Effect of clay-stickie interaction on centrifugal cleaner efficiency

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ABSTRACT: Small clay particles can agglomerate with polyvinyl acetate (PVAc) to form neutral-buoyancy aggregates. When clay is centrifuged in water, a small quantity of the clay remains suspended in water. Clay is heavier than water and the suspended solids are particles too small to be centrifuged down. At 45°C, adding PVAc to the mixture before centrifuging does not change the concentration of suspended solids in the experiment. This is because both clay and PVAc are heavier than water at this temperature; any aggregates that form would also be heavier than water and would not affect the number of suspended particles. However, centrifuging the clay-PVAc mixture at 60°C increases the amount of suspended solids because PVAc floats at this temperature, and aggregation of the now lighter PVAc with the heavier clay increases the quantity of neutral-buoyancy particles. The formation of aggregates is confirmed by electron microscopy and by particle size measurements. Centrifugal cleaners will not remove these neutral-buoyancy aggregates. Furthermore, the stickies coat onto and increase the effective surface area of the particles. Hence, clay can extend the impact of stickies by increasing their effective concentration and decreasing their cleanability.

Application: The study shows that clay and stickies can form neutral-buoyancy agglomerates that cannot be removed by centrifugal cleaners.

The efficiency of centrifugal cleaners depends principally on the size and specific gravity of the particles to be removed [1]. Mills use cleaners extensively in paper recycling, but their performance is frequently less than optimal, suggesting that other factors might come into play. Contaminants range greatly, from heavy particles such as ink and clay to lighter materials such as organic adhesives. Typically, heavy contaminants are removed more successfully than are the adhesives. In a survey of stickies from various process streams at two newsprint mills, we found that clay was frequently associated with stickies even after passage through both forward and reverse cleaners [2]. This was curious since clay has a specific gravity of 1.8 g/cm^3, and should have been easily removed. In this paper we demonstrate that clay can associate with polyvinyl acetate (PVAc) to form neutral-buoyancy aggregates that will not be rejected by centrifugal cleaners.

EXPERIMENTAL

We obtained polyvinyl acetate (MW 500,000) from Polysciences Inc. and kaolin clay (DB KOTE 2 Spray Dried) from Dry Branch Kaolin Co. For the turbidity measurement, we continuously stirred the mixture of clay and PVAc as we heated it to the desired temperature. We then centrifuged the suspension in an insulated vessel at 400 g for 15 min and measured the turbidity immediately with an Orbeco-Hellige 65-10A turbidimeter. Total suspended solids (TSS) present in the same sample were measured gravimetrically; the uncertainty in the TSS measurement was about 7%. The relationship between TSS and turbidity established from several clay suspensions is provided in equation 1.

$$\text{TSS (g/L)} = 0.0002\ \text{turbidity (NTU)} - 0.0015\ (r^2 = 0.92, n=4) \quad (1)$$

We saw no change in TSS when a mixture of 0.4% clay and 0.2% PVAc in water was stirred at 60°C for 0.5-4 h and centrifuged, indicating that steady-state conditions are reached rapidly. Hence, we used a stirring period of 30 min throughout. All measurements were made in triplicate. No measurable turbidity resulted when we centrifuged pure PVAc in water at either 45°C or 60°C. A series of experiments was run where mixtures of clay (0.1%-0.4%) and PVAc (0.2%) were added to water at various temperatures with stirring and centrifuged. We measured the turbidity and converted to TSS through equation (1).

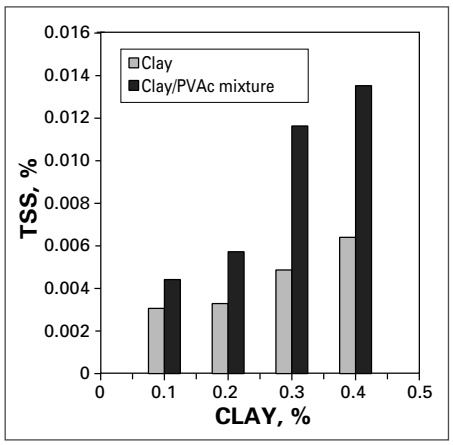
For the electron microscopy work, a 0.4% clay suspension in water was centrifuged as above to isolate the neutral buoyancy particles and PVAc (0.2%) was added to the centrifugate at 70°C with stirring. We then filtered the suspension through a YM1 membrane (Millipore Corp., Bedford, MA), and took images of the residue with a JSM-6400 instrument. For the particle size measurements, suspensions of clay in water (0.1%-0.4%) were centrifuged, PVAc (0.2%) was added, and the suspension heated to 70°C with stirring. Particle size was measured with a Malvern Zetasizer.

RESULTS AND DISCUSSION

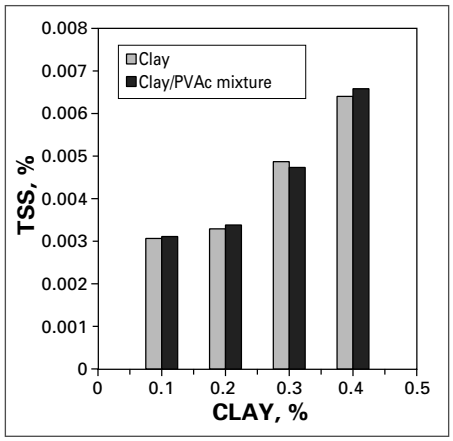
The specific gravity of PVAc in water is temperature-dependent [3]; the polymer used in this study floats at temperatures above 50°C and sinks at cooler temperatures. We reasoned that if PVAc and clay (which is heavier than water) were added to water, then at high temperatures we would have one floating and one sinking component, whereas at temperatures below 50°C, both components would sink. Hence, there is a potential for neutral-buoyancy clay/PVAc agglomerates to develop in the former situation, but not in the latter.

