Using chematronics to improve filtration equipment

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USING CHEMATRONICS TO IMPROVE FILTRATION EQUIPMENT

E.S. Tarleton (e.s.tarleton@lboro.ac.uk) and D.L. Hancock
Department of Chemical Engineering, University of Technology, Loughborough, LE11 3TU, UK.

ABSTRACT

Mechatronics combines the philosophies of mechanical and electrical engineering with computer technology to aid the design and control of mechanical processes. This paper will propose the concept of 'chematronics' which involves the combination of these disciplines to solve problems within chemical engineering. A non-invasive tomographic technique has been used to obtain in-situ solids concentration profiles and hence the information required to understand more closely the phenomena which occur during the pressure filtration cycle. A novel filter cell and its associated experimental rig, constructed to acquire data for the filtration, dewatering and washing phases of a filter cycle, are described along with some data obtained from filtration tests using calcium carbonate suspensions. The data serve to highlight the potential of a chematronics approach.

INTRODUCTION

During the filtration and post-filtration phases of a pressure filter cycle many, only partially understood, phenomena occur. These phenomena affect the cake formation, dewatering and washing phases of the cycle and thus the efficiency of the solid/liquid separation process as a whole. By providing carefully controlled experimental apparatus and sensing methods such as Electrical Impedance Tomography (EIT), where the resistivity distribution of an object such as a filter cake is correlated to its structure and solids concentration, a deeper understanding of the underlying mechanisms can be obtained. Such an experimental rig has been designed and commissioned and some initial experimental data are presented here.

EXPERIMENTAL APPARATUS

The principle hardware for the experimental apparatus comprised the filter cell and its associated computer driven, electronic circuitry (shown schematically in Figure 1). The 43 cm long filter cell was constructed from a 316L stainless steel tube, 150 lb class flanges and a water jacket surrounding an epoxy filled plastic (PVC) liner. The liner acted as support for sixteen rings of horizontally oriented electrodes. The first six rings above the filtering surface were equi-spaced vertically at 10 mm intervals, the next five were spaced at 20 mm intervals with the final five spaced at 30 mm intervals. Each ring comprised sixteen s/s electrodes evenly spaced around the circumference of the plastic liner. The filter cell, capable of operation at internal pressures up to 800 kPa had a filtration area of 80 cm^2 and was designed, fabricated and tested in accordance with the British Standard for unfired pressure vessels, BS5500.

To allow impedance measurements to be taken each electrode in the filter cell was able to either pass an electrical current (known as pulsed), receive a current (known as earthed) or be neither pulsed nor earthed (known as floating). The co-ordination of the electrodes was performed by computer software and a system of printed circuit boards designed with the Easy-PC^{TM} Professional CAD package. The electronic hardware, which was similar in principle to an EIT system, comprised a distribution board, sixteen daughter boards, a mimic display board and two other distribution boards which allowed data transfer through the system. Once an electrode was pulsed and another earthed, an electric current passed from one to the other. The voltage produced could be related the AC resistance (impedance) of the filtering suspension and measured using a Fairchild^{TM} PCL-812PG LabCard situated in the computer.

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The remainder of the experimental rig, which has been described in detail previously by Tarleton and Hancock[1], comprised two 5 l vessels for the storage of slurry and wash water in addition to a water bath which circulated heating/cooling water through the jackets surrounding the filter cell and storage vessels. A rotary table with twenty sample bottles allowed the collection of washings from the cell, an electronic balance facilitated the continuous monitoring of liquor transport rates and a computer driven air regulator and ball valves controlled suspension delivery. All components in contact with the feed suspension were constructed from stainless steel or plastic to prevent contamination.

RESULTS

A series of batch experiments were performed for the constant pressure filtration of 10% v/v, aqueous based, calcium carbonate (calcite) suspensions. Tarleton *et al.*[2] have shown that such calcite suspensions form only slightly compressible filter cakes during filtration and thus represent a model test system. Standard plots of cumulative volume of filtrate vs. time and time/volume vs. cumulative volume at pressures of 100-600 kPa are shown in Figures 2 & 3 respectively. The filtration end-times, where the transitions between filtration and cake dewatering occur, can be readily determined from Figure 3. For pressures of 200 kPa, 400 kPa and 600 kPa these were identified to occur at 1200 s, 560 s and 440 s respectively. Such data also show that by using computer controlled and sequenced apparatus, reliable and accurate filter cycle data can be obtained, repeatedly, without the need for excessive operator interference.

