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Research Article

Comparative Study on the use of Filter aids for Reducing the Resistance in Vacuum and Pressure Filters

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Abstract

The objective of the present work is to investigate the effect of filter aid on specific cake resistance and filter medium resistance for filtration of slurry in vacuum leaf filter and plate and frame filter press. Homogeneous suspension of calcium carbonate was used as feed slurry for all experimental runs. Perlite and diatomite were used as filter aid at 0.2, 0.4, 0.6, and 0.8 % concentrations (one filter aid at a time) for the filtration of 2, 3 and 4 percent calcium carbonate slurry as body feed. It was observed that the use of filter aid was effective in minimizing the specific cake resistance at lower initial concentration of the slurry. The resistance, particularly the specific cake resistance, was found to decreases with increase in concentration of the filter aid for both perlite and diatomite. From the results obtained, it is clear that the resistance for filtration is reduced to a considerable extent by the use of filter aid which in turn would reduce the total power consumption for filtration.

Keywords: Filtration; Filter aid; Leaf filter; Filter press; Perlite; Diatomite.

Introduction

Filtration is one of the separation/purification operations that find applications in a variety of industries either in continuous or discontinuous modes. The major problem in discontinuous filters is the pressure drop due to increase in resistance, which increases the energy requirement and hence the operating cost. The pores of the filter medium are smaller than the size of particles to be seperated [1]. Requirements of filtration equipment include mechanical support for the filter medium, driving force in the form of pressure on the upstream side or vacuum on the downstream side, flow accesses to and from the filter medium and provision for removing excess filter cake. The effects of particle size and particle size distribution were presents by Bourcier et al [2]. The influence of filtration variables on the filterability of green liquor sludge was presented by Golmaei [3]. Numerical analysis of the cake filtration was done by Bai and Tien [4]. Stickland et al [5] reported optimum throughput for slow-filtering and fast-filtering suspensions. The rate of filtration is an important factor since it is always desirable to filter the slurry as quickly as possible [6]. The factors affecting rate of filtration is given by *Darcy's law* and may be expressed as eq. (1).

$$R_m = \frac{A\,\Delta P\left(1/q_o\right)}{\mu} \qquad (1)$$

If the cake is incompressible, cake resistance α is independent of the pressure drop ΔP and if the cake is compressible, cake resistance can be expressed as eq. (2).

$$\alpha = \frac{A^2\,\Delta P\,K_c}{c\,\mu} \qquad (2)$$

The values of the specific cake resistance α range from 10^{13} to 10^{15} m/kg for raw sludge and 10^{11} to 10^{12} m/kg for well-conditioned sludge. When particles in the feed slurry are smaller, the pores in the filter medium are too small, which leads to higher resistance for filtration, i.e., the resistance to filtration is inversely proportional to the particle size in the feed slurry. For solid/liquid systems in which materials are highly viscous, collodial, stable, or deformable, the resitsnce for filtration becomes much higher. In order to minimise the resitance for filtarion and to make process economical, the addition of filter aid is needed. Filter aids can be

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used as a precoat or bodyfeed or their combination. Diatomite and perlite are two filter aids used in this study.

Diatomite

Diatomaceous earth, also known as DE or diatomite, is a naturally occurring soft, siliceous sedimentary rock that is easily crumbled into a fine white to off-white powder. It has a particle size ranging from less than 3 micrometer to more than 1 millimeter, but typically it has 10 to 200 micrometers [7]. The typical chemical composition of oven-dried diatomaceous earth is 80 to 90% silica, with 2 to 4% alumina (attributed mostly to clay minerals) and 0.5 to 2% iron oxide. It has a high porosity, because it is composed of microscopically small, coffin-like, hollow particles.

