MUD CONDITIONING FOR GOOD FILTER OPERATION

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Abstract

The specific cake resistance concept, which is based on filtration theory, has been used to investigate mud filtration. It has been shown that filtration efficiency (e) is related to specific cake resistance (α). Optimising α thus also optimises e. Plant conditions such as mud solids concentration, bagacillo content and size distribution, mud pH and flocculant addition have been investigated and optimum levels have been established.

Introduction

One of the side effects of the introduction of diffusion in South Africa has been a significant change in both the quantity and quality of clarifier muds. The reduced quantity of mud is made evident by the fact that diffuser factories report a value of filter cake % cane which is about half that for milling factories. Sucrose lost in filter cake % sucrose in cane is another figure which shows a difference, with diffusion factories reporting[1] an average of 0,25% for the 1982/83 season while milling factories report 0,38%. The fact that the sucrose loss for diffusion is now some two-thirds that of milling indicates that the change in quality may have been detrimental to filter operation. This conclusion is strengthened by an examination of the purity drop between clear juice and filtrate which shows average values for the same season of 3,6 units and 1,1 units for diffusion and milling respectively.

These observations prompted the SMRI to use the specific cake resistance concept to investigate the filterability of cane muds.

Specific resistance to filtration is a quantitative measure of filterability which has been used by a number of investigators. Swanwick and Davidson[2] have used it to investigate the filtration of sewage sludge. Using laboratory determined values of specific resistance they predicted the full scale performance of rotary vacuum filters and filter presses. They also discuss the precision of the method, which they found to be around about 5%. Measurement errors were found to be small with respect to changes in specific resistance which was reduced by factors of up to 400 through chemical conditioning. More recently Carleton and Cousens[3] used the same principle to investigate the performance of industrial filters such as table filters for sand and drum filters for chalk. One of the criteria used was the rate of dry cake production, determined in the laboratory through leaf tests. They also found that slurries may "age" and that ageing could result in either improvements or deteriorations of performances.

Purchas[4] discussed the application of filtration theory to industrial problems and proposed a number of approaches for making initial budget estimates for cake filters.

Schoenrock, Henscheid and Kearney[5] present an apparatus and a test procedure to measure the filterability of particles in solid/liquid separation. The method, based on the specific cake resistance concept, is stated to be simple, quick and to have excellent precision. They used it to look at the filtration of carbonatation sludges.

Bennett[6] uses the same concept to study the filterability of carbonated liquors in the laboratory. Values for the specific cake resistance fell in the middle of the range $1,6 \times 10^{9}$ m.kg^{-1} for free flowing kieselguhr to $1,5 \times 10^{14}$ m.kg^{-1} for thixotropic muds.

Schultz, Papirer and Nardin[7] working with mixtures of cement and fibres, stress the importance of both the filtration rate and the filtration efficiency. They studied the effects of quantity of fibre, solids concentration and fibre quality on the filtration of the cement/fibre mixtures.

Experimental Procedure

The theory behind the specific cake resistance concept has been given elsewhere, and it has also been shown that this concept may be used to investigate cane mud filtration.[8]

Specific cake resistance is a measure of filtration rate and a second quantity is necessary to quantify the efficiency of filtration which deals with the quality of the filtrate produced. This quantity has been defined[9] as

$$e = \frac{\text{Mass of solids in cake}}{\text{Mass of solids in cake} + \text{Mass of solids in filtrate}}$$

which is given by

$$e = 100 \times \frac{\begin{matrix}\text{Mud solids}\\ \text{\% feed}\end{matrix} - \left(\dfrac{\text{Mud sol \% filt. } (100 - \text{Mud sol. \% feed})}{100}\right)}{\text{Mud solids \% feed}}$$

e is obviously dependent on the analyses of solids % in filtrate and feed, which are notoriously difficult and time consuming. Furthermore the last equation assumes no changes in concentration during filtration which is not the case industrially.

