USING ELECTRICAL IMPEDANCE TOMOGRAPHY TO INTERPRET THE FILTER CYCLE

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SUMMARY

An experimental pressure filtration rig, capable of automatic operation and data collection, has been used to acquire data for a number of filter cycles. The computer controlled apparatus uses electrical resistance measurements and suitable transducers to determine the status of a filter cake during combinations of cake formation, gas dewatering and displacement washing. The experimental arrangement is briefly described together with the principal equations of a computer simulation. Experimental data obtained for aqueous calcite suspensions are compared with the predictions made by simulation and conclusions are drawn.

INTRODUCTION

The application of tomographic imaging to engineering processes has been a subject of increasing international interest for several years now. Publications have shown how a variety of imaging techniques can be applied to interpret processes such as flow in pipelines and fluid and/or particle motion in fluidised beds, hydrocyclones and stirred tanks[1-5]. The recent introduction of Electrical Impedance Tomography (EIT) allows more extensive investigations of these and other particulate related processes to be considered. EIT is a soft field technique whereby the application of an alternating electric field to an array of peripheral electrodes enables the resistivity distribution of an object to be correlated to its concentration.

Electrical resistance measurement techniques, which are related to EIT, have previously been used to investigate filter cake formation and cake dewatering[6-8]. However, the work has failed to investigate the important cake formation, dewatering and washing phases in a sequential filter cycle. As the availability of microprocessor based equipment becomes more widespread such investigations are now feasible where electrical resistance measurements are coupled to dedicated, computer controlled, experimental apparatus.

EXPERIMENTAL APPARATUS AND PROCEDURES

The experimental rig has been described in detail previously[9,10]. Briefly, it comprised two stainless steel (s/s) storage vessels connected by s/s piping to a filter cell. The vessels stored the feed suspension and wash water respectively. The filter cell contained 256 electrodes throughout its height, arranged in 16 horizontal rings around the internal periphery. By switching diametrically opposite pairs of electrodes within the cell the status of a filter cake could be determined at any time. Driving pressures were supplied to the control valves on the rig and to the storage vessels/filter cell via an electronic regulator. 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. All components related to data acquisition and rig operation were sequenced by a computer through dedicated computer software.

Series of constant pressure experiments were performed with 10% v/v aqueous based calcite suspensions and Gelman Versapor septa using the computer controlled apparatus described. Filtration, washing and dewatering phases were included in each filter cycle and the tests spanned a range of pressures between 100 and 600 kPa. To enable the computer simulation to be tested it was necessary to characterise the compressibility of the calcite filter cakes. This was done using a

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similar apparatus[11] to that described. Constant pressure filtrations were performed over the range 50-600 kPa with a filter cell of area 22.8 cm^2 incorporating 32 pairs of electrodes arranged in a single vertical plane. Solids concentration profiles were measured at regular intervals throughout each test and these were subsequently used to determine the relations between specific cake resistance, cake voids ratio and applied pressure to give

$$\alpha_{av} = \alpha_0 (1-n) \Delta p_c^n \tag{1}$$

$$e_{av} = e_0 - b_1 . \log(\Delta p_c) \tag{2}$$

where α_{av} is the average specific cake resistance, e_{av} is the cake voids ratio, Δp_c is the pressure gradient over the cake and α_0, e_0, b_1 and n are the empirically derived scale-up constants given in Table 1.

DESCRIPTION OF COMPUTER SIMULATION

The computer simulation used in this work is based on a development of an author's previous work[12]. The filtration phase of a filter cycle has been modelled using a modified version of conventional filtration theory such that

$$t_f = \frac{\alpha_{av} \mu \rho M_s}{2A^2 \Delta p_c \left(1 - M_s \left(1 + e_{av} \left(\rho / \rho_s\right)\right)\right)} V_f^2 + \frac{\mu R_m}{A \Delta p_c} V_f \tag{3}$$

$$h = \frac{V_f \left(1 + e_{av}\right)}{A \left(\frac{\rho_s}{\rho} \left(\frac{1}{M_s} - 1 \right) - e_{av} \right)} \tag{4}$$

where t is time, V is cumulative filtrate volume, μ is liquid dynamic viscosity, ρ is liquid density, ρ_s is solids density, A is filter area, R_m is filter medium resistance, M_s is solids mass fraction in the feed and h is the cake height.