Perlite

Perlite is an extrusive rock that forms when high-silica lava has high water content. It is an important industrial material which tends to be lightweight and strong, easy-to-use as a building material. In the temperature range of 850 - 900 °C, perlite softens (because it is a glass) [8]. It is chemically a sodium potassium aluminum silicate. It is lower in density than diatomite and this enables using less filter media (by weight). A unique property of perlite is that it expands up to 20 times of its original volume when it is heated to its softening range. Perlite filter aids do not impart taste, color or odour to liquids being filtered and they are virtually insoluble in mineral and organic acids at all temperatures. Its typical bulk density is 0.16 g/cm^3. Typical analysis of perlite gives 70–75% silicon dioxide: SiO_2, 12–15% aluminum oxide: Al_2O_3, 3–4% sodium oxide: Na_2O, 3–5% potassium oxide: K_2O, 0.5-2% iron oxide: Fe_2O_3,, 0.2–0.7% magnesium oxide: MgO, 0.5–1.5% calcium oxide: CaO, 3–5% loss on ignition (chemical/ combined water).

Material and methods

Pre-coat

A filter aid pre-coat protects the filter septum (the support for the filter cake) and ensures clarity by retaining solids at the surface. The concentration should be as slow as possible, with 0.5% being typical. Agitation in the pre-coat tank should be sufficient to keep the filter aid in suspension. Filter aids should be added at 500 to 1200 g/m^{2}of filter area. Slurry is made from filtered liquid, or sometimes water, and filter aid. Much lower rates are used with higher viscosity liquids. There should be at least 0.07 kg/cm² (1 psi) differential pressure during the Pre-coat process. Pre-coating liquor should clear up within 10 to 15 minutes. A pre-coating rate of 40 liters/(m^2 min) is standard.

Body-feed

Body-feed is the addition of filter aid to the liquid being filtered. Body-feed filter aid is continuously added to the unfiltered liquid to keep the dirt solids apart, thus maintaining a porous cake. Body-feed maintains clarity and flow-rate throughout the filter run. The solids content will determine the filter aid dosage levels. Addition of filter aid to the liquid to be filtered is referred to as body feed. The type and grade as well as quantity to be added is vitally important to obtain the highest filtration flow rate consistent with the clarification required [9]. In general, a dosage of ½ of the percent solids by weight is close. Body feed can be added directly to the tank of liquid to be filtered, or dosed from a slurry tank into the filter inlet.

Leaf Filter

A vacuum leaf filter has a filter leaf (A disk like setup having metal wire screens on its two ends). A flexible rubber hose is connected to this leaf. The other end of rubber hose is connected to vacuum pump. Vacuum gauge is provided to lead this sub-atmospheric pressure, when the vacuum is switched on the inner side of the filter leaf is subjected to vacuum. The level of the vacuum can be adjusted using the valve provided [10]. The slurry moves towards the leaf the filter, liquid passes through the filter medium, and the solids are deposited over the surface of the filter cloth. The filtrate then passes through the rubber hose and then goes to a cylindrical collecting tank which has the provision to measure the volume of the filtrate by measuring the level of filtrate.

The slurry is pumped under pressure into a vessel that is fitted with a stack of vertical leaves that serve as filter elements. Each leaf has a centrally located neck at its bottom which is inserted into manifold that collects the filtrate. The major advantage of leaf filter is that the slurry can be filtered from any vessel. Removal of the cake is facilitated by the use of reverse air flow. The cake can be washed simply by immersing the filter in a vessel of Water. It is

mechanically simple since there are no complex sealing glands or bearings. The disadvantages of leaf filter are (i) large floor space is required for discharging the cake on horizontal vessels and (ii) high headroom is required for dismantling the leaves on vertical vessels.

Plate and Frame Filter Press

A filter press uses increased pump pressure to maximize the rate of filtration and produce a final filter cake with water content under 65%. This is more efficient than regular filtration because of the increased filtration pressure applied by the pump that can reach anywhere between 50–200 pounds per square inch. The filter press consists of a set of plates designed to provide a series of chambers or compartments in which solids may collect. The plates are covered with a filter medium such as canvas slurry is admitted to each compartment under pressure. Liquor passes through the canvas and out a discharge pipe, leaving a wet cake of solids behind. In the given filter press, plates and frames sit vertically in a metal rock, with cloth covering the face of the plate and are squeezed by a screw [11].