By switching series' of diametrically opposite electrodes within the filter cell, transient solids concentration profiles, and hence moisture content profiles, could be obtained throughout a chosen cycle. With the current experimental arrangement it was possible to take virtually simultaneous readings over four distinct vertical planes. Figures 4 & 5 show examples of solids concentration and moisture content profiles for a fixed pressure of 400 kPa and cycle times of 560 s and 2000 s respectively. During the cake formation stage of the cycle (up to 560 s) the scanned profiles clearly showed progressive cake growth at the filtering surface. The four independent concentration profiles measured at each time interval during this period were similar and confirmed the expected homogeneous nature of the ~110 mm deep filter cake. During the dewatering phase of the cycle, however, significant saturation profiles appeared within the cake. The saturation appeared to decrease toward the top of the cake and some separation of the scanned profiles was observed, suggesting that areas of the cake had dewatered preferentially.

CONCLUSIONS

Techniques such as EIT can provide real time information to aid the understanding of filtration and post-filtration processes. In combination with a carefully controlled experimental apparatus, accurate and comprehensive data can be readily acquired and many new avenues of research become feasible. For instance, future work should realise the ability to provide for constant pressure, constant flow and variable pressure/flow filtration tests within one experimental apparatus. Suspensions could be introduced to the filter in a consistent manner by controlling the delivery pressure. By mimicking pumping operations in this manner reliable data would be generated to allow the testing and development of computer simulations. Moreover, a chematronics approach may ultimately lead to the development of intelligent controllers for filtration equipment, whereby data are acquired in real time from within the filter system and utilised to improve overall performance. Whilst the data provided in this paper represent only an initial step towards these ultimate goals, it is hoped that the potential of a chematronics approach will provide the necessary stimuli to advance research in solid/liquid separation for many years to come.

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FIGURES AND TABLES

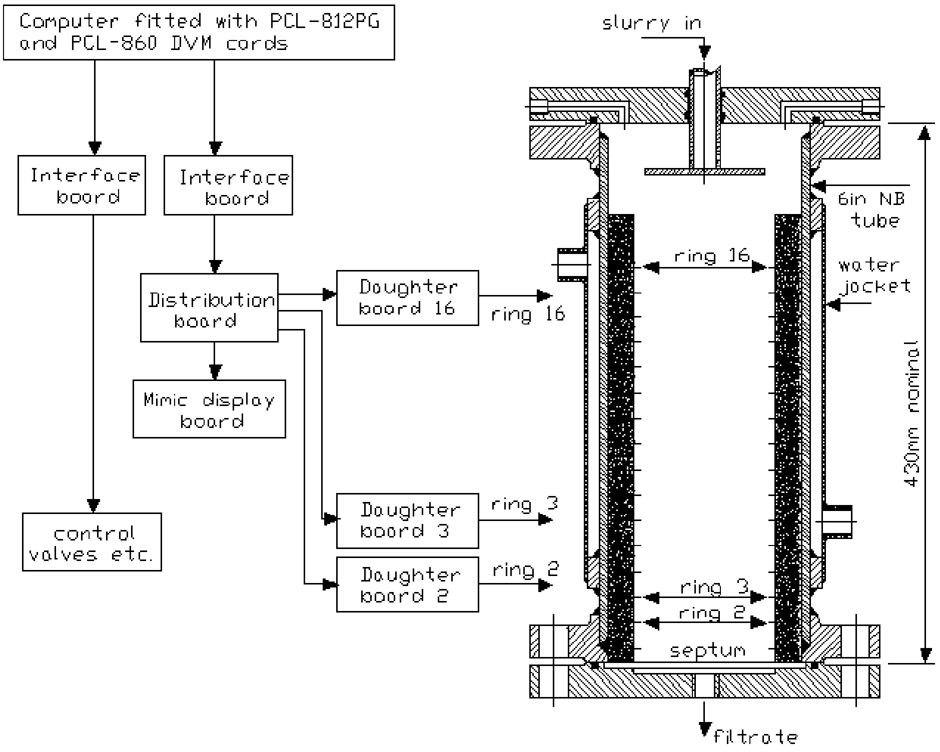

Figure 1: The pressure filter cell and a schematic of the electrode control system.

