Aspects of modelling in compressible filter cake formation

ASPECTS OF MODELLING IN COMPRESSIBLE FILTER CAKE FORMATION

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ABSTRACT

Solids concentrations through a solid/liquid mixture were determined using an electrical impedance measuring technique described previously. A number of pressure leaf filter experiments have been performed for two materials exhibiting a range of compressibility at differing applied filtration pressures, initial solids concentrations and surface charges. The paper indicates how such experimental data can be interpreted and modelled using both the classical and so-called 'modern' filtration theory. The need to enhance these models for compressible materials is highlighted with reference to the experimental data and the influential particulate and process parameters. Suggestions for the ways in which models can be improved are made.

INTRODUCTION

The majority of filter cakes exhibit a degree of compressibility. The filtration theory used in the design of industrial filters has yet to take into account all the parameters which affect this compressibility. Thus, scale-up of full scale filters is often done from (costly) pilot scale plant data. In this paper some results are presented from an EPSRC funded project studying the effects of particulate and process parameters on the compressibility of filter cakes and the filtration characteristics of a range of feed suspensions.

EXPERIMENTAL EQUIPMENT

The experimental rig and measurement techniques used in the test program have previously been described in detail by Willmer *et al.*[1] and Holdich and Sinclair[2]. Briefly, the rig comprised a stainless steel leaf filter cell of filtration area 23 cm^2 situated downstream from a slurry feed vessel of 5 l capacity. Constant driving pressures up to 800 kPa were provided for the filtrations from a dedicated air compressor and a constant temperature for the feed slurry was maintained throughout the filtration procedure using a constant temperature heating circuit. Control of the rig and data acquisition was fully automatic, being sequenced by a dedicated personal computer (see Figure 1).

A number of tests were completed to investigate the effect of the important particulate and process parameters. Calcite suspensions were filtered at initial solids concentrations ranging from 5-20% v/v at pressures of 100-600 kPa. The filtration performance of zinc sulphide (ZnS) suspensions was also investigated at similar concentrations and pressures. In this case, however, the range of surface charges investigated (equivalent to average zeta potentials 0 to -50 mV) yielded varying degrees of filter cake compressibility.

THEORY

Data produced for this paper has been processed using conventional filtration theory and (adapted) theory originally developed by Shirato *et al.*[3].

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Modern filtration theories which consider compressibility, describe cake formation in relation to the compressive stress gradient experienced by the solid particles ($\mathrm{d}P_s/\mathrm{d}x$) as shown previously by Tarleton *et al.*[4]. Due to the lack of necessary values for the terms given in the relationship (e.g. local solids velocity and local concentrations in the filter cake) it is usual for the simpler relationship proposed by Sperry[5] to be used in order to investigate the filtration characteristics of a slurry. By plotting the filtration data as t/V vs. V, where V is the cumulative volume of filtrate collected in time t, values of specific cake resistance and resistance of the filter medium can be obtained. Formerly, information for the value of the effective feed concentration, c, (kg m^{-3}) had to be gained from mass sampling of the filter cake and for a compressible material the sample rarely represented the true nature. In the current experimental program the value of the effective feed concentration is obtained from a knowledge of the concentration gradient within the cake and can be computed via

$$c = \frac{sC\rho_s\rho}{(1-s)C\rho_s - s(1-C)\rho} \qquad (1)$$

where C is the average cake concentration (volume fraction), s the mass fraction of solids in the slurry feed (mass fraction), ρ the liquid density (kg m^{-3}) and ρ_s the solids density (kg m^{-3}). This single value of average concentration in the cake (C) is computed at a time when a fixed percentage of the slurry has been filtered thus giving a value comparable between tests.

By plotting values of specific cake resistance and average cake concentration vs. pressure drop over the cake, values for the relating empirical constants n & α_0 and m & C_0 can respectively be found[1] and used to theoretically predict the cake solids concentration and cake height as given by

$$C = C_0 \Delta P_c^m \left(1 - \frac{x}{L}\right)^{m/(1-m-n)} \qquad (2)$$

where ΔP_c is the pressure drop over the cake (N m^{-2}), x the distance from the septum (m) and x/L the dimensionless distance into the cake measured from the septum. A comparison has been made between profiles obtained from experimental data, conventional mass sampling and the 'modern' filtration theory through the use of the measured local cake concentration.