The need to measure e during each investigation would not be necessary if a relationship between the rate orientated specific cake resistance and efficiency could be obtained. This relationship then allows the study of the influence of the relevant parameters only on cake specific resistance.

The apparatus used to measure the specific resistance consists essentially of a 2ℓ capacity jacketted cylinder, with a circular piece of Oliver filter screen at the bottom. The outlet of this cylinder leads into a graduated vessel which is itself connected to a vacuum system. A thermometer may be inserted into the mud for temperature measurement, while the vacuum is set using a precalibrated gauge.

The procedure for a run is as follows:

- The equipment is set up and water at 70°C is circulated through the jacket.
- The vacuum is adjusted at the desired level.
- A metal container, with a lid, is used to obtain a catch sample of about 3 litre of mud or filter feed. The sample is brought to 70°C by placing the container into a water bath at that temperature. Vigorous stirring of mud or feed could damage the floc and must therefore be avoided. A swirling motion is used.
- When the sample has reached 70°C, it is mixed by swirling and poured into the jacketed cylinder. The top of the cylinder is put on and a digital thermometer probe is inserted into the mud.
- The vacuum is switched on and times are read when 10, 20, 30 etc. cm^{3} of filtrate have flowed into the graduated container.
- A sample of mud is taken from the sample container for a suspended solids analysis. A sample of filtrate is also needed for viscosity, brix and suspended solids.

Results

Relation between specific cake resistance and filtration efficiency

The possibilities of conditioning muds to improve overall filterability, which involves both the rate and the efficiency of filtration, were investigated.

The relation between the specific resistance, α, and the efficiency, e, was therefore investigated. The materials used were clarifier muds to which varying amounts of bagacillo, water, lime and flocculant were added. α and e were then measured.

The results obtained at different factories are shown in Table 1.

TABLE 1

The relation between specific resistance (α) and filtration efficiency (e)

Factory	Relation	No. of observations	Corr. coeff.
ME	$e = 97{,}8 - 2{,}3 \times 10^{-11} \times \alpha$	11	-0,86**
DL	$e = 98{,}7 - 2{,}3 \times 10^{-11} \times \alpha$	7	-0,87**
IL	$e = 91{,}7 - 3{,}5 \times 10^{-11} \times \alpha$	6	-0,87*
SZ	$e = 86{,}9 - 0{,}1 \times 10^{-11} \times \alpha$	4	-0,92*
AK	$e = 89{,}9 - 0{,}1 \times 10^{-11} \times \alpha$	4	-0,95*
UC	$e = 96{,}0 - 1{,}6 \times 10^{-11} \times \alpha$	8	-0,91**

Some of the results have been plotted in Figure 1

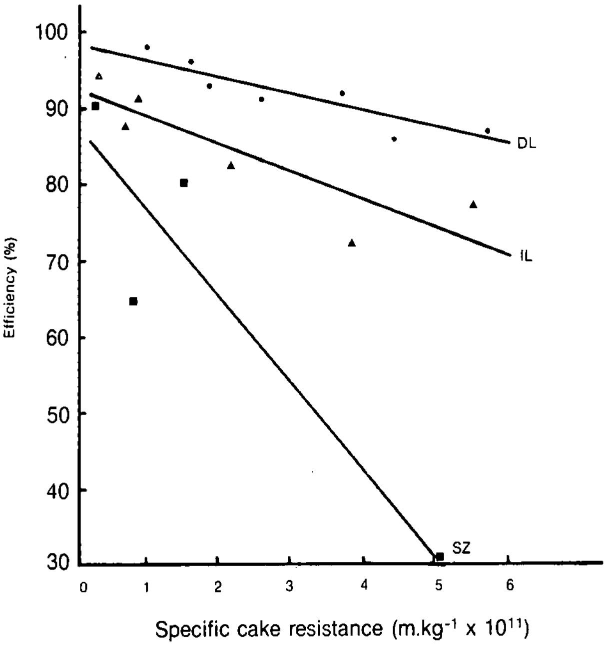

FIGURE 1 The relation between filtration efficiency e and cake specific resistance α

These results show that there is an inverse relation between specific cake resistance and filtration efficiency. Thus, by optimising the specific cake resistance, filtration efficiency is automatically optimised.