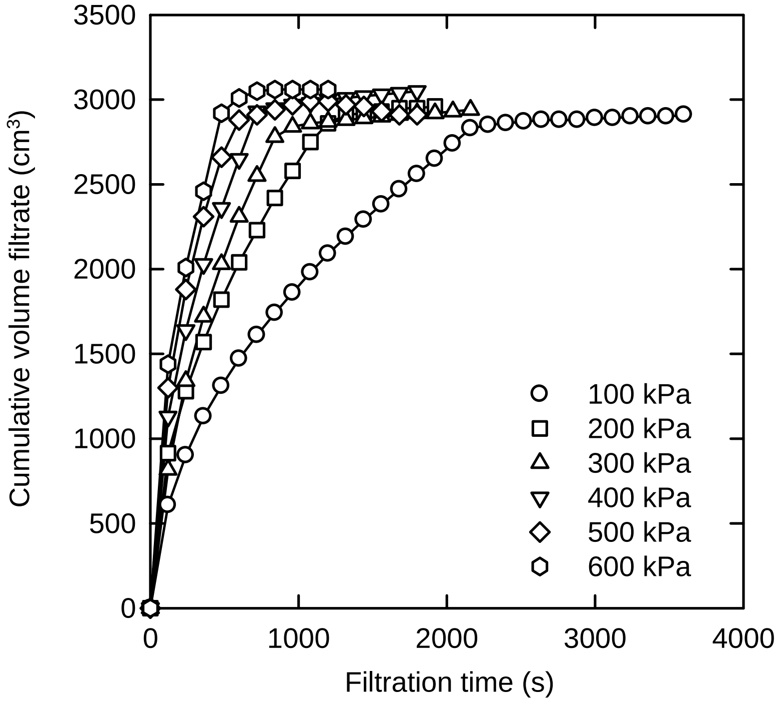

Figure 2: Cumulative volume vs. time for the filtration of 10% v/v calcite suspensions.

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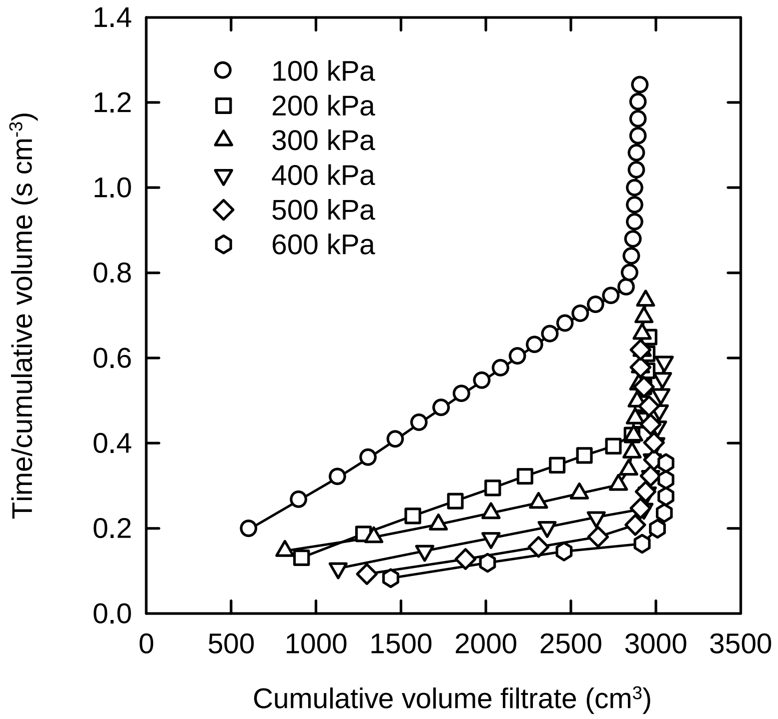

Figure 3: Time/volume vs. cumulative volume for the filtration of 10% v/v calcite suspensions.