The dewatering phase of a cycle has been modelled using a theory attributed to Wakeman[13] such that

$$\theta = \left(\frac{1}{b_2} . \frac{1-S}{S - S_\infty} \right)^{-b_3} \tag{5}$$

$$t_d = \frac{\theta \mu e_{av} h^2 \rho_s \alpha_{av} \left(1 - S_\infty\right)}{\Delta p_c \left(1 + e_{av}\right)^2} \tag{6}$$

$$V_d = \frac{A h e_{av} \left(1 - S\right)}{1 + e_{av}} \tag{7}$$

where θ is a dimensionless time, S is cake saturation and b_2 and b_3 are empirical constants.

Simulating the washing phase using the dispersion model[13] gives

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$$t_w = \frac{Whe_{av}\Delta p_c}{\mu\left(\alpha_{av}\rho_s h + R_m\left(1+e_{av}\right)\right)} \qquad (8)$$

$$V_w = \frac{WhAe_{av}}{1+e_{av}} \qquad (9)$$

where W is the wash ratio.

The modelling theories for the three phases have been combined together in computer software. This produced a flexible simulation package capable of providing data from virtually first principles for filter cycles involving any valid combination of filtration, washing and dewatering.

EXAMPLE RESULTS AND DISCUSSION

It has previously been shown how reliable experimental data can be acquired for a filter cycle[9,14] when 10% v/v suspensions of calcite dispersed in distilled water are used. Experimental data from cycles involving constant pressure cake formation, washing and dewatering have been compared with corresponding computer simulations and the results are shown in Figures 1-4. Figure 1 gives the comparisons between simulation and experiments for cake growth at two different filtration pressures. The excellence of the predicted cake growth is indicative of the accuracy of the simulation when essentially incompressible systems are considered. The data in Figure 2 illustrate the sometimes poor prediction of washing performance. The dispersion theory was generally observed to over-predict washing efficiency and it is thought that some correction to dispersion number is required to make the predictions more accurate (e.g. equivalent to those employed with rotary vacuum filters[13]). Figure 3 shows that as dewatering pressure is incremented over a number of tests, so equilibrium cake moisture falls. Predictions of cake moistures were reasonably good. Figure 4 shows experimental data and theoretical predictions for volume of liquid removed from the filter vs. time at a cycle pressure of 200 kPa.

CONCLUSIONS

The now widespread availability of microprocessor based equipment such as computers, controllers, transducers and sequencers opens many new opportunities for research in solid/liquid separation. The ability to monitor and control a process and acquire reliable and repeatable data allows researchers to devise new and novel methods of experimentation, and thus develop accurate computer simulations. For instance, it has been shown in this paper how scale-up constants for filtration can be evaluated on one rig (filter area = 22.8 cm^2), and used in a computer simulation to accurately predict the performance of another rig (filter area = 80 cm^2). If such a procedure can be repeated at larger scales then commercial operations will undoubtedly benefit.

ACKNOWLEDGEMENT

The authors would like to express their thanks to the EPSRC for the receipt of a studentship to expedite the current research.