The value of the slopes and intercepts is different at different mills because of differences in the physico-chemical properties of the muds such as particle size, electrical charges, etc.

Mud conditioning

Clarifier muds at IL, SZ, AK, NB, UC, DL and ME were sampled and sub-samples were treated in different ways. In each case α was measured and the mud quality was recorded. About 10 samples were done at each factory.

The averaged results obtained for untreated muds are compared to those from factory filter feed in Table 2.

TABLE 2

Untreated mud against factory filter feed

	Mud solids %	Bagacillo %	pH	α	Suspended solids % filtrate
Average for untreated muds	5,3	0	6,9	$6{,}0 \times 10^{11}$	1,3
Average for factory filter feed	4,4	2,2	7,1	$2{,}5 \times 10^{11}$	0,6

It is evident from Table 2 that factory mud conditioning achieves a significant improvement in mud filterability, reducing α from 6×10^{11} to $2{,}5 \times 10^{11}$ m.kg^{-1}, while also reducing the filtrate suspended solids level.

Laboratory conditioning of mud

The samples of mud were treated in the laboratory and α was measured. The results obtained are summarised in Table 3 which shows the values for untreated and treated muds at each factory.

TABLE 3

Untreated muds against laboratory conditioned muds

	Muds solids %	Bagacillo %	pH	Flocc ppm	α	Suspended solids % filtrate
IL*	8,8	0	7,2	0	$5{,}5 \times 10^{11}$	2,2
	4,6	2,1	7,6	4	0,3	0,3
SZ	3,6	0	6,4	0	5,0	2,6
	3,0	2,6	6,1	4	0,2	0,3
AK	1,5	0	7,3	0	8,2	1,4
	1,6	3,5	7,7	4	0,1	0,05
NB	3,6	0	7,1	0	0,6	0,04
	3,0	3,2	8,0	5	0,02	0,03
UC	4,4	0	6,9	0	11,3	0,9
	2,2	2,4	7,2	5	0,5	0,1
DL	9,1	0	6,6	0	6,0	1,2
	5,1	2,5	7,3	0	1,0	0,1
ME	6,0	0	6,6	0	5,0	0,7
	3,9	3,0	7,6	5	0,4	0,1
Average untreated	5,3	0	6,9	0	$6{,}0 \times 10^{11}$	1,3
Average treated	3,3	2,8	7,4	4	$0{,}4 \times 10^{11}$	0,1

* The first line applies to untreated muds while the second applies to the laboratory treated muds.

The average for treated muds in Table 3 is based on about 70 samples from 7 of the South African factories and is considered fairly representative.

These results may be used to set the conditions leading to improved filterabilities and filtrate qualities at the factory filter station. For specific resistances of the order of $0{,}4 \times 10^{11}$ m.kg^{-1} and suspended solids in filtrate of less than 0,4%, the following are required:

- Mud solids % feed between 3 and 4%. The 4% level should be viewed as the maximum permissible.
- Dry bagacillo % feed of between 2,5 and 3%. Again, the lower value should be the limit.
- The pH of the feed should be adjusted to about 7,5 with milk of lime. This value is only an approximation because pH could not be optimised.

- The use of 4 - 5 ppm (on feed) of flocculant would be beneficial, but is not seen as essential.
- Feed temperature should be kept around 85°C.

The above recommendations are within the practically achievable range at factories and will result in all round improvements.

Quantitative measures in mud conditioning

The tests at UC, DL and ME were planned in such a way as to allow multilinear regressions to be performed. Solids %, bagacillo % and flocculant were treated as factors in a fractional factorial to avoid correlations between them. This was generally successful except for pH which had to be discarded from the regressions.

