UTILISING PARTICLE-LIQUID INTERFACIAL PHENOMENA TO AUGMENT CROSSFLOW MICROFILTRATION

[1]R.J. Wakeman and [2]E.S. Tarleton (e.s.tarleton@lboro.ac.uk)
[1]Separation Processes Centre, University of Exeter, North Park Road, Exeter, EX4 4QF, UK.
[2]now at Department of Chemical Engineering, Loughborough University, Loughborough LE11 3TU, UK.

ABSTRACT

Results from an experimental study of field assisted crossflow microfiltration are presented. Both electric and ultrasonic fields, either in isolation or in combination, can reduce membrane fouling by utilising particle-liquid interfacial phenomena. Synergistic effects were observed when the fields were applied simultaneously. Lower crossflow velocities can be utilised when force fields are employed, implying that pumping costs, heat transfer in recirculation loops, and the degradation of shear sensitive streams can be substantially reduced.

INTRODUCTION

Suspensions containing a proportion of colloidal material are difficult to separate due to the combined influence of fine particle size and the surface forces at the solid/liquid interface. Whilst membrane techniques such as crossflow ultra- and micro- filtration, where the bulk suspension flow is tangential to the filtering medium, are successfully used in many industries the phenomenon of membrane fouling remains a problem that prevents their more widespread use. Accumulation of macromolecular and finer particulate material at the septum during filtration can cause rapid flux decline and unacceptably low separation rates. Although mechanical techniques such as backflushing can be used to (partially) clean fouled membranes, the utilisation of particle-liquid interfacial phenomena through imposed force fields to augment filtration could provide an attractive solution to the fouling problem[1-5]. This paper presents results from an experimental study examining the influence of imposed electric and ultrasonic force fields on crossflow microfiltration. The technique utilises the particle surface charge to prevent the formation of fouling layers at the membrane surface. It is the subject of an on-going investigation which has been extended to include fouling by molecular matter.

MICROFILTRATION EXPERIMENT RESULTS AND DISCUSSION

The experimental rig used to assess the effectiveness of electric and ultrasonic fields in microfiltration has been described previously[5], and has been further developed for UF studies. The experimental programme identified the principal process and suspension characteristics which most affect the field assisted microfiltration of aqueous streams - applied field strengths, acoustic frequency, suspension concentration, liquid viscosity, particle size and particle surface charge all influence membrane fouling to an extent dependent on their relative magnitudes[1-5]. Both individual electric and ultrasonic fields reduced membrane fouling over a range of process conditions, induced by electrokinetic effects, such as electrophoresis and electroosmosis, and cavitation.

The extent of flux improvement when using a DC field is dependent primarily on particle size, the magnitude of the imposed field gradient and the particle surface charge. The latter is closely associated with the environment around the particle surfaces and can be tailored such that flux levels are significantly improved. Greater flux enhancements are possible in electrofiltration for finer particles carrying higher surface charges when using steeper field gradients. Enhanced performance can be obtained at much lower crossflow velocities than those used in conventional crossflow microfilters. Crossflow velocities of 0.1 m s^{-1}, rather than the more normal 2-8 m s^{-1}, can

Cite paper as: Wakeman R.J. and Tarleton E.S., 1993, Utilising particle-liquid interfacial phenomena to augment crossflow microfiltration, *Proc. IChemE Research Event*, pp.537-539, IChemE, Birmingham.

be used to advantage[5]. The potential advantages are reduced pumping costs, less heat input into the process stream, and the improved possibilities of processing shear sensitive streams, albeit at the expense of the energy input required to generate the electric field.

An ultrasonic field, in the absence of an electric field, can reduce particulate fouling. By increasing the intensity of the ultrasound field (expressed as a power density gradient W cm^{-2} cm^{-1}) filtrate flux improvements up to an order of magnitude could be achieved. The gradient was varied by using an ultrasonic source with a fixed power output and changing its separation distance from the membrane surface. Many factors influence the operation. Although flux enhancements may be produced with crossflow velocities near to 0.1 m s^{-1}, higher ultrasonic frequencies, suspension concentrations, suspension viscosities and the presence of larger size particles in the feed stream reduce the effectiveness of the ultrasound[5]. Alterations to the surface chemistry of the particles in suspension can influence the flux enhancements achievable[3]. Near to the suspension iso-electric point and the point of maximum surface charge less flux improvement seems to occur with ultrasound; the reasons for such behaviour are unclear.

Figure 1 shows the contributions of each field to combined field filtration. Both electric and ultrasonic fields were seen to reduce fouling when applied individually, but the extent of improvement by the ultrasonic field could be minimal when the feed stream concentration was higher. The improvement by the electric field was usually greater than that due to the ultrasonic field, particularly when the particles were well dispersed. When the electric and ultrasound fields were applied simultaneously a synergistic interaction occurred whereby flux levels were above those which could be expected from the simple addition of the flux improvements due to the individual fields. The synergy seemed greater with the more problematic suspensions and in particular at higher feed concentrations (tests were performed with concentrations up to 10.1% by weight).

The data illustrate the large flux increases achievable when electric and/or ultrasonic fields are used to aid microfiltration. However, to increase the filtration rate is not a sufficient criterion by which to assess filter performance. The energy consumed in achieving that rate is equally as important.

