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USE OF THE TENSION CELL TO MONITOR PARTICLE INTERACTIONS IN SUSPENSIONS

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Abstract

The tension cell was able to monitor the effect of adsorbing either a nonionic or ionic surface active agent on particle arrangements in kaolinite suspensions. Adsorption of polysorbate 80 affected particle interactions by steric stabilization. Adsorption of sodium dodecylbenzenosulfonate produced dispersion by a combination of electrostatic repulsion and steric stabilization. The interpretation of the effect of the adsorbed surface active agents was supported by rheological studies.

Introduction

Particle interactions are important in suspensions because they contribute to many of the physical properties. Techniques to study particle interactions are therefore important in the formulation and manufacture of suspensions. Several techniques to monitor particle interactions have been recently described. These include fiber optic Doppler anemometry (1,2), the pressure cell (3) and capillary suction (4). It was believed that the discharge of water from suspensions under very low applied tensions could give insights into the nature of particle interactions. A device, termed the tension cell, was recently developed to quantify the outflow of water under very small pressure loads, i.e., 2 to 19 cm of water (5-7). This applied tension represents only a fraction of an atmosphere (1 atmosphere is equal to a tension of 1036 cm of water). These low applied loads are unlikely to destroy any particle interactions present in the suspension. The utility of the tension cell in suspension formulation and manufacture was evaluated by examining the effect of surface active agents on particle interactions in a model kaolinite suspension.

Materials and Methods

A simplified schematic drawing of the tension cell is presented in Figure 1. A suspension is placed into the cylindrical chamber which is fitted at its base with a membrane filter. Initially, the suspension is in equilibrium with a constant load, τ_o, applied to the suspension which has an initial length of L_o. An additional load is placed on the suspension by lowering the outflow port by $d\tau$, so that the new load is $\tau_1 = \tau_o + d\tau$. Water will flow out of the suspension until the system is reequilibrated with the length of the suspension

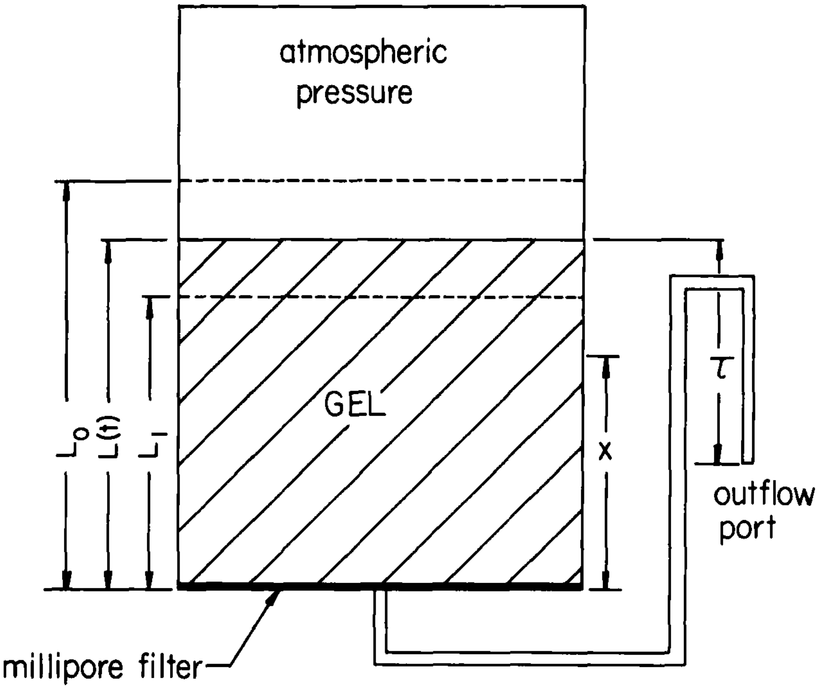

Figure 1

Schematic of the tension cell.

column decreasing from L_o to L_1. Equilibration occurs when interparticle and hydration forces are capable of preventing further consolidation of the suspensions. The position of the outflow port is automatically lowered as the length of the suspension decreases in order to maintain a constant applied tension. Detailed procedures for constructing and operating the automated tension have been reported (7).

