 1. MF/K1 microfiltrtation equipment [9]

Before each experiment, the water flux was measured with destillated water at 20 ◦C. Membrane regeneration was achieved by washing in a 10gL⁻¹ NaOH solution and rinsing with distilled water under flux. A classic industrial cleaning procedure is carried out and followed by another determination of the clean membrane resistance:

$$J_W = \frac{\Delta p_{TM}}{\eta_W \cdot R_M} \quad (1)$$

where J is the permeate flux rate (m s^{-1}) and Δp_{TM} is the transmembrane pressure (Pa). The resistance (R_M) of the membrane was calculated from the flux using:

$$R_M = \frac{TMP}{\eta_W \cdot J_W} \quad (2)$$

where η_W is the dynamic viscosity of water (Pa s). The membrane resistance at a TMP of 100 kPa was 1.16.±0.21×10^{11} m^{-1}.

The total resistance (R_T) is calculated as:

$$R_T = R_M + R_{Cake} \quad (3)$$

where R_M is the membrane resistance and R_{Cake} the cake-layer resistance [10].

For the Re numbers, the following equation is used:

$$Re = \frac{d_e \cdot v \cdot \rho}{\eta} \quad (4)$$

where d_e is the equivalent pipe diameter, the v is the velocity, the ρ is the density and the η is the viscosity [11].

3. RESULTS AND DISCUSSION

The relation between flux and TMP was measured for the different particles used in chulk-dust solution. The results are presented in Fig. 2.

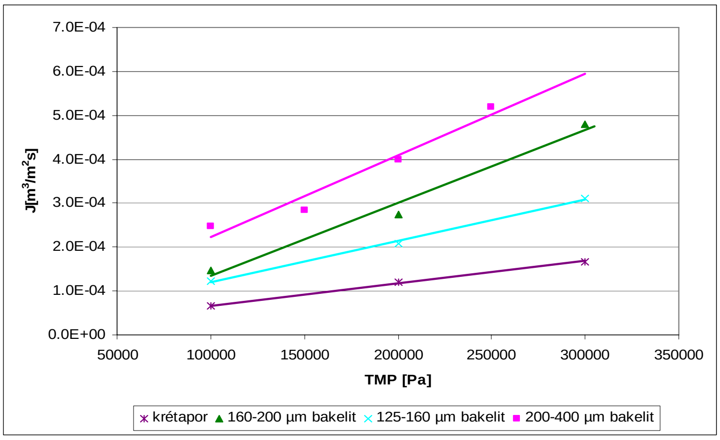

Figure 2. Flux change on the different TMP

There is a linear relationship between the flux and the transmembrane pressure difference at each case. The fluxes of the culk-dust solution are always lower than the bakelite solution because of the bakelite particles cause turbulence on the surface of the membrane. Due to the greater shearing on the membrane surface the cake layer resistance reduced and the molecules of the solvent can go easier though the membrane pores. I measured the lowest fluxes with the 125-160 µm size bakelite. The increasing of the diameter of particles caused increasing in the flux. I received the best fluxes with the 200-400 µm size bakelite, so here was the largest the shearing force.

We examined the hydrodynamic effect and we calculated the Re numbers. Increasing of Re numbers caused increasing of the permeate flux as well (Figure 3.).

