THE ADAPTATION OF MECHATRONIC PRINCIPLES TO THE DESIGN AND CONTROL OF THE FILTER CYCLE

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SUMMARY

A mechatronics approach has been employed to improve the performance of a solid-liquid separation device. The basic principles of the 'chematronics' task are described with reference to a computer controlled, pilot scale, pressure leaf filtration rig capable of measuring in-situ solids concentration profiles. By combining suitable sensors, transducers and control software it is shown how data can be acquired to correctly control and monitor all aspects of the filter cycle and yield a flexible apparatus capable of operating in a number of modes.

INTRODUCTION

In filtration, a solid is separated from a suspending liquid by forcing the liquid component through a septum under an imposed pressure gradient. The transient nature of the separation process, where the filter cake formed with time may continually change its structure and form, can lead to numerous problems such as low liquor removal rates. The need to control a filtration under conditions of constant pressure, constant flow or variable pressure/variable flow is thus imperative if solid or liquid product(s) are to be successfully separated as a part of the manufacturing process. The combination of mechanical, electrical and computer philosophies, which has become known as mechatronics, enables such control to be implemented over not just the filtration stage of a filter cycle, but also the downstream gas dewatering and displacement washing stages. By providing carefully controlled experimental apparatus and a sensing method similar in principle to Electrical Impedance Tomography (EIT), where the resistivity distribution of an object such as a filter cake is correlated to its structure and solids concentration, data have been obtained for the filtration and dewatering stages of a cycle.

EXPERIMENTAL APPARATUS

The principal hardware for the experimental apparatus comprised the filter cell and its associated computer driven, electronic circuitry (see 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 resistance 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™ 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. Their combination allowed data transfer through the system. Once an electrode was pulsed and another earthed, an electric current passed from one to the other. The

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voltage produced could be related the AC resistance (impedance) of the filtering suspension and measured using a Fairchild™ PCL-812PG LabCard situated in the computer.

The remainder of the experimental rig comprised two s/s storage vessels, incorporating temperature sensors and stirrers, connected by s/s piping to the filter cell. The vessels stored the feed suspension and wash water respectively. Compressed air at pressures up to 8 bar was supplied to the control valves on the rig pipework and also fed to the storage vessels/filter cell via an electronic regulator such that the driving force for the filtration and cake dewatering/washing phases of the filter cycle could be manipulated. A mimic display panel indicated which electrodes were pulsed and earthed within the filter cell at any one time and a heater/cooling system regulated the temperature of the filter cell and storage vessel contents by continuously passing heating/cooling water through their surrounding jackets. This counteracted any fluctuations in ambient temperature and eliminated temperature transients induced by slurry flow during an experiment. When a washing phase was included in the filter cycle, liquor samples could be taken using a 20 interval rotary table situated directly below the filter cell. An electronic balance, also situated below the filter cell, enabled liquor transport rates to be continuously monitored and mass balance calculations to subsequently be performed. All components related to data acquisition and rig operation were sequenced by the computer through dedicated computer software.

RESULTS

A series of batch experiments, involving cake formation and dewatering, were performed for the constant pressure processing of 10% v/v, aqueous based, calcite suspensions. A standard plot of cumulative volume of filtrate vs. time at pressures of 100-600 kPa is shown in Figure 2. Such data illustrate 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 were obtained throughout a chosen cycle over four distinct vertical planes. Figure 3 shows an example of solids concentration profiles during cake formation for a fixed pressure of 400 kPa. 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.

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 data can be acquired repeatedly. 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 through control of the delivery pressure; thus mimicking pumping operations. 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 manufacturing 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 promote research in solid/liquid separation for many years to come.

