# CROSSFLOW ELECTROACOUSTIC SEPARATIONS

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## ABSTRACT

Experimental data are presented to show how imposed force fields can reduce flux decline during the crossflow microfiltration of aqueous, mineral based suspensions. Both electric and ultrasonic fields, employed individually or in combination, help prevent particle accumulation at the separating surface. This allows fluid removal rates an order of magnitude higher than those obtained in comparable tests without imposed force fields to be achieved. Such process intensification is demonstrated to have the added benefits of lower overall power requirements, reduced pumping requirements and smaller filtration areas.

## INTRODUCTION

Many suspensions containing a proportion of colloidal material are difficult to process by conventional filtration due to the combined influence of fine particle size and the surface forces generated at the solid/liquid interface. Whilst membrane techniques such as crossflow ultra- and micro- filtration can be successfully employed, their more widespread use is often restricted by unacceptably low separation rates brought about through the accumulation of macromolecular and finer particulate material at the septum during filtration. In the past practitioners have attempted to alleviate fouling and particle deposition by utilising high crossflow velocities, often in conjunction with large trans-membrane pressures. The limited success of these rather crude, and potentially very expensive, techniques has led researchers to examine alternative, crossflow based, methods for separating colloidal material more efficiently[1-4].

In this paper experimental data are presented which show that applying process intensification principles to crossflow filtration, allows the dual advantages of improved separation rates and reduced pumping costs to be realised. Comparisons of the energy requirements for conventional and field assisted microfiltrations indicate that lower overall power consumptions are often achieved with the latter. Moreover, the reduced pumping requirement has practical implications concerning the processing of shear sensitive feed streams which undergo less degradation by the recirculation pump and require reduced cooling in batch systems.

## EXPERIMENTAL PROCEDURES

The experimental apparatus used in the investigation has previously been described in detail[1]. Essentially the apparatus comprised a flow loop around which an aqueous, mineral based suspension of known and essentially constant composition was pumped continuously through a planar geometry microfilter at a fixed crossflow velocity and trans-membrane pressure. The filter was designed with integral electrodes to provide an electric field gradient across the 38 $cm^2$ polymeric membrane and generators in contact with the flowing suspension, positioned opposite the filtering membrane, allowed ultrasonic waves to impinge upon any membrane deposits.

Experiments were performed with well characterised suspensions of anatase, calcite and china clay dispersed in double distilled water. The matrix and range of properties investigated are shown in Table 1.

## RESULTS

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Field assisted crossflow filtration requires the addition of electric and/or ultrasonic field(s) to enhance the removal of the liquid phase from the challenge stream. The technique utilises the presence of interfacial phenomenon such as particle surface charge and helps to prevent particulate deposition at the membrane surface(s). Figures 1 and 2 show the typical results of applying electric and ultrasonic force fields in crossflow microfiltration. It is apparent that both individual electric and ultrasound fields can reduce membrane fouling over a range of process conditions; this being principally induced by electrokinetic effects and cavitation respectively. The reduction in particulate fouling was found to be dependent on parameters such as imposed field strength, suspension concentration and the surface properties of the dispersed phase. The increased filtration rate, which resulted from less particle deposition at the membrane surface(s), could be in excess of an order of magnitude higher than a corresponding experiment without an imposed field. Furthermore, such results could be obtained using crossflow velocities very much lower than those commonly employed in conventional microfiltration and typically in the region of 0.1 m $s^{-1}$. When electric and ultrasound fields were applied simultaneously during an experiment a synergistic interaction was observed, particularly when higher suspension concentrations were used. This resulted in filtration rates above those which could have been expected by simply adding the effects of the individual fields.

The experimental data shown illustrate the large flux increases which can be obtained when force fields are used to aid crossflow microfiltration. However, such process intensification is not justifiable unless the increased flux can be achieved at sufficiently low energy inputs. Figure 3 gives an indication of the power requirements for the imposed field test data presented in Figures 1 & 2 and some comparison experiments using similar suspensions, no force fields and crossflow velocities of 2.3 m $s^{-1}$. Whilst it should be realised that 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. Moreover, the time taken to extract a unit volume of filtrate from each suspension was reduced by x18 and x10 respectively when combined electric and ultrasonic fields were applied.

## CONCLUSIONS

The experimental data presented in this paper illustrate that the process intensification of crossflow filtration using imposed force fields is potentially viable. Although the data are encouraging they should be viewed in the light that to date little attempt has been made to minimise the power consumed by either the electric or ultrasonic fields. There is probably an optimum balance, which is specific to each application, between increasing the rate of separation and the added cost of the energy required to generate the field(s). If it proves possible to further reduce power input levels, and preliminary experiments indicate that this is possible, then field assisted filtration will compare even more favourably with conventional crossflow filtration, particularly for ‘difficult to filter’ and ‘higher value’ suspensions.