Table 1 gives a breakdown of the power consumptions for two groups of tests. The data indicate the contributions to the power consumed by the filter system for the pump used to provide the crossflow, the constant voltage (50 V cm^{-1}) DC field and the 23 kHz (1.7 W cm^{-2} cm^{-1}) ultrasonic field. The power input figures are quoted per unit membrane area; the energy consumed is expressed per unit volume of filtrate. Experiments performed with no imposed force fields employed a crossflow of 2.3 m s^{-1} (for comparison purposes), whereas the assisted filtrations used 0.1 m s^{-1}. While the data highlight that actual power inputs with imposed fields were in all cases higher than the corresponding tests with no fields, the energy required to produce a unit volume of filtrate could be decreased significantly for both anatase and china clay suspensions. The time taken to extract a unit volume of filtrate from each suspension was reduced with the combined fields by x18 and x10 respectively.

No attempt has been made to minimise the power consumed by either the electric or ultrasonic fields. It is considered that the energy consumed by the electric field could be reduced by 25 to 30%, and that consumed by the ultrasonic field by factors somewhat larger.

CONCLUSIONS

Whilst some of the observations in the experiments are difficult to interpret theoretically due to the complexity of the interactions the effects generated during assisted filtrations are substantial. Such effects were observed with a range of suspensions having different particle size, shape and surface properties, viscosity and feed concentration. The ability to prevent membrane fouling

Cite paper as: Wakeman R.J. and Tarleton E.S., 1993, Utilising particle-liquid interfacial phenomena to augment crossflow microfiltration, *Proc. IChemE Research Event*, pp.537-539, IChemE, Birmingham.

using imposed force fields offers the potential advantage of improved separation rates at reduced pumping costs. Preliminary comparisons of the energy requirements for conventional and field assisted microfiltrations indicate that lower overall power consumptions can be achieved with the latter. The reduced pumping requirement has practical implications concerning the processing of shear sensitive feed streams, which will suffer less degradation by the recirculation pumps and require less heat exchange area for cooling in batch systems.

REFERENCES

1. Wakeman R.J. and Tarleton E.S., 1986, *Chem. Eng. Sci.*, **42**, 829-842.

2. Tarleton E.S., 1986, *PhD Thesis*, University of Exeter.

3. Tarleton E.S., 1988, *Filtration & Separation*, **25**(6), 402-406.

4. Tarleton E.S. and Wakeman R.J., 1990, *Filtration & Separation*, **27**(3), 192-194.

5. Wakeman R.J. and Tarleton E.S., 1991, *Chem. Eng. Res. Des.*, **69**(A5(A)), 386-397.

ACKNOWLEDGEMENTS

The authors wish to acknowledge receipt of grants from the Specially Promoted Programme in Particulate Technology of the Science and Engineering Research Council in support of this work, and of additional support from the company members of the Separation Processes Centre at Exeter University.

Cite paper as: Wakeman R.J. and Tarleton E.S., 1993, Utilising particle-liquid interfacial phenomena to augment crossflow microfiltration, *Proc. IChemE Research Event*, pp.537-539, IChemE, Birmingham.

FIGURES AND TABLES

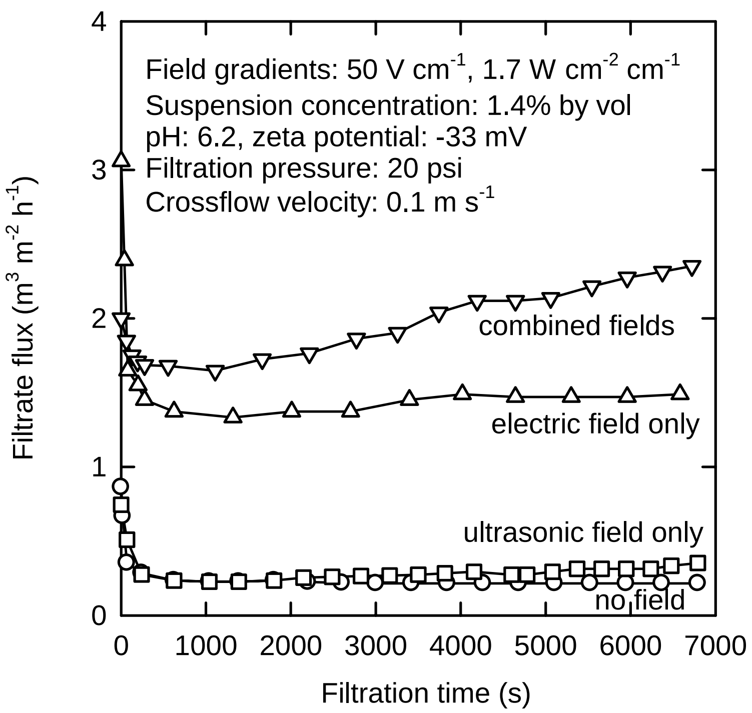

Figure 1: Synergy between electric and ultrasonic field in the filtration of china clay suspensions.

Process conditions	Power inputs to system, pump + electric + ultrasonic field (kW m^{-2})	Energy input per unit volume of filtrate (kWh m^{-3})	
no fields	19.6 + 0 + 0 = 19.6	39.3	1.4% v/v china clay suspensions
electric field only	0.02 + 9.1 + 0 = 9.12	6.1	
ultrasonic field only	0.02 + 0 + 24.9 = 24.92	62.3	
combined fields	0.02 + 13.0 + 24.9 = 37.92	16.5	
no fields	19.6 + 0 + 0 = 19.6	89.1	2.8% v/v anatase suspensions
electric field only	0.02 + 93.9 + 0 = 93.92	132.3	
ultrasonic field only	0.02 + 0 + 24.9 = 24.92	113.3	
combined fields	0.02 + 124.7 + 24.9 = 149.62	33.9	

Table 1: Power consumptions during augmented microfiltrations.

Cite paper as: Wakeman R.J. and Tarleton E.S., 1993, Utilising particle-liquid interfacial phenomena to augment crossflow microfiltration, *Proc. IChemE Research Event*, pp.537-539, IChemE, Birmingham.