RESULTS

In Figure 2, data showing specific cake resistance at a range of pressures for calcite and ZnS suspensions close to their iso-electric point is plotted. It can be seen that the compressible nature of ZnS filter cakes yields significantly higher resistances than corresponding incompressible calcite cakes. For both materials specific cake resistance increases with filtration pressure at a rate dependent on cake compressibility. Figure 3 gives the average cake porosity for these two materials over the same range of pressures. Values for n, m, α_0 and C_0 are given in[1].

Using equation (2) the cake concentration profile predictions using empirical constants derived from both conventional mass sampling and modern theory can be compared to the experimental results as shown in Figure 4 and 5. The predictions for calcite show a good agreement between all profiles, indicating that the mass sampling technique gives an accurate prediction for the cake concentration profile. It is noted that the cake is of homogenous composition throughout its height. Figure 5 shows the theoretical predictions to be incorrect for ZnS filter cakes. Both predictions give inaccurate cake heights but the mass sampling technique accurately predicts the cake concentration. This is thought to lend weight to the argument that

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the first few layers of the filter cake govern the filtration characteristics of the suspension. At the current stage of the project, however, it is unclear whether the result is a one off.

CONCLUSIONS

The degree of compressibility of a filter cake has been shown to influence the filtration characteristics of a slurry. This compressibility is in turn influenced by a number of factors[1] and modelling theory must be able to take these into account. It would seem that the best theoretical predictions currently available for cake concentration profiles are inaccurate for many compressible materials. Moreover, data suggests that the empirical constants n & α_0 and m & C_0 are inexorably linked and that they must all be known when modelling filtration.

ACKNOWLEDGEMENTS

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TABLES AND FIGURES

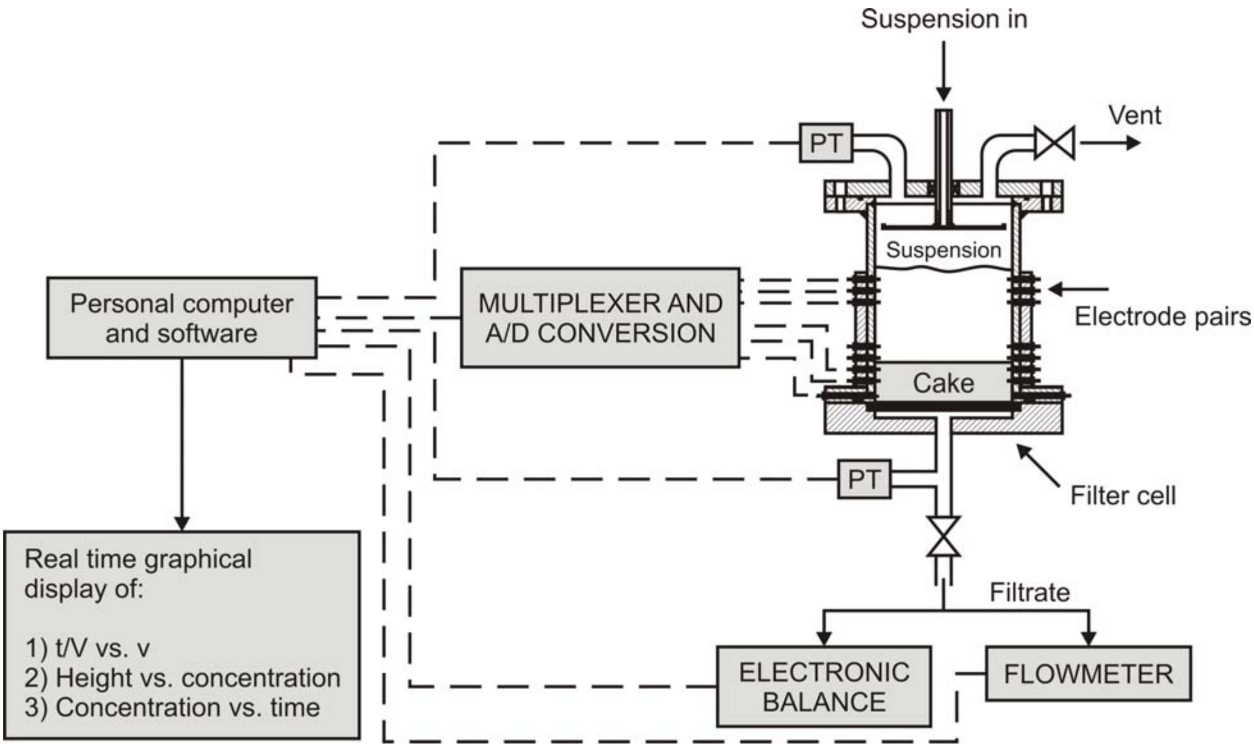

Figure 1: Schematic of the pressure filtration rig.