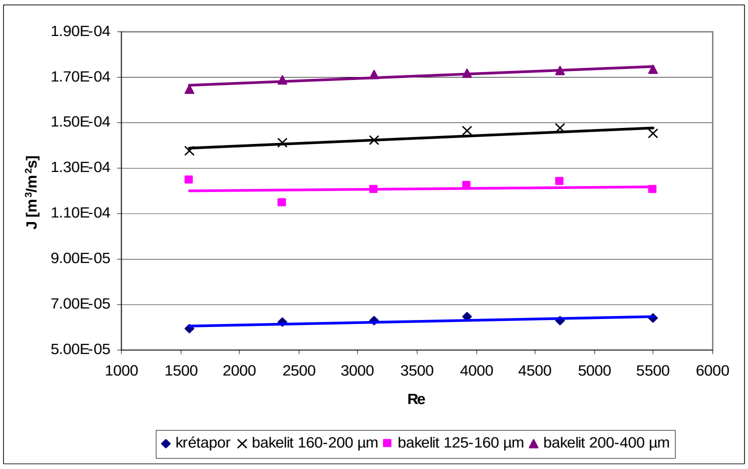

Figure 3. The measured fluxes vs. Re numbers

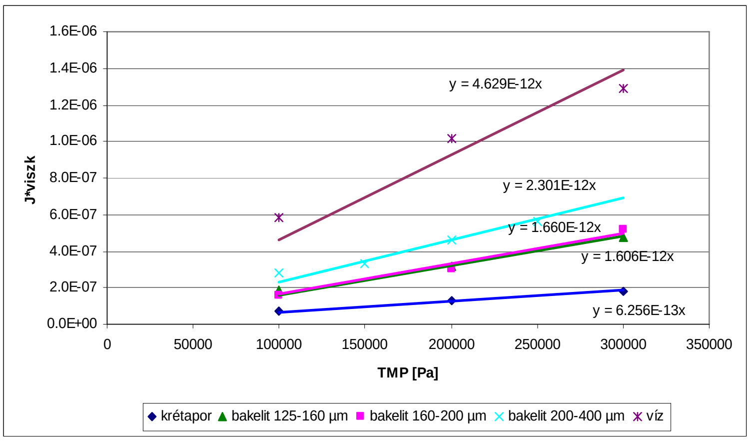

Figure 4. The total resistance (R_T) determination by fitted lines

The fluxes of the culk-dust solution are the lowest. The Re number values are into the laminar and transitional range, but the bakelite particles caused local turbulence on the surface of the membrane, that show the higher flux values. From the slopes of the lines according to Eqs. (5) the total resistance (R_T) at the end of the process can be calculated (Figure 4.).

$$J \cdot \eta = \frac{1}{R_T} \cdot \Delta p_{TM} \tag{5}$$

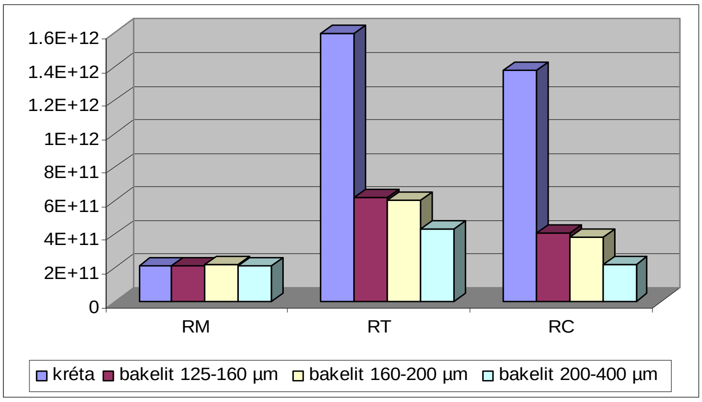

Figure 5. The comparison of resistance values

In the Figure 5 we can see, that the total resistance and the cake resistance are significant higher with the chulk-dust solution. The total resistance is the lowest with the 200-400 µm size bakelite, so these particles made the highest shearing force on the membrane surface, so decreased the thickness of the cake. The membrane resistance values are similar in all cases, because the membrane purification was efficient.

4. CONCLUSIONS

This work reports new results in the alternative approach to reduce of fouling. The use of bakelite can improve the performance of membrane processes. Introducing scouring particles seems very beneficial some microfiltration processes using conventional equipment. The bakelite enhances the local shear near the membrane surface. This approach has been successful in increasing fluxes of microfiltration. The larger particles induce much higher shear-induced diffusion and therefore dramatically improve mass transfer. The shear force is dependent on the square of the particle radius. Increasing size of bakelite was associated with an increasing flux. The total and the cake resistance were significant higher with the chulk-dust solution than with the bakelite. So the bakelite particles decreased the resistance of the filtration.

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