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The Effect of a Pure Surfactant on the Damping of Liquid-column Oscillations

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In a previous communication (McComb, 1974) it was reported that polyethyleneoxide (PEO: Polyox grades WSR301 and N3000) in aqueous solution reduced the damping of manometer types of oscillations in a 1.25 cm bore PVC tube. It was concluded that this form of drag reduction was probably due to an adsorbed layer of PEO on the wall of the pipe. During a further investigation of this phenomenon, it was observed that the PEO additive also improved the wetting of the PVC tube wall above the liquid meniscus. This suggested trying the effect of a wetting agent which did not act as a drag reducer in shear flow. The surfactant chosen was Aerosol OT which, although it is used to disperse drag reducing fiber suspensions (Radin et al., 1975), does not itself affect turbulent flow (Lee et al., 1974).

The experimental setup and methods were described by McComb, but, briefly, a 1.25 cm bore PVC tube was formed into a semicircle of 29 cm radius. In each experiment the length of liquid column was 88 cm, and this was given an initial displacement of 25 cm. The time period of the subsequent oscillations was 1.8 s.

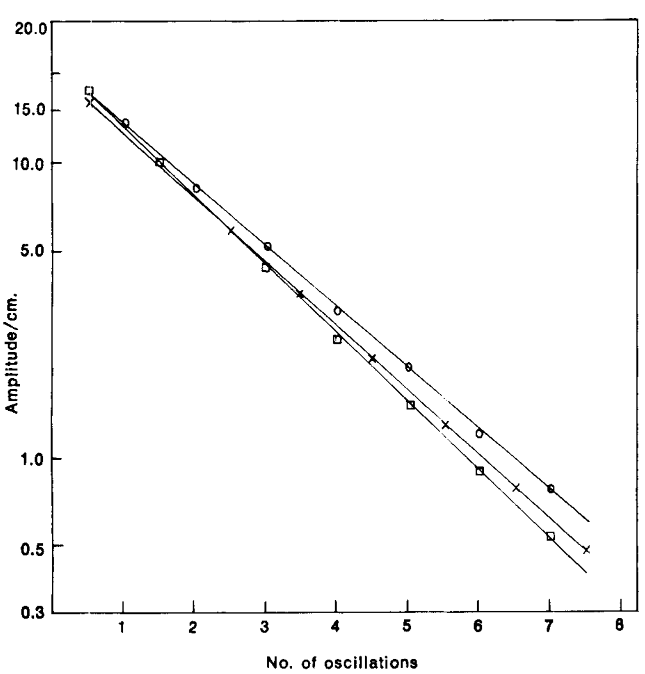

Fig. 1. Amplitude of oscillation against time for Aerosol OT in a semicircular PVC tube. □ Water. ○ 150 p.p.m. Aerosol OT. × 10 000 p.p.m. Aerosol OT.

Tests were carried out for a range of concentrations of Aerosol OT in water. In each case the rate of decay of manometer oscillations was reduced, relative to pure water. Also, in each case it was observed that Aerosol OT had the same effect as PEO in wetting the tube wall, above the meniscus.

In Figure 1 the logarithm of amplitude of oscillation is plotted against number of oscillations for water and two representative concentrations of Aerosol OT. It is clear that at 150 p.p.m. the Aerosol OT (like the Polyox additives) reduced the damping of the oscillations. Results are also given for a 1% solution of Aerosol OT as this is a typical concentration when it is used as a dispersant in drag reducing suspensions. Again, there was similar behavior to PEO (McComb, 1974), but this time at high concentrations where there was initially a more rapid decay followed by a decrease in damping in the final stages of the decay.

When these observations are put on a more quantitative basis, it may be seen that the effect of the surfactant is much smaller than the Polyox additives. If the total num-

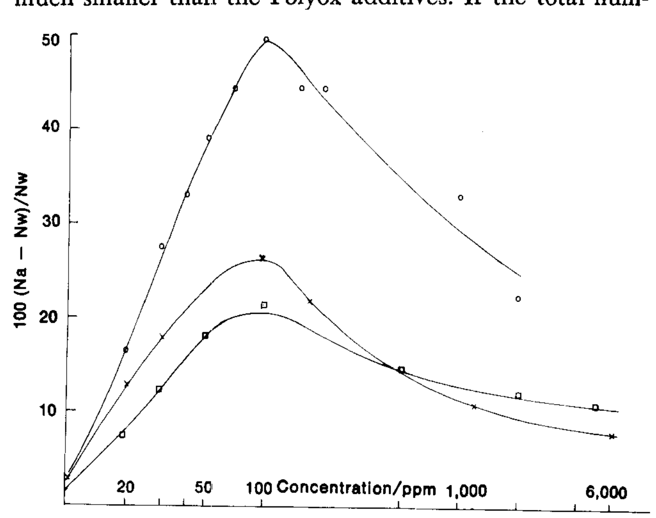

Fig. 2. Variation of damping reduction with additive concentrations (1) in a semicircular PVC tube. ○ Polyox WSR N3000. × Aerosol OT. (2) in a U shaped PVC tube □ Aerosol OT.

