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Removal of Moisture from the Ultra Fine Particles Using Both High Centrifugal Force and Air Pressure

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Abstract: A newly developed centrifugal batch dewatering unit was developed and used to remove the moisture contents of ultra fine particles (e.g., kaolin clay, silica, talc, and precipitated calcium carbonate). In the present method, air pressure was applied into the vessel of a conventional centrifuge to improve the efficiency of the dewatering. The experimental results showed that the moisture reductions of the samples could be enhanced more than 50% depending on dewatering conditions (i.e., G-force, spin time, applied pressure, cake thickness, particle size, surface hydrophobicity, and particle agglomeration). As a result, when the new centrifuge modification is used for the fine particle dewatering, cost and environmental concerns of thermal dryers could be considerably reduced and the handleability of the filter cakes could be significantly increased.

Keywords: Air pressure and moisture reduction, centrifugal force, ultra fine particles

INTRODUCTION

Recently, the production of ultra fine particles has been increased due to the advanced wet production methods, which necessitates better filtration efficiency (1–3). There are presently several centrifugal filtration methods designed for fine particles filtration/dewatering (i.e., powder, coal,

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mineral, sludge, and tailings). These centrifuges are mostly used in the absence of air/vacuum pressure (so called classical centrifuges) with a wide variety of models (1–4). Prior to the present study, a method of creating a negative pressure on the outside wall of a centrifuge was developed to increase the filtration rate. In that method, as the water in the chamber is subjected to a larger centrifugal force, a negative (or vacuum) pressure is created due to the siphon effects (3–6).

In addition, a method of injecting hot steam into the bed of particles during the centrifugation was developed to reduce the surface moisture of the particles (7). In this invention, hot steam is directly injected into an open space without the pressure drop across the bed of particles. This technique is useful if the particle sizes are in the range of 0.5 to 30 mm in basket centrifuges. However, it is difficult to increase the pressure drop, when a scrawl, which is widely used to move the particles in the centrifuges, continually disturbs the filter cake. Therefore, a blower rather than a compressor, which would make it difficult to create a high pressure drop across a filter cake, creates only the airflow (7–10).

Water flow through the cake is dependent on the surface hydrophobicity of the fine particles. When a low hydrophilic-lipophilic balance (HLB) surfactant is used to increase the hydrophobicity of the particulate materials, the rate of drainage during the centrifugal dewatering can be enhanced. According to the Laplace equation, an increase in hydrophobicity should result in a decrease in capillary pressure, which in turn helps increase the drainage rate (11–13). This is particularly important for difficult-to-dewater materials, such as sludge, clay, precipitated calcium carbonate (PCC), and silica, to receive lower cake moisture products.

In the present work, G-force and air pressure were considered together to further reduce the moisture contents of the ultra fine hydrophobized particles (fine kaolin clay, silica, talc and PCC) after the first step of filtration. Figure 1 shows the schematic illustration of the novel batch centrifuge where three forces (capillary pressure, centrifugal pressure, and air pressures) act on the cake surface. In this scenario, the centrifugal and air pressures work against the capillary pressure to remove more water.

EXPERIMENTAL

Samples

Several mineral samples including kaolin clay, silica, talc, and PCC were received from various plants. The samples introduced to the centrifuge dewatering tests were not initially hydrophobic, so they were hydrophobized using appropriate surfactants. During the entire period of the

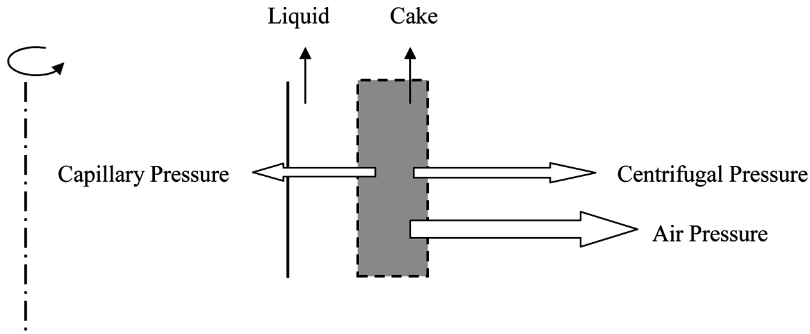

Figure 1. Schematic illustration of three acting pressures on the cake into the novel centrifuge at a given moment.

tests, new samples were prepared to avoid the superficial oxidation of the particle surface that could prevent the change of dewatering results. In addition, particle size distribution of the sample was measured by wet sieve screening before the tests. The samples received from the hydrophobization process were in the form of slurry, so the solid content of the samples was improved by using a large funnel filter. The centrifugal dewatering tests were conducted on the thickened samples at different G-force, air pressure, cake thickness, and spin (or centrifugation) time.