Figure 1 compares the TSS of clay alone to that of mixtures of clay and PVAc at 60°C. The TSS of the mixture is substantially higher than those of the individual components. We obtained similar results at 70°C and 80°C, but contrasting results at 45°C (**Fig. 2**), where the presence of PVAc makes no significant difference to the TSS. Interpretation of these results is straightforward. At the higher temperature, the light PVAc partially agglomerates with the heavy clay to form a neutral-buoyancy mixture. Both components are heavy at the lower temperature, and agglomeration does not bring the clay into suspension.

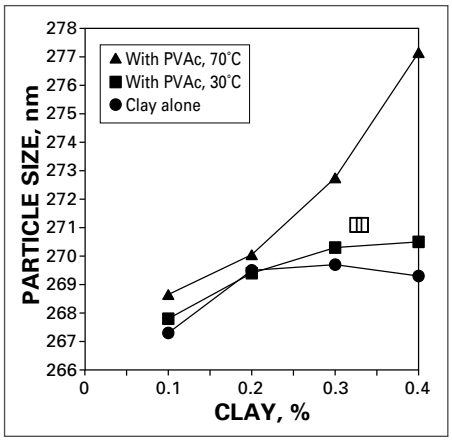
Clay is much heavier than water, and the TSS of the suspension derived from clay alone must be due to particles that



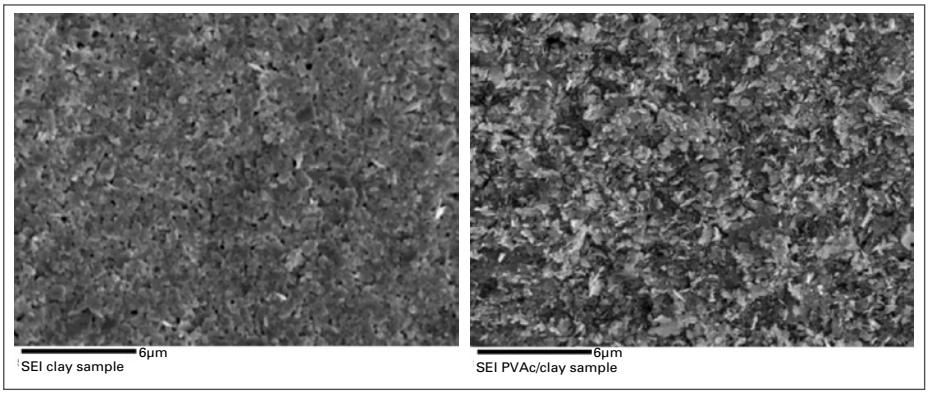
1.Effect of 0.2% PVAc on the TSS of clay in water at 60°C. The bold and hatched bars represents clay and the clay/PVAc mixture, respectively.



2. Effect of 0.2% PVAc on the TSS of clay in water at 45°C. The bold and hatched bars represents clay and the clay/PVAc mixture, respectively.



3. Particle size of solids in clay-PVAc centrifugate. The clay values reflect the quantities initially added.



4. SEM images of clay (left) and clay-PVAc aggregates (right).

are too small to be centrifuged down [4]. It is likely that the adhesive coats the clay particles and reduces their specific gravity at the higher temperature. This brings a subset of the population into the neutral-buoyancy region. Increasing the quantity of clay relative to that of PVAc increases the subset affected. The difference in TSS in Fig. 2 increases almost linearly with clay content, which suggests at least a quasi-equilibrium. We calculated a value of 0.0016 gL^{-1} for the ratio [TSS]/[clay][PVAc]. We believe this value is a measure of the sub-population brought to neutral buoyancy.

Aggregate formation should increase particle size, and measurements were first made on the centrifugate from suspensions of 0.1%-0.4% clay in water. The results presented in **Fig. 3** demonstrate that the particle size stabilizes at 269-270 nm. The particles grow in the presence of PVAc at 70°C in keeping with the formation of aggregates. In contrast, the 30°C profile is similar to that of clay alone. The differences in particle size are barely outside experimental uncertainty, but they are consistent with the TSS results in Figs. 1 and 2. The particle size increases by a maximum of only 3% in Fig. 3, which means that the aggregate is still much heavier than water. We believe that clay particles of a size range just large enough to be centrifuged down in the absence of PVAc are brought into suspension through agglomeration with the polymer.

Finally, scanning electron microscope (SEM) images provide direct evidence for the association of PVAc and clay. **Figure 4** compares images of aggregates to those of clay alone. A relatively uniform coating of polymer on clay is visible. Considered together, our results demonstrate that clay associates with PVAc (and probably other stickies) and that a fraction of the aggregate is of neutral buoyancy. This explains why clay and stickies can be found together downstream of the cleaners. The stickie-coated clay particle behaves like a stickie itself. In effect, agglomeration extends the surface area of the stickies and increases its impact. Practical application of these results will be mill-specific. Clay that enters with the furnish is intentionally retained in some mills; its removal could be beneficial if stickie/clay deposits are found in the product. **TJ**

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