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FIGURES AND TABLES

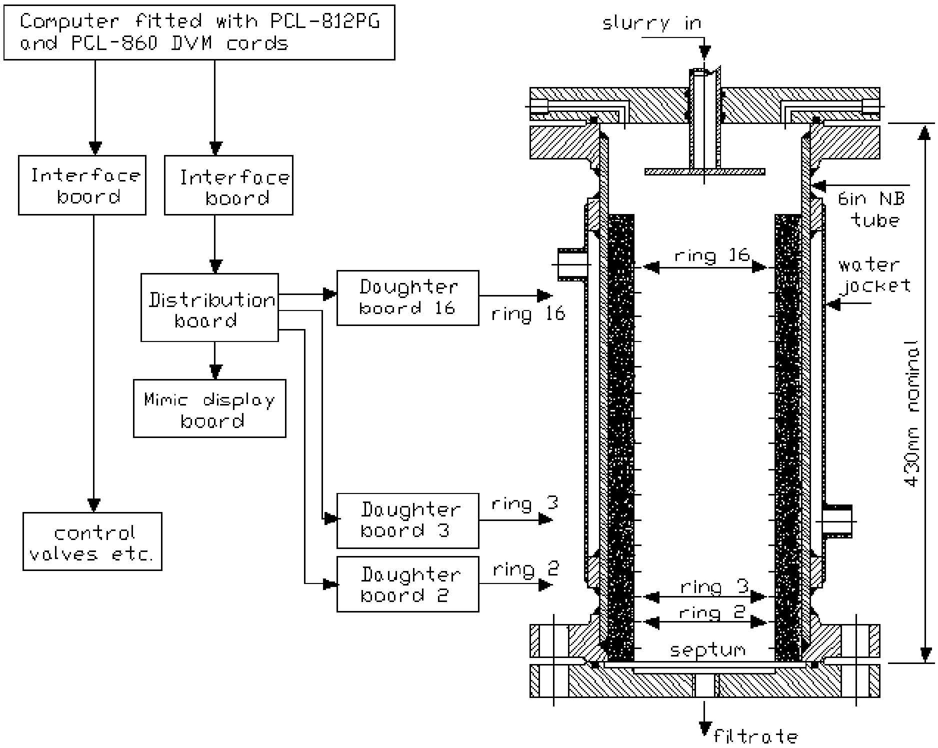

Figure 1: The pressure filter cell and a schematic of the electrode control system.

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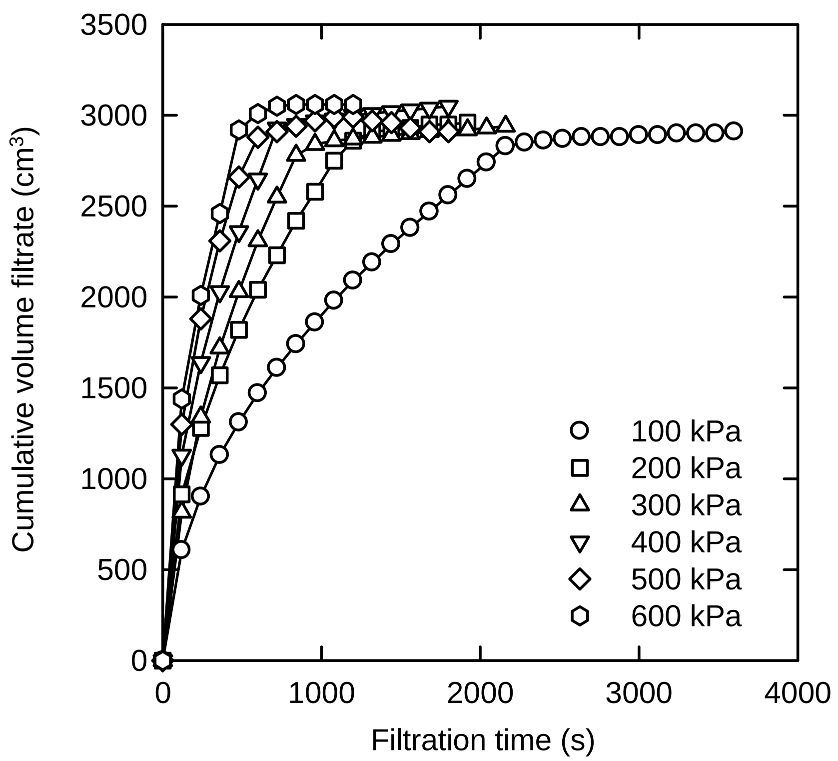

Figure 2: Cumulative volume vs. time for the filtration of 10% v/v calcite suspensions.

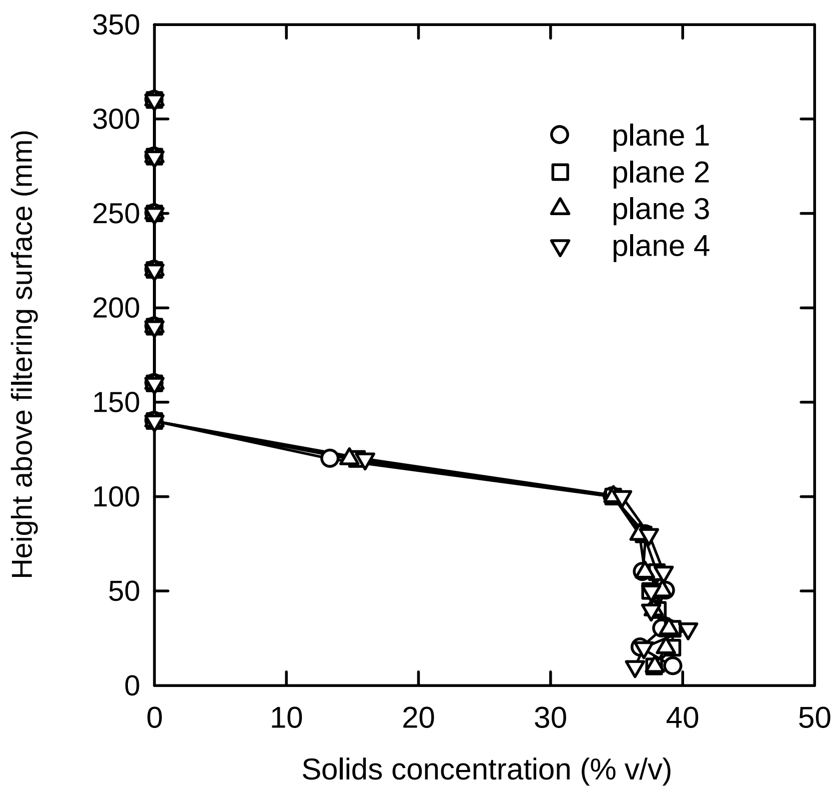

Figure 3: Solids concentration profiles during cake formation.

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