Method

A 9 cm in diameter stainless steel basket was installed inside of a centrifuge (Beckman J2 Series), and then connected to an external supply of compressed air, which was varied from 25 kPa to 600 kPa [19]. The rotational speed (or applied G-force) of the vessel and cake thickness (between 0.5 cm and 1.5 cm) were changed depending on the dewatering conditions. After the centrifugation tests were completed, the cake was removed from the filter vessel, weighed, dried in a conventional oven overnight, and then weighed again to determine the percent moisture contents of the filter cakes.

Figure 2 shows the novel centrifuge developed for the fine particle dewatering. The compressed air was injected to create a pressure drop across the filter cake into the centrifuge vessel (19). The sidewall was made of perforated stainless steel with 2 mm, 3 mm, and 4 mm holes. The filter vessel was tightened against the rotor of the centrifuge by means of a screw. A filter cloth, which was designed to fit the contour of the centrifuge vessel, was placed inside the vessel. Thickened slurry was then poured into the filter cloth and the sidewall of the filter vessel

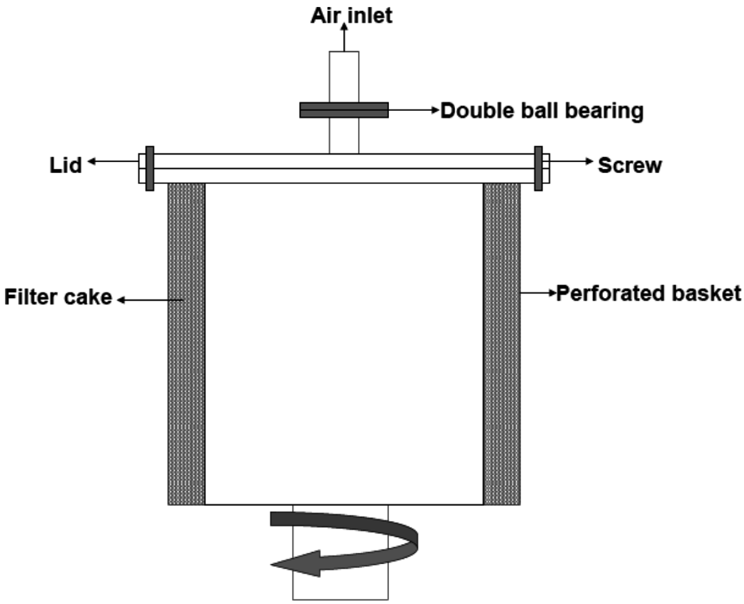

Figure 2. Schematic representation of the novel centrifuge with an air inlet addition.

to form a cake. The filter vessel was then covered by a lid, which was tightened against the filter vessel by means of screws. Compressed air inlet tubing was connected at the center of the cover lid. A double ball-bearing connector was used to couple the compressed air inlet tubing that also carried an airflow meter and a pressure gauge to measure the airflow rate through cake and pressure drop across the cake.

RESULTS AND DISCUSSION

Clay Sample

A kaolin clay sample (80% lower than 20 μm) received from the Far East was conditioned by adding 1000 g/ton dodecylamine and 150 g/ton methylisobutylcarbinol (MIBC) at pH 9.1 (adjusted by lime addition). It is expected that when a surfactant was added to the clay sample, the moisture reduction can be elevated due to the hydrophobicity improvements of the fine particles (8,17–20). The slurry was then flocculated in the presence of 300 g/ton Super Floc 214 (Ciba), and then thickened to 45.9% moisture content before the tests. Table 1 gives the dewatering

Table 1. Effects of G-force and air pressure on the dewatering of the kaolin clay sample at 1500 G-force and 1 cm cake thickness

Spin time (sec.)	Cake moisture (%) Air pressure (kPa) None	150	300	450	600
0	45.9	45.9	45.9	45.9	45.9
30	40.3	31.3	30.2	27.7	25.4
60	39.7	30.0	28.6	27.2	24.3
90	39.0	29.1	28.2	25.8	23.8
120	38.7	28.0	26.1	25.3	23.4

results of the clay sample at 1500 G-force, 1 cm cake thickness and various air pressures.