Slurry enters at one end of the assembly of the plates and frames. It passes through the setup and the solids are deposited on the cloth-covered faces of the plate. Liquor passes through the cloth, down grooves in the plate faces. As the filtration operation precedes the thickness of the cake increases and hence total resistance increases, the resistance offered by filter medium becomes very low and is usually neglected. Filter presses generally work in a "batch" manner. The plates are clamped together, and then a pump starts feeding the slurry into the filter press to complete a filtering cycle and produce a batch of solid filtered material, called the filter cake. The stack of plates is opened, solid is removed, and the stack of plates is re-clamped and the filtering cycle is repeated.

Results and discussions

The experiments were carried out in leaf filter and plate and frame filter press to observe the effect of use of filter aid on specific cake resistance and the results are presented. Diatomite and perlite at various concentrations such as 0.2, 0.4, 0.6 and 0.8% were used as body feed in $CaCO_3$ slurry in water and the results are presented. Fig. 1 shows the effect of filter aid concentration on specific cake resistance for both diatomite and perlite for 4 % (by weight) calcium carbonate slurry in water in leaf filter. It was observed that the specific cake resistance decreased with increase in concentration of filter aid for both diatomite and perlite. It was also noticed that for 4 per cent calcium carbonate slurry, perlite was more effective in reducing the specific cake resistance for filtration in vacuum leaf filter. Fig. 2 presents the effect of filter aid concentration on specific cake resistance for both diatomite and perlite for 3 % (by weight) calcium carbonate slurry in water in plate and frame filter press. Results showed that the increase in concentration of filter aid decreased the specific cake resistance. It was noticed that though both perlite and diatomite reduce the specific cake resistance for filtration in plate and frame filter press, perlite is effective in reducing the resistance.

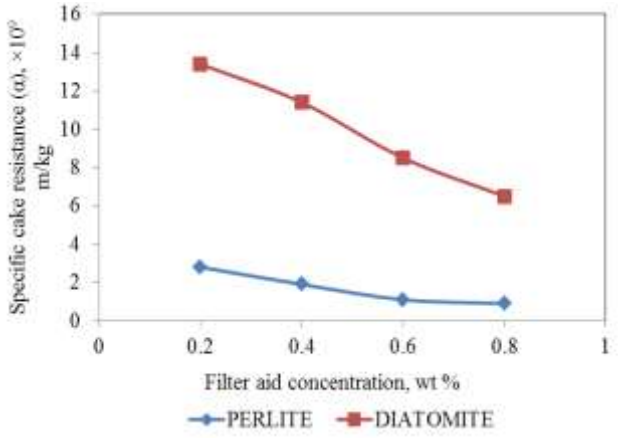

Fig. 1. Effect of filter aid concentration on specific cake resistance in leaf filter for 4 per cent concentration of $CaCO_3$ in leaf filter

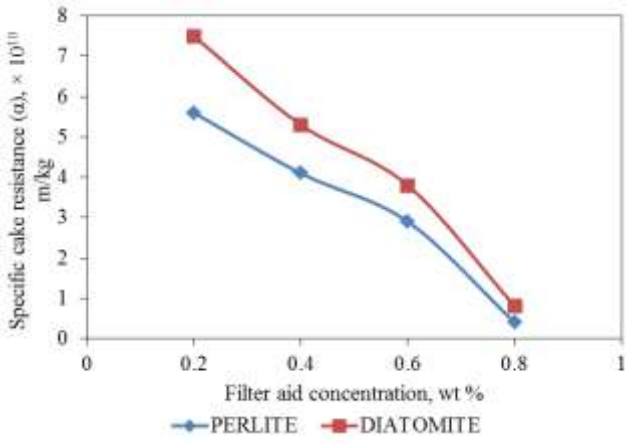

Fig. 2. Effect of filter aid concentration on specific cake resistance in leaf filter for 3 per cent concentration of $CaCO_3$ in plate and frame filter press

