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Flow of Liquid-Liquid Dispersions through Metal Filters and Porous Media: Effect of Liquid Entrapment

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NOTE

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Abstract

An experimental study was done to determine the effect of water on flow resistance of crude pinanol during filtration. At constant pressure drops, pinanol-water dispersions had lower flow rates than pinanol in metal filters. For the pinanol-water dispersions, higher flow rates occurred at both high and low water volume fractions, indicating a critical volume fraction at which resistance to flow is maximum. The result also implies that water is entrapped at low water volume fractions while pinanol entrapment occurs at low pinanol volume fractions. In a constant rate pinanol-water displacement in a sandpack, the ratio of mobility of pinanol to the effective mobility of pinanol in the presence of residual water was approximately 1.5.

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The flow of liquid-liquid dispersions through filters is important in many industrial separation and processes. In the present study we investigated the flow behavior of pinanol-water dispersion. Pinanol is produced from pinene in a series of reactions (*1*) using nickel catalyst:

$$\underset{\text{pinene}}{C_{10}H_{16}} + H_2 \xrightarrow{\text{nickel}} \underset{\text{pinane}}{C_{10}H_{18}}$$

$$C_{10}H_{18} + O_2 \rightarrow \underset{\text{pinane hydroperoxide}}{C_{10}H_{18}O_2}$$

$$C_{10}H_{18}O_2 + H_2 \xrightarrow{\text{nickel}} \underset{\text{pinanol}}{C_{10}H_{18}O} + \underset{\text{water}}{H_2O}$$

Water is a by-product of these reactions and constitutes as much as 15% by volume of the produced pinanol-water dispersion (crude pinanol), not accounting for the amount dissolved in the pinanol.

The nickel catalyst is either packed in reaction columns or used as silica-floated particles. When used as floated catalyst, the nickel must be recovered by passing the crude pinanol through filtration columns. In the filtration columns, pinanol, water, and a very small amount of nickel particles flow through porous metal tubes. In nickel-packed reaction columns (beds), the nicekl constitutes the matrix of the porous medium through which reactants and the final products must flow. Thus, the simultaneous flow of pinanol and water in a porous medium is a phenomenon common to the different pinanol production processes.

Reported high-pressure drops during filtration (*2*) and subsequent collapse of filter tubes in a plant filtration column led to our experimental study of the surface-chemical aspects, rheology, and flow behavior of pinanol-water dispersions (*3*). We used crude samples from the plant. Our work showed that the presence of water, even in a residual amount, could cause high-pressure drops during the flow of pinanol. Here, we report our findings regarding the effect of water on the resistance developed during the filtration of crude pinanol.

Crude pinanol was centrifuged and the supernatant was used in the experiments reported here. In the first set of experiments, pinanol was mixed with distilled water and the tubes were shaken thoroughly for 3 min. The mixture (dispersion) was displaced by air in a vertical filtration cell containing a horizontal, 1/16 in. thick, 316-C steel filter plate. The plate had a flow area of 5.1 cm in diameter, and the same pore geometry and pore size distribution as the plant filter tubes. The displacement was performed at 5 and 10 psi pressure drops across the filter plate for various pinanol–water ratios, and the total flow rate of the pinanol–water dispersion was determined. In a base run, only the centrifuged pinanol was displaced through the filter plate. To show the effect of the water on the flow of pinanol–water dispersion, the total flow rate of the dispersion was divided by the pinanol flow rate (base run) and the ratio plotted versus the volume fraction of water in the dispersion. The plot, Fig. 1, shows lower flow rates for the pinanol–water dispersions. Higher flow rates occurred at both high and low volume fractions of water. This implies that water is entrapped at low water volume fractions while pinanol entrapment occurs at low pinanol volume fractions. The results also indicate a critical volume fraction of water, 30% in this case, at which the resistance to flow can be expected to be maximum.

In a second set of experiments, pinanol was pumped at a constant flow rate (2.32 cm^3/min) into a glass tube sandpack completely saturated with water. The sandpack (28 cm length by 2.4 cm i.d.) consisted of a 14 mesh sand with porosity and permeability of 0.39 and 4 darcies, respectively.