Permeability, which is inversely related to the amount of resistance offered to fluid flow, can be determined from the data obtained from the tension cell. The hydraulic conductivity, K, is defined by Darcy's Law, which in one dimension has the form:

$$J_{rel.} = -K \frac{dh}{dx} \qquad \text{Eq. 2}$$

where $J_{rel.}$ is the flux of the fluid relative to the porous medium, h is the total water potential and x is the usual space coordinate. Since the hydraulic conductivity depends on liquid phase properties as well as those of the porous particle network, the permeability, k, a property of the porous particle network, is extracted through the following equation:

$$K = \frac{k\rho g}{\mu} \qquad \text{Eq. 3}$$

where ρ is the density of the liquid phase, μ is the viscosity of the liquid phase and g is the acceleration due to gravity (7).

A 46% w/v suspension of kaolinite (Hydrite-10, Clay Mineral Repository, Department of Geology, University of Missouri, Colorado, MO) was prepared by mixing the proper amounts of clay and water for 24 hours with a propeller mixer and passing the suspension through a hand homogenizer.

Langmuir adsorption isotherms at 25°C for the adsorption of polysorbate 80 or sodium dodecylbenzenosulfonate by kaolinite were determined by the following procedure. Suspensions containing various concentrations of the appropriate surface active agent and 1 g of kaolinite per 100 mL were shaken for 1 hour and the supernatant was separated by centrifugation. The concentration of surface active agent in the supernatant was determined by ultraviolet spectroscopic analysis. The amount of surface active agent adsorbed was determined by difference.

Suspensions containing 46% w/v of kaolinite were prepared which contained a quantity of the appropriate surface active agent equivalent to the adsorptive capacity as determined by the adsorption isotherms. These suspensions were evaluated in the tension cell and by a rotational viscometer (Model RV 12, Haake Buchler).

Results and Discussion

The decrease in permeability as water was discharged from the kaolinite suspension is shown in Figure 2, line A. The water content of the suspension is expressed as the void ratio which is the ratio of the pore volume to the solids volume. The kaolinite exhibited characteristic plastic rheology with a yield value of 260 dynes cm^{-2} (Fig. 3, line A).

Surface active agents have been found to alter particle interactions in kaolinite suspensions (8). It was, therefore, decided to determine if the tension cell could detect changes in particle interactions following adsorption of nonionic or anionic surface active agents. Polysorbate 80 was selected as a model nonionic surface