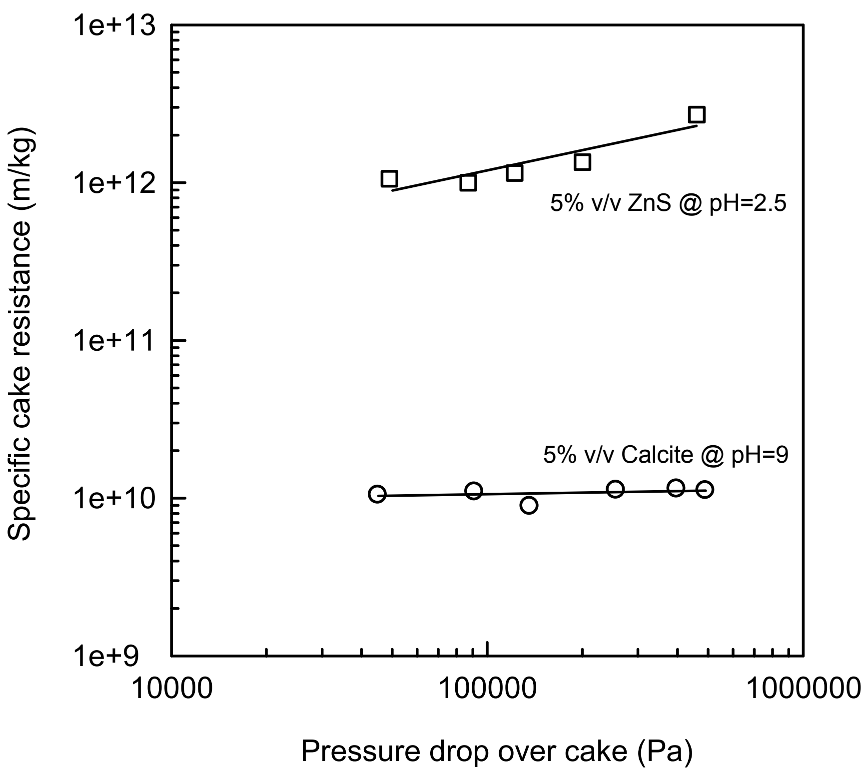

Figure 2: Average specific cake resistance vs. pressure drop over the cake.

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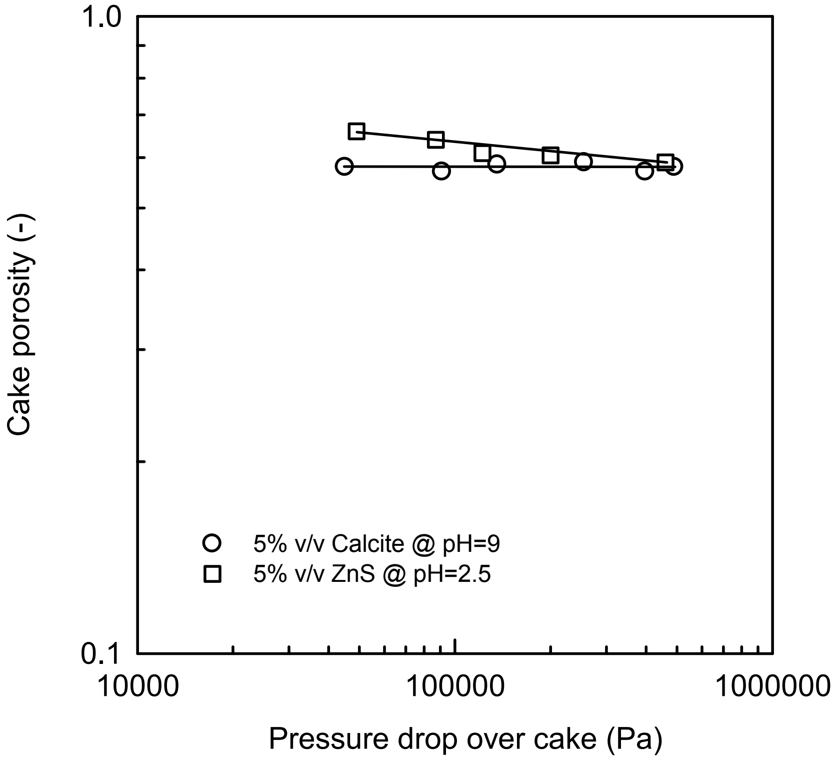

Figure 3: Average cake porosity vs. pressure drop over the cake.