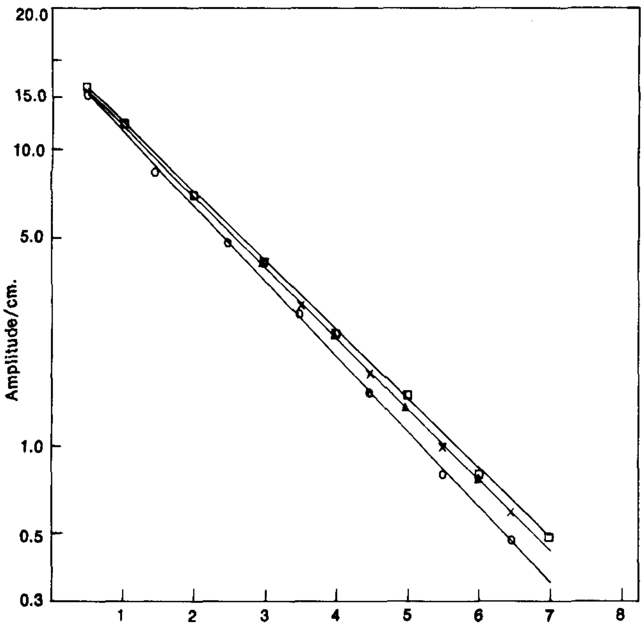

Fig. 3. Amplitude of oscillation against time for Aerosol OT in a semicircular glass tube. □ Water. △ 10 p.p.m. Polyox WSR-301. × 250 p.p.m. Aerosol OT. ○ 2 500 p.p.m. Aerosol OT.

ber of oscillations with pure water is N_w and with an additive present is N_a, the percentage increase in the number of oscillations is defined as

$$100(N_a - N_w)/N_w$$

In Figure 2 we compare the behavior of Aerosol OT with Polyox grade WSR N3000 (N3000 is a relatively inefficient grade of Polyox and only gave a peak enhancement of 50%, compared with WSR301, which gave 120%; see McComb, 1974) over a wide range of concentrations in a semicircular PVC tube. It is clear that Aerosol OT behaves very much like PEO, although the total effect at any given concentration is a lot smaller. Results are also given for Aerosol OT in a U shaped tube. It may be seen that the behavior of the surfactant is not affected much by the change of configuration. This contrasts with the behavior of PEO (McComb, 1974), where the effect in a U tube was much smaller than in the semicircular tube.

Various other tests were carried out. To test the effect of a different tube material, we used a 1.1 cm bore glass tube in the same configuration as the PVC tube. Experiments with both PEO and Aerosol OT did not show any obvious change in the wetting of the glass tube above the meniscus. The only quantitative effect was an increased damping with both additives. When Aerosol OT was used, quite large concentrations were needed to produce a measurable difference in the decay rate. Some representative results are given in Figure 3.

To exclude any sample anomaly, we tested the Aerosol OT solutions (at two different concentrations) in turbulent shear flow in a 1.9 cm bore pipe. As expected, there was no measurable effect on the pressure drop.

Finally, it appeared that the damping reduction was due to an adsorbed layer of PEO on the pipe wall (McComb, 1974). In the present case we did not find this effect. Tubes which had contained Aerosol OT solutions were emptied and refilled with clean water, but no reduction in damping then occurred.

To summarize, in some ways Aerosol OT behaved like PEO in its effect on manometer types of oscillations. It reduced the damping in a PVC tube and increased the wetting of the PVC tube above the meniscus. It did not reduce the damping in a glass tube and did not have any noticeable effect on the wetting of the glass tube above the meniscus.

In other respects the two additives behaved differently. The effect of Aerosol OT was very much smaller than that of PEO, and apparently it (unlike PEO) did not act by coating the pipe wall. Also, Aerosol OT had a roughly equal effect in both semicircular and U shaped manometers of PVC tube, with a peak enhancement of about 20 to 25%. This contrasts with the behavior of PEO. McComb (1974) showed that the enhancement due to Polyox WSR301 in the U tube was very much smaller (30%) than in the semicircular tube (120%).

The only firm conclusion we can draw is that Aerosol OT (although not a drag reducer in turbulent shear flow) does reduce the damping of manometer types of oscillations. However it has a very small effect compared to PEO. In view of this, and the other differences between the two additives, it seems quite unlikely that the wetting of the tube wall plays a major role in the phenomenon reported by McComb (1974).

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Enhancement and Effectiveness Factors in Gas-Liquid Absorbers and Reactors

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The rates of chemical processes in two phase systems are customarily expressed as a ratio of the rate under influence of the interphase mass transfer to the rate to be expected in a mass transfer, free reference condition. Thus, in heterogeneous catalysis, the effectiveness factor (Thiele, 1939) is the ratio of the rate of reaction in a catalyst pore to the rate expected if the full pore surface were in contact with gas at the temperature, pressure, and composition of the gas at the pore mouth or catalyst pellet surface. Recently, Kulkarni and Doraiswamy (1975) have extended this idea to bubbling gas-liquid reactors. In gas-liquid absorption accompanied by chemical reaction, the enhancement factor (Danckwerts, 1950) is the ratio of the rate of absorption under reacting conditions to the