Drop Sizes in Turbulent Liquid–Liquid Dispersions Containing Polymeric Suspension Stabilizers. I. The Breakage Mechanism

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Synopsis

Polymeric suspension stabilizers, when used in sufficient quantities, can stabilize liquid–liquid dispersions against coalescence. Experiments were performed using an *in situ* photomicrographic technique to determine the critical surface coverage of a hydroxypropyl methylcellulose product. The critical surface coverage was between 2.35×10^{-7} and 1.2×10^{-6} g/cm^2. Noncoalescing dispersions can be prepared by using high concentrations of suspending agents so that the surface coverage is above the critical value. Such noncoalescing dispersions can be used to study the breakage mechanism even at high dispersed phase volume fractions. The study of the breakage mechanism reveals that the volume swept by the turbine impeller is applicable in calculating the power input per unit mass. The new correlation between the Sauter mean diameter and the extent of agitation under turbulent conditions that is found here is in fair agreement with those available in literature.

INTRODUCTION

Agitated dispersion of one liquid in another occurs in many chemical engineering operations which include direct contact heat exchange between two immiscible liquids and solvent extraction. In most of these operations, dispersion of one liquid in another by agitation is employed in order to increase the interphase transport rates by increasing the interfacial area. The dispersion is later separated by a settling mechanism. All these operations employ unstable dispersions since these settle out readily. Any kind of suspension stabilizers would prohibitively increase the residence time in the settling equipment. On the other hand, suspension polymerization is one unit process involving liquid–liquid dispersions where sufficient amounts of suspension stabilizers must be incorporated in the system in order to prevent coalescence or agglomeration during the time polymerization is taking place.[1-5] Failure to achieve adequate stabilization would lead to mass polymerization and reactor setup.[4] While there exists a large volume of published literature on both theoretical and experimental aspects of drop dispersion, very little of it is relevant to stabilized dispersions and high dispersed phase volume fractions.

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When two immiscible liquids are agitated, a dispersion of one liquid in the other is formed. In the absence of sufficient concentrations of suspension stabilizers, continuous breakage and coalescence of droplets occur until, after a short time, a dynamic equilibrium is established.[6-9] At equilibrium, the breakage and coalescence occur at the same rate, and the average size and the size distribution of the drops are governed by the type and extent of agitation and the physical properties of the two liquids. Under turbulent conditions, breakage occurs due to turbulent velocity and pressure variations[10,11] along the surface of the drop. The coalescence occurs due to the collision of drops in a turbulent field, some of these collisions resulting in coalescence.[6,9,12] At high dispersed phase volume fractions the collisions between drops are frequent. In the absence of any suspension stabilizers, the coalescence efficiency, which is defined as the fraction of collisions resulting in coalescence, is close to unity.[6] When stabilizers are used, the coalescence efficiency is reduced as the stabilizers adsorb on the surface of the drops. As the bulk concentration of the stabilizer is increased, its surface concentration increases and coalescence efficiency decreases until, at a certain surface coverage, called the critical surface coverage, the coalescence is completely eliminated. Above this coverage the dispersion is noncoalescing.

Very little information is available in literature about the dynamics of dispersions containing stabilizers. There exists a need to generate a fundamental understanding of the breakage and coalescence processes and the influence of suspension stabilizers on these interaction processes. The objective of this investigation is to conduct a systematic experimental study of drop dispersion in the presence of suspension stabilizers, particularly polymer-stabilized dispersions, and carry out model development in order to better understand these interaction processes. Polymeric suspension stabilizers have been known to adsorb on the droplet surface forming a viscoelastic layer.[1-3] It is the purpose of this work to examine the relationship between the dynamics of drop dispersion and the interfacial properties—the interfacial tension and the interfacial rheological properties.[13] However, before we can understand the dynamics of drop dispersion, it is necessary to study the breakage and coalescence mechanisms individually. Thus, in this paper we focus our attention on the breakage mechanism by investigating systems at low dispersed phase volume fraction when the number of collisions between drops is low, and, thus, coalescence is low. The breakage mechanism can also be studied at high dispersed volume fractions under noncoalescing conditions by employing high concentrations of the stabilizer so that the coverage exceeds the critical surface coverage.

Thus, in this article we first present the results of our experimental investigations of critical surface coverage for a polymeric suspension stabilizer. We have also studied the breakage process at both high and low dispersed phase volume fractions under noncoalescing conditions using polymeric suspending agents. The results are interpreted in terms of theoretical considerations. Leng and Quarderer[4] had conducted similar investigations; however, as we shall note later, their conclusions are not applicable to our case, probably because we used a turbine impeller whereas they used the anchor and loop types.