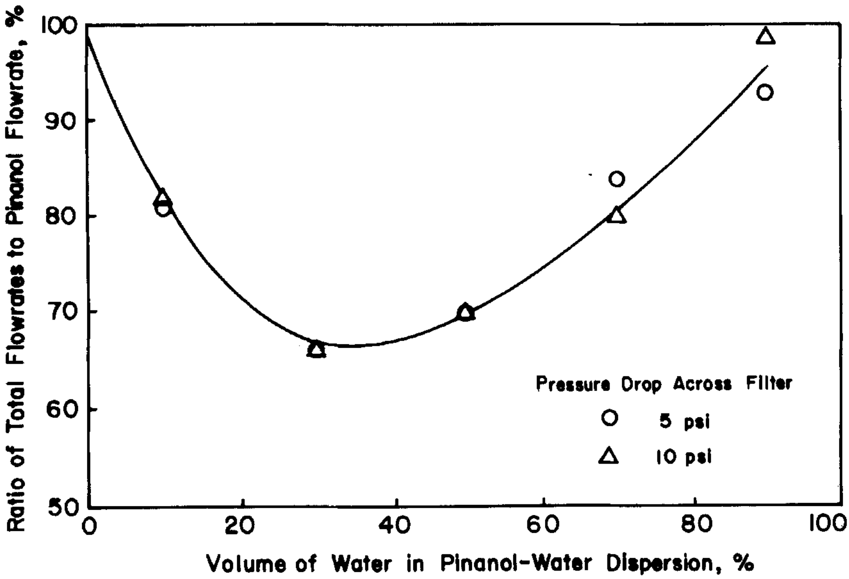

FIG. 1. Flow of pinanol–water dispersion through metal filter plate.

The pressure drop across the sandpack and the liquid recovered during the displacement were monitored. In Fig. 2 the volume of water produced and the pressure drop are plotted versus the volume of pinanol injected. Pinanol breakthrough occurred at 0.85 pore volume. At 2.0 pore volumes of pinanol injection, referring to Fig. 2, a residual water saturation of less than 0.1 pore volume and a pressure drop of 8.0 psi were obtained. The same pinanol (obtained from centrifuging the crude sample) was displaced through an identical sandpack at 100% saturation and at 2.32 cm^3/min. A constant pressure drop of 5.5 psi was obtained. This experiment shows that the presence of residual water in the porous medium increased the flow resistance for pinanol from 5.5 to 8.0 psi total pressure drop. For identical flow rates and porous media, one can show from Darcy's law (*4*) that the ratio of the mobility of pinanol to the effective mobility of pinanol in the presence of residual water is the inverse ratio of their pressure drops, 8.0/5.5, which is approximately 1.5. This phenomenon is similar to the effect of water on the flow of oil and gas in petroleum reservoirs (*4*).

In conclusion, our study has shown that the presence of water impedes the flow of pinanol in porous media, and the flow resistance is a function of water saturation. Entrapment of water or pinanol will contribute in

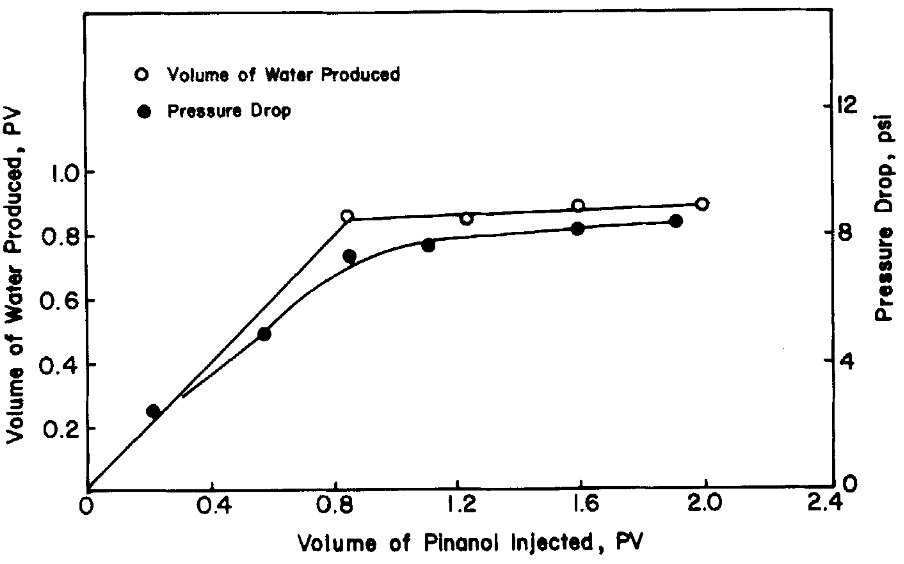

FIG. 2. Water displacement by pinanol in sandpack.

reducing the flow or increasing the resistance to the flow of pinanol-water dispersions. An improvement of both the filtration characteristics of pinanol-water dispersion in multitube filters and the flow behavior of pinanol in catalyst-packed reaction columns can be expected if produced water is effectively removed from the production system.

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