In the absence of air pressure, the moisture content was reduced from 45.9% to 38.7% after 120 seconds of spin time. However, when 600 kPa air pressure and 1500 G-force were performed together, the cake moisture was further reduced to 23.4% at the same spinning time, representing an approximately 49% moisture reduction. It is known that one of the most difficult materials to dewater is the fine kaolin clay. These results confirm that such a high moisture reduction can be obtained using the novel centrifuge modification.

The second sets of tests were also conducted on kaolin clay samples (95% below 2 μm) from South America after the hydrophobization and thickening (61.3% moisture content) steps as described in the previous clay sample. Table 2 presents the dewatering results of the clay samples at 2000 G-force and 0.5 cm cake thickness at different air pressures. The test results show that the moisture contents of the kaolin clay could be decreased from 61.3% to 26.7% at 2000 G-force, 600 kPa air pressure and 240 second spin time. This will obviously reduce the energy need for a spray thermal drying unit, which is a costly and not environmentally friendly method in the clay industry (2,13,19).

Clay is a plate-like mineral that absorbs more water molecules into plates (19). Thus, the surface area of the clay mineral is 10 to 300 times higher than that of the other minerals (silica, sulfide, phosphate, talc, etc.), so the capillary pressure in the cake can be considerably high for the clay particles. This indicates that removing the water from clay minerals and other ultra fine particles requires higher G-forces (or energies) and longer spinning time (13–20). However, the novel method could be a solution for the clay minerals dewatering for many plants worldwide.

Table 2. Effects of G-force and air pressure on the dewatering of the kaolin clay at 2000 G-force and 0.5 cm cake thickness

Spin time (sec.)	Cake moisture (%) Air pressure (kPa)				
	None	150	300	450	600
0	61.3	61.3	61.3	61.3	61.3
30	51.7	42.8	38.6	36.0	33.1
60	49.6	38.6	34.5	32.9	30.2
120	48.3	37.0	32.2	30.0	28.4
240	47.5	35.2	30.1	28.4	26.7

Silica Sample

A series of centrifugal dewatering tests were conducted on a fine silica sample (–150 µm) obtained from a plant located in the Eastern USA. Figure 3 shows the size distribution of the silica sample, which confirms that an approximately 80% is below 65 µm. To increase the hydrophobicity of the silica particles, standard flotation tests were conducted on the

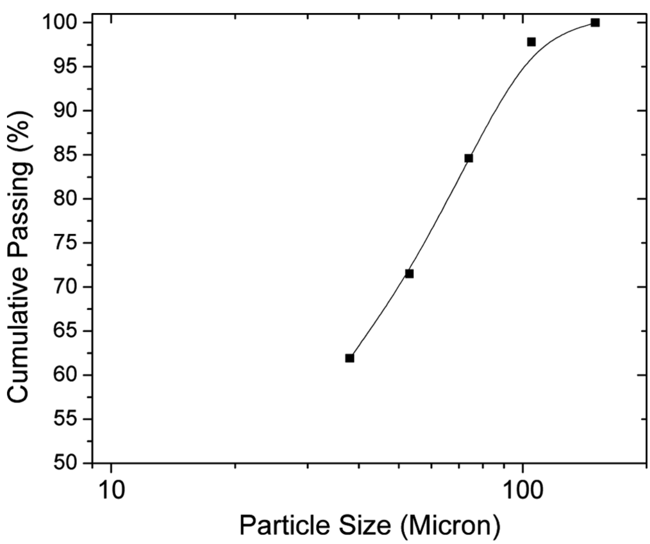

Figure 3. Size distribution of the silica sample (−150 µm) used in the present dewatering tests.

sample using 500 g/ton dodecylamine and 100 g/ton MIBC at pH 9.5 (lime) in a conventional flotation cell. The centrifuge test results conducted on the thickened sample at 1000 G-force, 1.2 cm cake thickness, and 2 minutes of spin time are given in Table 3.