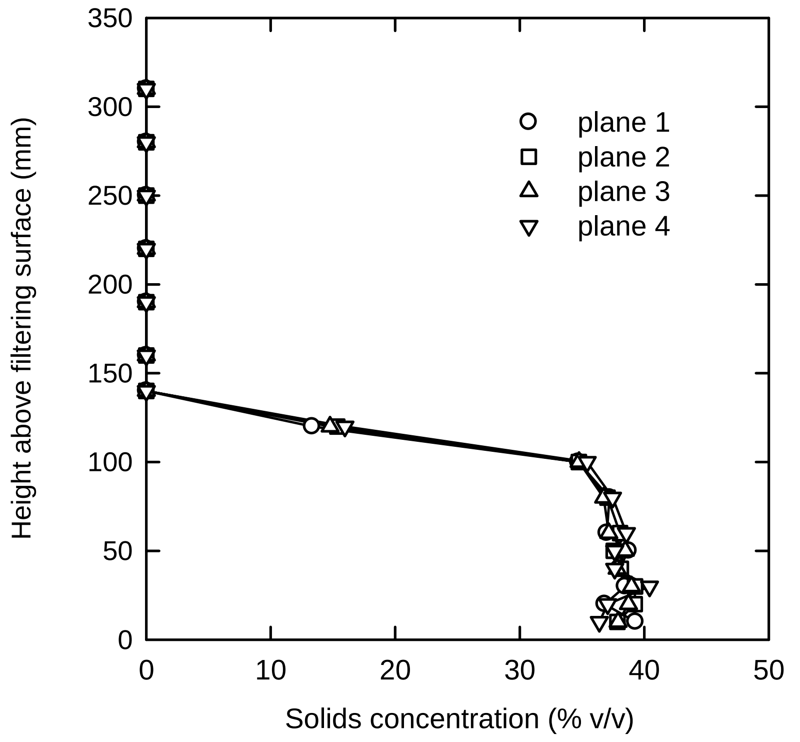

Figure 4: Solids concentration profiles at the end of cake formation (i.e. after 560 s).

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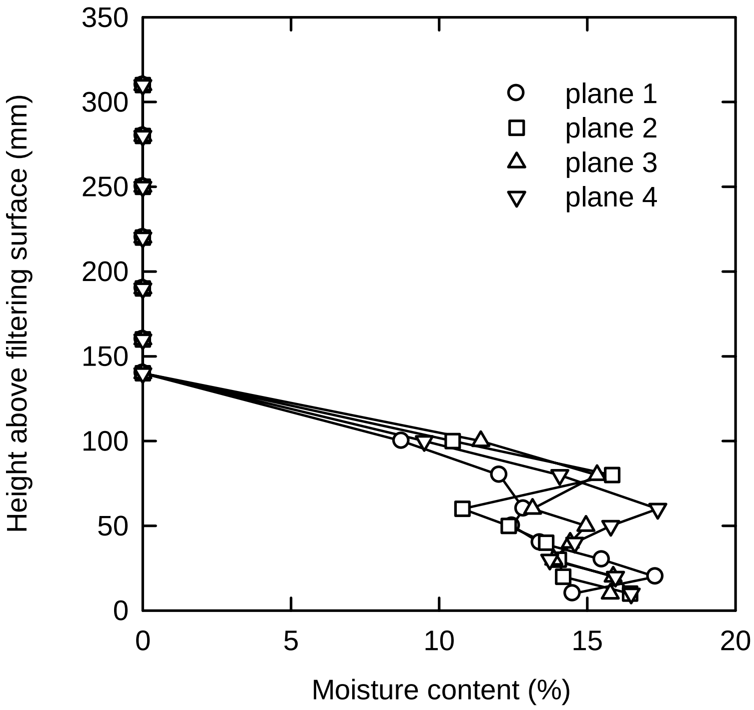

Figure 5: Moisture content profiles at the end cake dewatering (i.e. after 2000 s).

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