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FIGURES AND TABLES

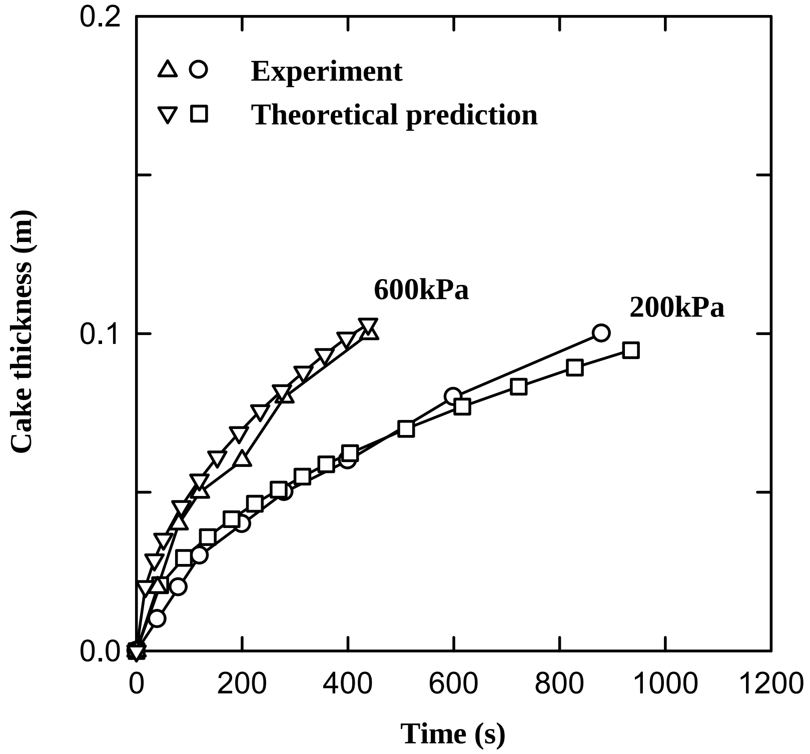

Figure 1: Filter cake growth for two different filtration pressures.

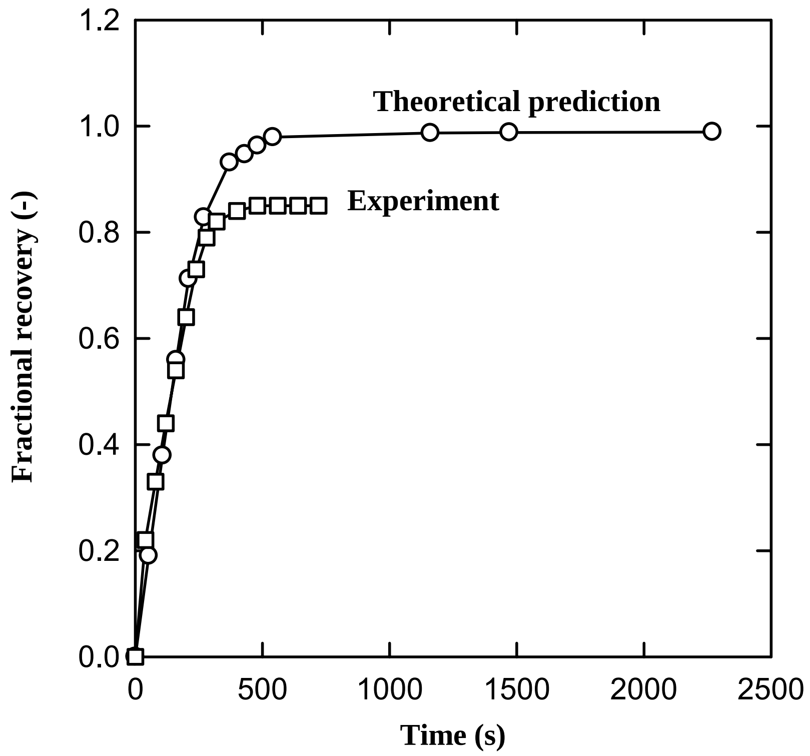

Figure 2: Fractional recovery for displacement washing at 400 kPa.