In the base line tests where no air pressure was applied, the cake moisture was reduced from 35.2% to 24.1% after 120 seconds of the spin time. At 300 kPa of air pressure and the same conditions, the moisture content was decreased nearly to 9%. This is an approximately 62% increase in moisture reduction as compared to the base case (24.1%). It is also seen that most of the moisture is removed from the cake at the early spin time (first 30 seconds). The test results clearly confirm that G-force combined with the air pressure provides significantly high moisture reductions; therefore, this product does not need too much energy input in the thermal dryers for the ongoing processes.

Talc Sample

Several dewatering tests were carried out on the fine talc samples to determine the novel centrifuge efficiency. The talc samples (–150 μm) received from a talc company in the USA were floated using 125 g/ton polypropylene glycol (PPG) type frother at neutral pH. The floated product was then thickened in a funnel before the centrifugation. The tests were performed at 2000 G-force and 1.5 cm cake thickness by varying spin times. The test results given in Table 4 exhibited that the cake moisture of the clean talc sample was reduced from 33.2% to 24.5% at 120 seconds of spin time. In contrast, when 50 kPa, 100 kPa, 200 kPa and 250 kPa, of air pressures were applied at the same conditions, the moisture contents of the filter cakes were reduced from 33.2% to 17.7%, 15.2%, 12.3%, and 11.7%, respectively.

Table 3. Centrifugal test results conducted on the silica sample at 1000 G-force and 1.2 cm cake thickness

	Cake moisture (%)				
	Air pressure (kPa)				
Spin time (sec.)	None	50	100	200	300
0	35.2	35.2	35.2	35.2	35.2
30	27.3	19.5	15.6	12.6	11.4
60	26.0	17.7	13.8	10.7	9.9
120	24.1	16.3	12.8	10.3	9.2

Table 4. Centrifugal test results conducted on the clean talc sample at 2000 G-Force and 1.5 cm cake thickness

Spin time (sec.)	Cake moisture (%)				
	Air pressure (kPa)				
	None	50	100	200	250
0	33.2	33.2	33.2	33.2	33.2
30	24.9	20.9	17.5	15.9	15.5
60	24.6	19.0	16.0	13.7	13.1
120	24.5	17.7	15.2	12.2	11.7

Precipitated Calcium Carbonate Sample

Synthetically produced precipitated calcium carbonate (PCC) is another ultra fine material that is very difficult to dewater in conventional dewatering methods. In this example, near nanosize PCC samples (–2 μm) received from the North Eastern UAS was subjected to the novel centrifugal filtration tests. According to the size of the PCC sample, the capillary diameter of the cake is the lowest among the other minerals (2,19). In this set of the tests, the PCC sample was conditioned using 500 g/ton sodium oleate at pH 9.5. The slurry was then thickened to 70.3% moisture content before the filtration experiments, and then the thickned samples were used for the dewatering tests at 1000 G and 1 cm cake thickness. As is shown in Table 5, the cake moisture was reduced from 70.3% to 59.0% after 3 minutes of spin time in the absence of the air pressure.

Table 5. Centrifugal test results conducted on the PCC sample at 1000 G and 1 cm cake thickness

Spin time (sec.)	Cake moisture (%)				
	Air pressure (kPa)				
	None	150	300	450	600
0	70.3	70.3	70.3	70.3	70.3
30	64.2	54.7	48.8	45.0	40.1
60	62.5	51.7	46.3	41.1	37.7
120	60.7	49.3	43.7	39.4	36.0
180	59.0	48.2	43.4	38.6	35.3

At 600 kPa air pressure, the moisture was reduced from the base line to 35.3%, representing an approximately 50% moisture reduction.

During centrifugation, it was observed that at higher air pressures the filter cakes were cracked into several small pieces. The author assumes that it may be attributed to the removal of a large volume of water from the cake causing shrinkage on the cake surface. If an appropriate method is found to prevent the breakage problem, the moisture contents of the filter cakes can be further reduced, which in turn will allow the filter cakes to be directly used in paper, ceramic, composite, or paint industries.

CONCLUSION

A novel centrifugal filtration unit was developed to remove the surface moisture of ultra fine particles (e.g., clay, silica, talc, and PCC) at various G-Force, air pressure, spin time, and cake thickness. The test results showed that the dewatering results of the fine particles were significantly higher when the air pressure was applied inside the centrifugal vessel. This method can be applicable to many other organic and inorganic fine particles filtration and dewatering, as well. As a result, it is concluded that the novel filter can decrease the costs of the dewatering process and environmental concerns of the thermal dryers in the fine particle processing plants.

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