EXPERIMENTAL

Apparatus

The mixing tank designed by Kurzeja[14] was used to study drop dynamics in liquid–liquid systems. This tank is equipped with the commonly used photomicrographic setup[8,15-18] for taking pictures *in situ* during the dispersion process.

The tank (R) consists of a Pyrex glass shell with an internal diameter of 6 in. (see Fig. 1). The effective height of the tank is 6 in. The tank is equipped with the standard baffling configuration of four equally spaced baffles of width equal to 1/10 the tank diameter. The stirrer is a six flat-bladed Rushton turbine, T, 3 in. in diameter, mounted on a 0.3125 in. shaft so that it rotates at the center of the mixing tank. The shaft is connected to the motor by a chuck attached to the motor shaft and is supported by a teflon sleeve which is press fitted in the top plate of the tank. For temperature control the mixing tank itself is jacketed by a large pyrex glass shell, OS, 8.75 in. internal diameter. Water is circulated through the jacket from an external water bath using an immersion circulator (Model 1126-00, Cole-Parmer Instrument Co.).

The tank is equipped with the specially designed photomicrographic setup[17,18] to obtain size distribution of the dispersed phase drops. As shown schematically in Figure 1, the optical system consists of a train of a microflash unit (MF), a condensing lens (CL), an optical filter (OF), an optical rod (OR), a microscope sleeve (MS), and a camera (C). The flash unit (EG & G #549-11) has a peak intensity of 5×10^7 candles in a short duration of only 0.5 μs, thus,
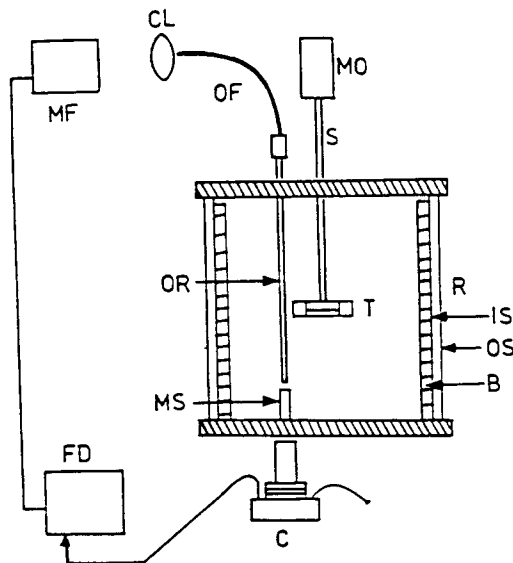

Fig. 1. Agitated contactor for dynamic stability of suspended oil droplets and optical system: (R) tank; (T) turbine; (S) shaft; (MO) variable speed motor; (IS) inner glass shell; (OS) outer glass shell; (B) baffle; (CL) condenser lens; (OF) optical fiber; (OR) optical rod; (MS) microscope sleeve; (C) camera; (MF) microflash unit; (FD) flash driver.

effectively freezing the droplet motion in the tank. The flash is synchronized with the camera shutter by a flash driver (FD). The camera (Honeywell Pentax H3V) is mounted without its lens and is coupled to the microscope adapter. The microscope sleeve is so designed that the focal plane of the microscope is about 1 mm above the window glass on the sleeve. Kodak plus-X 35 mm pan film (ASA 125) was selected for use in this work. The film is developed in HC-110 developer for 5 min to obtain a high contrast image. Fixing is done with regular Kodak fixer for 4 min. The drop sizes are measured by a semiautomatic image analyzer (MOP-3, Carl Zeiss, Inc.).

Materials

In order to simulate the drop dispersion for suspension polymerization, we chose the model system of 30% (by volume) 1,2-dichloroethane and 70% ethylbenzene to match the solubility parameter and density of vinyl chloride monomer.[19] Chung[20] has investigated several hydroxypropyl methylcellulose (HPMC) products of the Dow Chemical Co. and poly(vinyl alcohol) (PVA) samples form Nippon Gosei and their mixtures for their interfacial properties and effectiveness as suspending agents. In order to study the breakage mechanism, we chose an HPMC product-F 50LV. It consists of 27.8 wt % of methoxy and 4.8 wt % of hydroxypropyl groups attached to the ring hydroxyls in cellulose molecules, and also contains 0.6 wt % NaCl. It has an HLB of 9.43.

Procedure

The polymeric solution was prepared by dissolving the necessary amount of F 50LV by slowly stirring at about 30–40°C until the solution became transparent. After cooling the solution to room temperature (25°C), this aqueous solution was introduced in the mixing tank. The organic phase (30-70 1,2-dichloroethane and ethylbenzene mixture) was then introduced in the tank. By adjusting the volumes of these two phases introduced, a desired dispersed phase (organic) volume fraction can be attained. Water was circulated through the jacket to maintain the temperature of the system at 25°C.