The effects of concentration of diatomite and perlite on filter medium resistance are

presented in Fig. 3 and Fig. 4 for filtration in leaf filter and plate and frame filter press, respectively. The results show that the resistance for filtration decreases with increase in filter aid concentration for both diatomite and perlite in both the filters used. Moreover, it was also observed that when compared with diatomite, perlite is more suitable for reducing the filter medium resistance for the filtration of calcium carbonate in both vacuum leaf filter and plate and frame filter press.

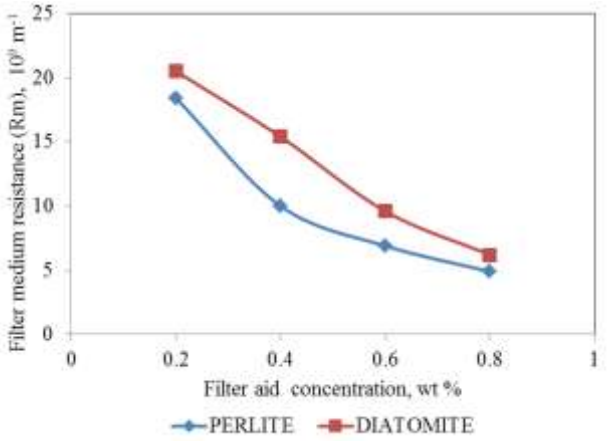

Fig. 3. Effect of filter aid concentration on filter medium resistance in leaf filter for 2 per cent concentration of $CaCO_3$ in leaf filter

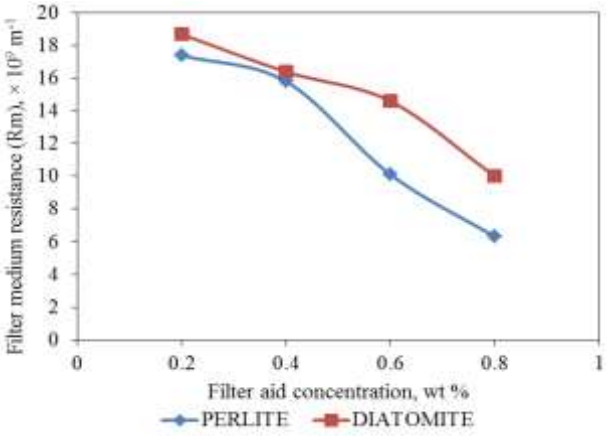

Fig. 4. Effect of filter aid concentration on filter medium resistance in leaf filter for 3 per cent concentration of $CaCO_3$ in plate and frame filter press

Conclusions

Perlite and diatomite were used as filter aid at 0.2, 0.4, 0.6, and 0.8 % (by weight) concentrations (one filter aid at a time) for the filtration of 2, 3 and 4 percent calcium carbonate slurry as body feed in vacuum leaf filter and plate and frame filter press. It was observed that the use of filter aid was effective in minimizing the specific cake resistance at lower initial concentration of the slurry. The resistance, particularly the specific cake resistance, was found to decreases with increase in concentration of the filter aid for both perlite and diatomite. Results indicated that when compared with diatomite, perlite is more effective in reducing both filter medium resistance and specific cake resistance in bath vacuum leaf filter and plate and frame filter press. From the results obtained, it is clear that the resistance for filtration is reduced to a considerable extent by the use of filter aid which in turn would reduce the total power consumption for filtration. Thus by reducing the resistances, the filtration efficiency is increased and the operating cost and filtration time can be reduced.

Conflicts of Interest

Authors declare no conflict of interest.

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