The results obtained are shown in Table 4.

TABLE 4

The effects of solids concentration, bagacillo and flocculant on specific cake resistance

UC	$\alpha = 1,5 \times 10^{11} + 2,0 \times 10^{11} \times$ mud solids % $- 2,7 \times 10^{11} \times$ bagacillo % $- 0,1 \times 10^{11} \times$ flocc. ppm	n = 10 r = 0,96
DL	$\alpha = 2,6 \times 10^{11} + 1,0 \times 10^{11} \times$ mud solids % $- 0,2 \times 10^{11} \times$ bagacillo %	n = 11 r = 0,83
ME	$\alpha = 2,3 \times 10^{11} + 0,4 \times 10^{11} \times$ mud solids % $- 0,7 \times 10^{11}$ bagacillo % $- 0,3 \times 10^{11}$ flocc. ppm	n = 11 r = 0,94

These results, which apply only to the range of values investigated, generally indicate that the lower the mud solids and the higher the bagacillo the better the filterability.

The coefficients are different from factory to factory due, as mentioned previously, to differences in the chemical and physical characteristics of the mud.

Effect of the quality of the bagacillo

Factory bagacillo was sieved to yield 3 size ranges:—

Size 1 : remaining on a 0,85 mm screen.
Size 2 : passing through a 0,85 mm screen but not through a 0,65 mm screen.
Size 3 : passing through a 0,65 mm screen.

Samples of mud were then conditioned using the 3 size fractions and the cake specific resistance and filtration efficiency were measured. The averages from 6 runs are given in Table 5.

TABLE 5

The effect of bagacillo quality on mud filtration

	Mud solids %	Bagacillo %	α	e
Size 1	3,7	3,7	$0,3 \times 10^{11}$	79,7
Size 2	3,8	3,5	$0,3 \times 10^{11}$	89,1
Size 3	4,0	3,5	$0,3 \times 10^{11}$	92,3
Untreated	4,2	0	$6,7 \times 10^{11}$	66,1

The results obtained show the importance of considering both the filtration rate and the filtration efficiency. The 3 size fractions gave similar filtration rates as indicated by the specific cake resistance of $0,3 \times 10^{11}$ m.kg^{-1} but different efficiencies. The efficiency results show that the finer fractions should be used.

Conclusion

Mud filterabilities have been investigated using the specific resistance concept. It has also been shown that filtration efficiency is inversely related to specific resistance. The optimisation of the cake specific resistance thus also optimises the filtration efficiency.

The following conclusions may be made from the results obtained:—

- Although untreated materials from diffusion factories generally showed poorer filterabilities, conditioning of both types of materials results in similar final values of specific resistance, namely about $0,4 \times 10^{11}$ m.kg^{-1}.
- The operating conditions for optimum filter operations are mud solids % feed of between 3 and 4%, dry bagacillo % feed of about 3%, a pH of feed of 7,5 and 4–5 ppm on % feed of a low molecular weight flocculant.
- The above conditions, which are achievable on the factory scale, would yield a specific cake resistance of about $0,4 \times 10^{11}$ m.kg^{-1}, a filtration efficiency of about 90 and a suspended solids % filtrate of under 0,5%.
- Tests investigating the quality of bagacillo show that the finer fractions (through a 0,85 mm screen) improve both the filtration rate and the filtration efficiency. Bagacillo separation must therefore be aimed at giving this size fraction.

The results obtained have shown the usefulness of the specific cake resistance concept. The experimental method is straightforward and has been found to be reliable if the required precautions are taken. Furthermore, the equipment is simple and each run requires only about 20 minutes. It is envisaged that this method could be used to investigate other areas such as the use of cloths or of other filter aids for the filtration of cane muds.

Acknowledgements

The author would like to thank the staff of all the factories where the experimental work was done. He is also indebted to the Analytical Services Division of the SMRI who carried out most of the analyses and to L. Bachan, G. Chetty and A. Williamson for their involvement.

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