## ACKNOWLEDGEMENTS

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**FIGURES AND TABLES**

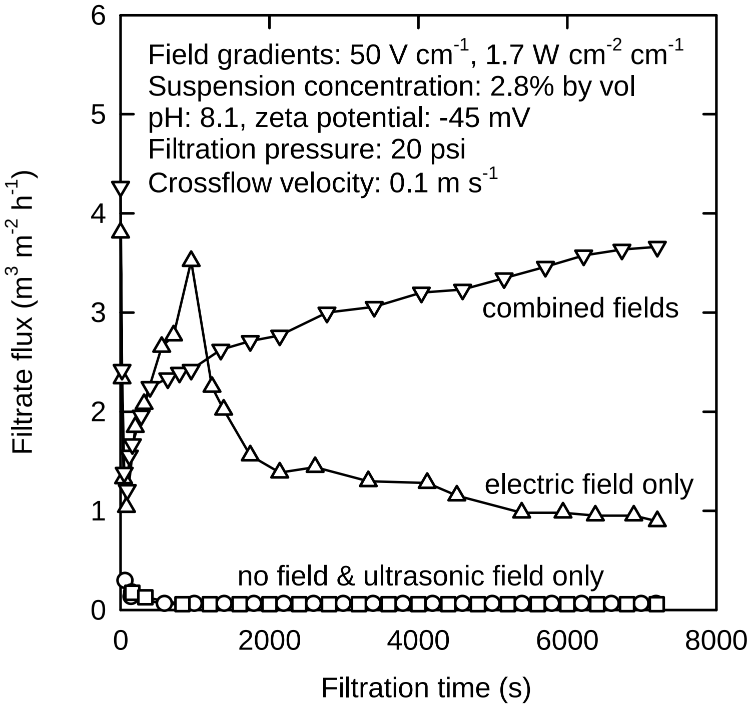


Figure 1: Effect of electric and ultrasonic fields for anatase suspensions.

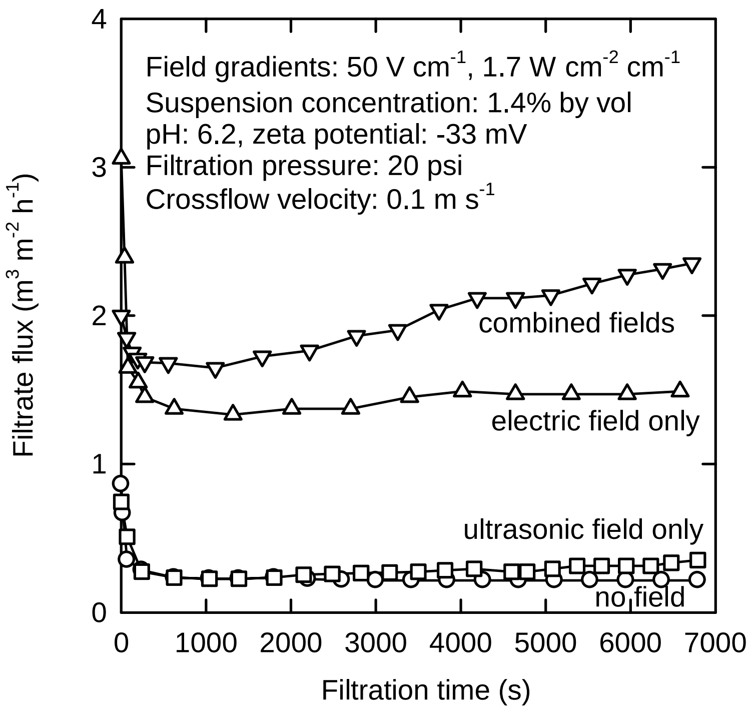


Figure 2: Effect of electric and ultrasonic fields for china clay suspensions.

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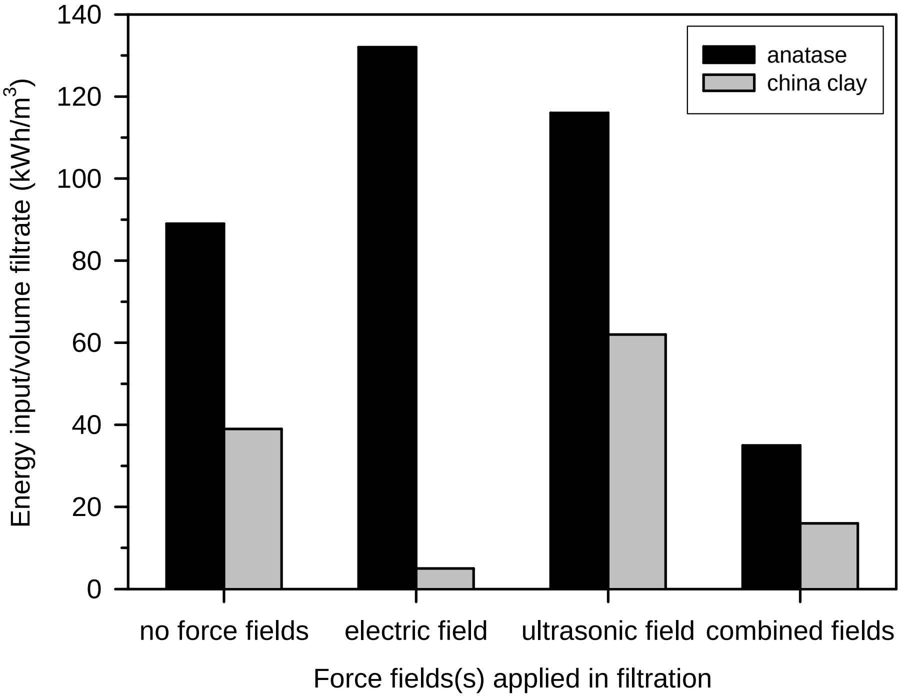


Figure 3: Energy inputs during no fields and imposed field(s) microfiltration.

| Feed stream | Membrane | Process parameters |
|---|---|---|
| 50% particle size (0.1-24 μm)<br>pH (2-11)<br>Feed conc. (0.01-5% v/v)<br>Particle shape<br><br>Mineral type | Pore rating (0.2-0.8 μm)<br>Morphology | Filtration pressure (0-350 kPa)<br>Crossflow velocity (0.1-2.3 m $s^{-1}$)<br>Electric field gradient (0-100 V $cm^{-1}$)<br>Ultrasonic density gradient (0-1.7 W $cm^{-2}$ $cm^{-1}$)<br>Ultrasonic frequency (23, 40 kHz) |

Table 1: Matrix of parameters investigated in the filtration experiments