(a) **Critical Surface Coverage Experiments.** The experimental procedure for the measurement of critical surface coverage is a modification of that used by Leng and Quarderer.[4] A desired amount of F 50LV was dissolved in water and the two phases introduced in the tank as detailed above to yield the dispersed phase volume fraction, $\phi = 0.25$. The system was agitated at 500 rpm for 2 h and pictures were taken to determine the drop size and size distribution. After that the agitation speed was suddenly reduced to 100 rpm, which is higher than that required for complete suspension, and the system was agitated at this low speed for 2 h and photographs were taken.

(b) **Breakage Experiments.** To study the breakage mechanism, experiments were conducted at varying agitation speeds with both low dispersed phase volume fractions ($\phi = 0.05$) and high dispersed phase volume fractions ($\phi = 0.2$) using 0.2% F 50LV solution. At this concentration, the surface coverage is above the critical surface coverage at all speeds studied. Agitation was started at 150 rpm and increased in steps up to 600–700 rpm. At each

agitation speed the system was allowed to stabilize for 2 h and pictures were taken before the speed was increased to the next desired value.

After the pictures were developed, slides were made from the developed negative film. The drop sizes and size distributions were determined by counting more than 300 drops projected on the digitized MOP panel using the MOP analyzer. Before obtaining the true drop sizes the scale factor must be determined. This was done by taking a picture of a scale through the same aqueous medium and developing a slide from the negative. The magnification was found to be 10 × .

The output of the MOP is the frequency f_i of drops in the size range d_i and d_{i+1}. The Sauter mean diameter was calculated as

$$d_{32} = \sum f_i \bar{d}_i^3 / \sum f_i \bar{d}_i^2 \tag{1}$$

where

$$\bar{d}_i = (d_i + d_{i+1})/2 \tag{2}$$

is the average diameter in the interval. From the size distribution other parameters such as d_{90} (the subscript indicates that 90% of the drops are smaller than d_{90}) can be easily determined.

THEORETICAL CONSIDERATIONS

For simplicity, we shall assume that the extent of agitation is sufficient to maintain a uniform level of turbulence throughout the tank so that the mean drop size and the size distribution is the same throughout. As mentioned earlier, the steady state drop sizes in agitated liquid–liquid systems are governed by the dynamic equilibrium between the breakage and coalescence processes. Under turbulent conditions, the breakage occurs due to turbulent velocity and pressure variations along the surface of the drop, while the coalescence process occurs due to collision of drops in the turbulent field, some of the collisions resulting in coalescence. Therefore, in order to understand the breakage and coalescence processes, it is necessary to understand the turbulence conditions.

Fortunately, both breakage and coalescence processes occur on a very small scale and drop sizes are determined by what happens in a very small volume of fluid surrounding the drop. Thus, the direct influence of large scale flows will be small and the influence of the large scale eddies will be *indirect* insofar as they affect the behavior of small scale eddies. Now, the hypothesis put forward by Kolmogoroff is that if the Reynolds number of flow is high, the behavior of small eddies (in statistical terms) can be estimated from the concept of local isotropy.[21,22] Furthermore, the small scale components of turbulent velocity fluctuations are statistically *independent* of the main flow and the turbulence generating mechanism, and are determined entirely by the local rate of energy dissipation per unit mass of the fluid ϵ and the kinematic viscosity ν. These small eddies are said to belong to the "universal equilibrium range."

Kolmogoroff defined the microscale μ from dimensional considerations as[21,22]

$$\eta = \left(\nu^3/\epsilon\right)^{1/4} \tag{3}$$

In eddies of size smaller than η the viscous forces are predominant. If the Reynolds number is sufficiently high, the eddies of size larger than η but smaller than the macroscale L (which corresponds to the macroscopic dimension, for example, the agitator diameter or the tank diameter) also fall in the universal equilibrium range, i.e., their behavior (in statistical terms) is independent of the main flow. These eddies are said to belong to the "inertial subrange" of the universal equilibrium range. In these eddies the inertial forces are predominant and the turbulent velocity fluctuations are determined for these eddies by ϵ alone.

This is the essence of the Kolmogoroff theory,[21,22] which plays a major role in drop dispersion. We shall use this theory extensively in our study of the breakage and coalescence processes.