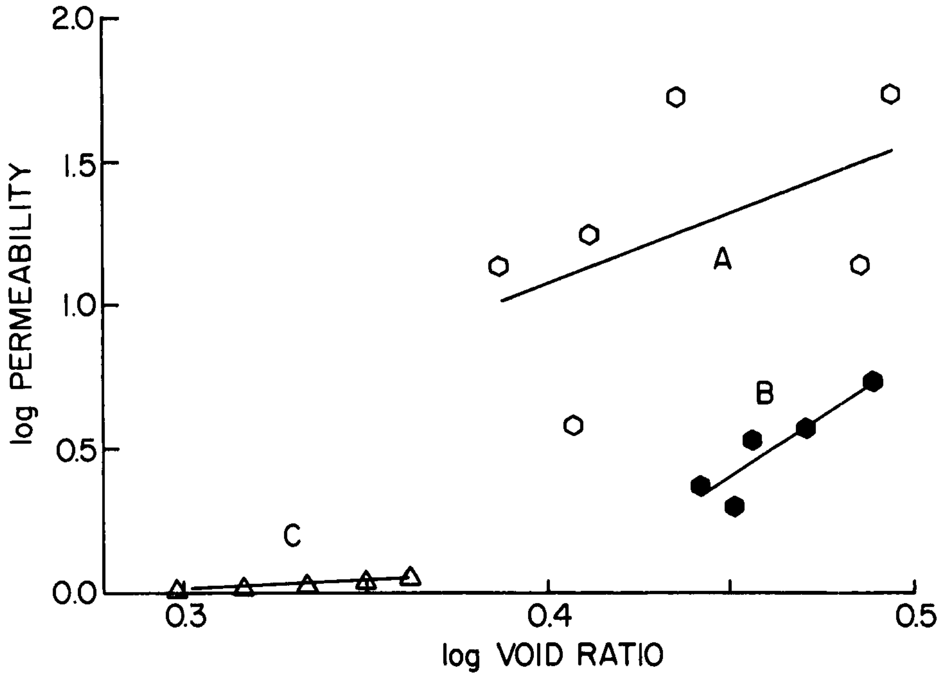

Figure 2

Permeability of a 46% w/v kaolinite suspension under applied tensions ranging from 2 to 18 cm water. Key: A, no surface active agent; B, 10 mg polysorbate 80 adsorbed per gram of kaolinite; C, 5 mg sodium dodecylbenzenosulfonate adsorbed per gram of kaolonite.

active agent. The Langmuir adsorption isotherm indicated an adsorptive capacity of 10 mg/g. Tension cell results show that the adsorbed polysorbate 80 had a significant effect on the permeability of the kaolinite suspension (Fig. 2, line B). The permeability was reduced at all applied tensions by approximately an order of magnitude and the void ratio increased slightly. These changes suggest that the adsorbed nonionic surfactant is reducing particle interactions by steric stabilization. The

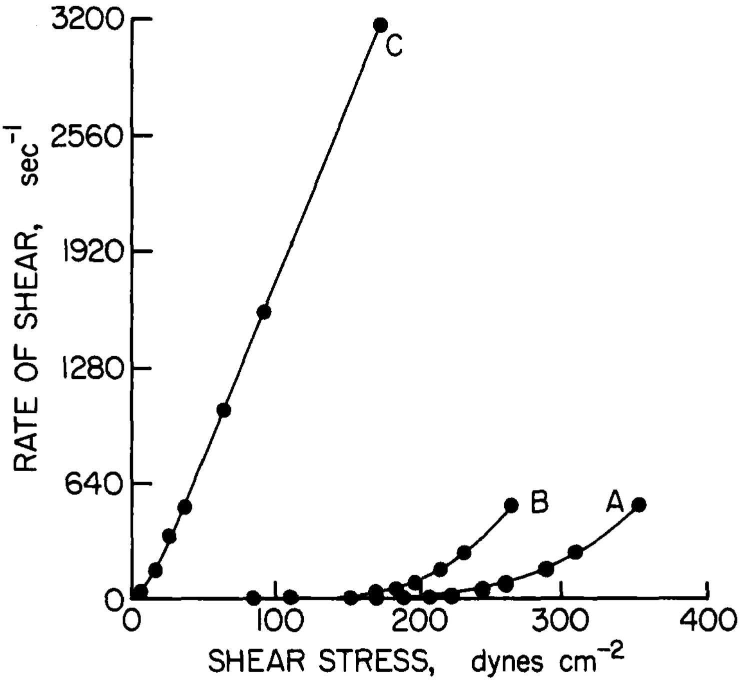

Figure 3

Rheograms of a 46% w/v kaolinite suspension. Key: A, no surface active agent; B, 10 mg polysorbate 80 adsorbed per gram of kaolinite; C, 5 mg sodium dodecylbenzenosulfonate adsorbed per gram of kaolinite.

conclusion that polysorbate 80 imparted steric stabilization was confirmed by the change in rheology seen in Figure 3, line B. The yield value was reduced from 260 dynes cm^{-2} to 200 dynes cm^{-2} by the adsorption of polysorbate 80.

Sodium dodecylbenzenosulfonate was selected as the model ionic surface active agent. The Langmuir adsorption isotherm yielded an adsorptive capacity of 5 mg/g. The adsorption of the anionic surface active agent by the kaolinite produced a decreased permeability (Fig. 2, line C). The large decrease in the permeability suggests that adsorption of sodium dodecylbenzenosulfonate caused the kaolinite suspension to become dispersed. One can visualize that dispersion will occur due to adsorption of the anionic surface active agent which will impart a negative surface charge to the kaolinite particle in addition to any contribution of steric stabilization. It is also important to note that the values of the void ratio were shifted to very low values by adsorption of the anionic surface active agent, indicating a tightly packed sediment. Likewise, the rheology became almost Newtonian (Fig. 3, line C) upon adsorption of the anionic surface active agent. These changes are characteristic of the dispersed state.

Acknowledgments

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