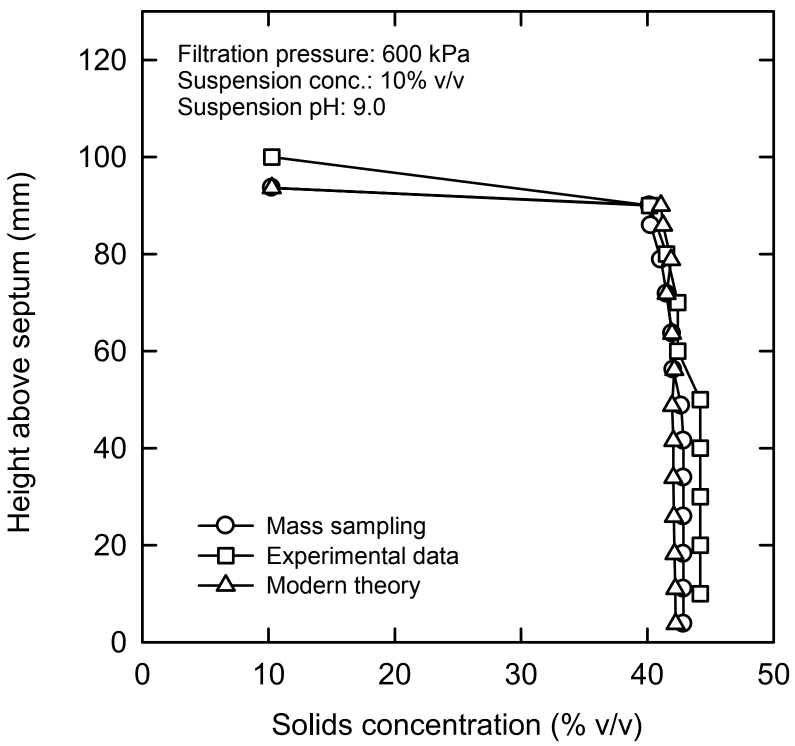

Figure 4: Theoretical cake profile predictions vs. experimental values for calcite.

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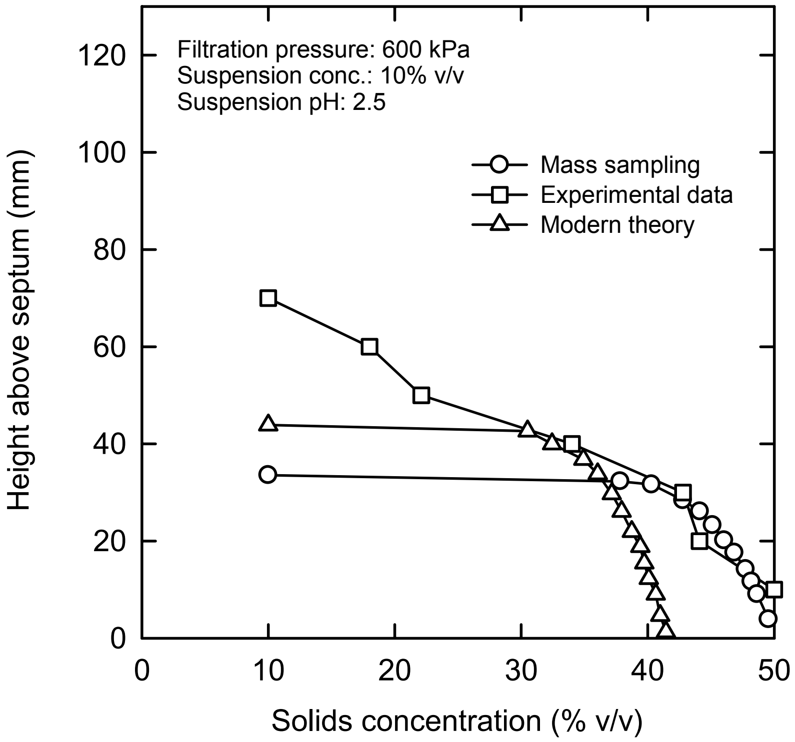

Figure 5: Theoretical cake profile predictions vs. experimental values for zinc sulphide.

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