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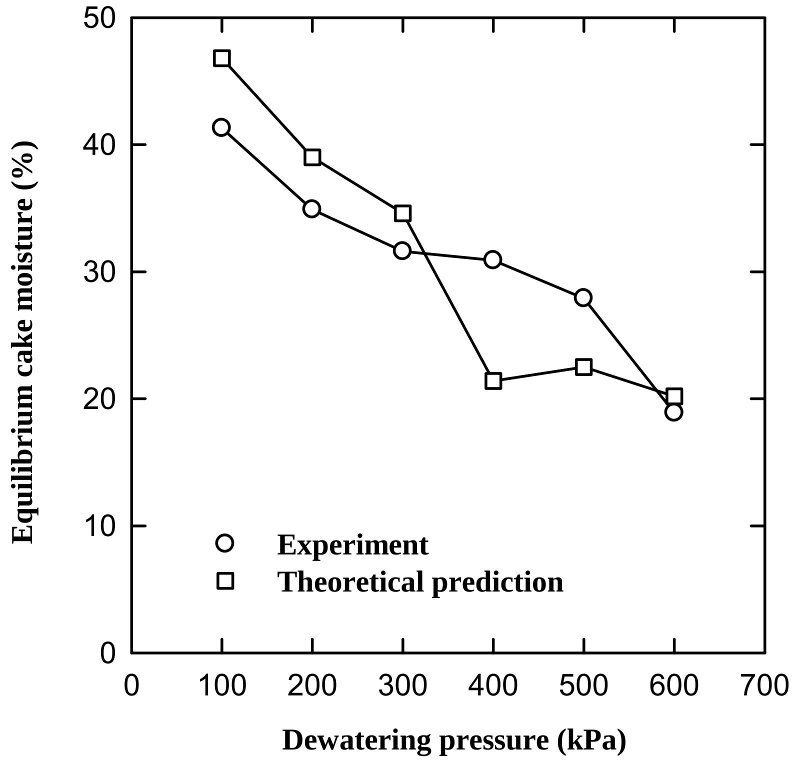

Figure 3: Filter cake moisture for increasing dewatering pressure.

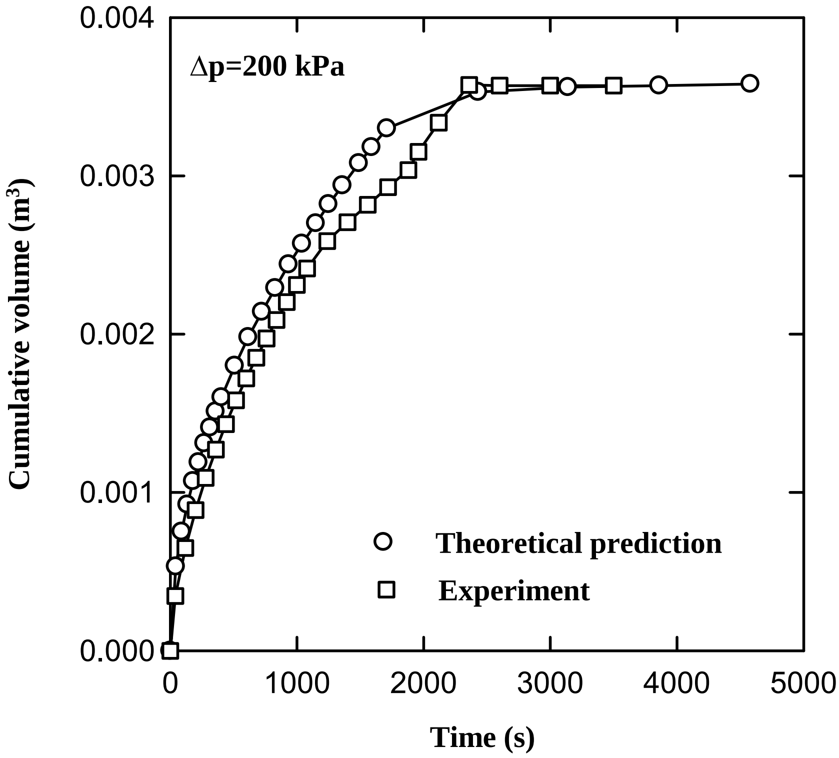

Figure 4: Volume vs. time for a filter cycle involving filtration, washing and dewatering.

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Feed conc. (% v/v)	α_0 (m kg^{-1})	n (-)	e_0 (-)	b_1 (-)
5	4.20×10^9	0.084	1.775	0.077
10	2.55×10^9	0.132	2.101	0.127
20	1.79×10^9	0.153	2.304	0.209

Table 1: Empirical scale-up constants for calcite suspensions (pressures in (Pa)).

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