Low Dispersed Phase Volume Fractions— The Breakage Mechanism

It is possible to study the breakage mechanism independent of the coalescence mechanism by working with very low volume fractions (low ϕ), whence the probability of collision between droplets is substantially reduced. The drop sizes for the case of low ϕ are thus governed by droplet breakage. For droplets of sizes less than the Kolmogoroff microscale, the breakage occurs by viscous forces since in the eddies containing them the viscous forces predominate. For drops of size greater than η but smaller than macroscale L, the eddies containing them belong to the inertial subrange, and, hence, breakage occurs by inertial forces. The application of the Kolmogoroff theory of local isotropy to breakage of drops can be considered in the following manner.[11,23]

In all our studies the drops were larger than the microscale η. Such drops break under the action of the dynamic pressure forces (inertial forces) of the turbulent motion. These dynamic pressure forces are caused by the changes in velocity over distances at the most equal to the diameter of the drop. The maximum dynamic pressure responsible for drop breakup is then $\rho_c \bar{u}^2(d)$, where $\bar{u}^2(d)$ is the average value (across the whole field) of the squares of velocity differences over a distance equal to d and ρ_c is the continuous phase density. The interfacial tension forces trying to hold the drop together are of the order σ/d, where σ is the interfacial tension. When the dynamic pressure forces exceed the interfacial tension forces, the drop will break. Kolmogoroff theory gives the relation between $\bar{u}^2(d)$ and ϵ and d as[11,20-23]

$$\bar{u}^2(d) = \text{const}(\epsilon d)^{2/3} \tag{4}$$

(The turbulence will, of course, be damped by the interfaces with their associated viscoelastic film of polymeric stabilizers, but, as pointed out by Davies,[24] this effect is quite insignificant at the high practical values of ϵ). Then we can obtain an expression for the maximum size of the drop that will resist breakage as[11,23]

$$d_{\max} = \text{const}(\sigma/\rho_c)^{3/5}\epsilon^{-2/5} \tag{5}$$

Any drop larger than d_{max} cannot exist since it cannot resist breakage. In deriving this expression we have used the average value of squares of velocity differences, and, since their actual values are distributed about the mean, a distribution of drop sizes results. One of the most common ways of characterizing the dispersion is by the Sauter mean diameter d_{32} defined by eq. (1). Usually, the Sauter mean diameter is related to d_{max} through a proportionality constant[15, 25, 26]; thus,

$$d_{32} = \text{const}(\sigma/\rho_c)^{3/5} \epsilon^{-2/5} \tag{6}$$

It is now necessary to relate the power input per unit mass of fluid to measurable quantities. For turbine and paddle impellers, McManamey[27] showed that this may be calculated from the total power input divided by the *volume swept by the impeller times the density*. Since, at high Reynold's number ($> 10^4$), the power number is a constant,[28] the final expression becomes

$$\epsilon = \text{const } N^3 D^2 \tag{7}$$

where N is the speed of rotation and D is the diameter of the agitator. This expression was used by Shinnar[11] in his work on drop dispersion.

On the other hand, Leng and Quarderer[4] suggested that the volume of fluid in question should be confined to the *wake behind the arm of the impeller*. The final expression then is

$$\epsilon = \text{const } N^2 D^2 \tag{8}$$

Substituting either eq. (7) or (8) in eq. (6), we get

$$d_{32} = \text{const}(\sigma/\rho_c)^{3/5} N^{-6/5} D^{-4/5} \tag{9}$$

from the McManamey formula, and

$$d_{32} = \text{const}(\sigma/\rho_c)^{3/5} N^{-4/5} D^{-4/5} \tag{10}$$

from the Leng and Quarderer formula. Equation (9) has been confirmed by a number of investigators from breakage studies (see Coulaloglou and Tavlarides[29] for a review) using turbine or paddle impellers. Equation (10) of Leng and Quaderer[4] was proposed by them from their studies using anchor or loop type agitators and, hence, may not apply for the case of turbine or paddle impellers.

High Dispersed Phase Volume Fractions—
Noncoalescing Conditions

At high dispersed phase volume fractions (high ϕ) the probability of collision between drops is greatly increased, and, if some of these collisions can result in coalescence, the steady state drop sizes will be governed by the dynamic equilibrium between the breakage and the coalescence processes. Addition of suspension stabilizers reduces the coalescence rate by decreasing the fraction of collisions that end up in coalescence.

Coalescence of drops occurs following the drainage of the continuous phase film trapped between the colliding drops.[8,11] In a turbulent field, the turbulent forces which bring the drops together change direction with a characteristic frequency. If the intervening film drains down to the "critical thickness" at which it ruptures before the turbulent forces reverse their direction, then coalescence will occur. Otherwise the droplets will reseparate. Shinnar[11,30] showed that the suspending agents added to the dispersion can slow down the drainage sufficiently such that coalescence under turbulent conditions can be completely prevented. Such dispersions, which he called "turbulence-stabilized" dispersions, are unstable in that if agitation is reduced or stopped rapid coalescence occurs.

By using sufficiently high concentrations of suspending agents, it is possible to form dispersions which will be stable for long periods of time even in the absence of agitation. Church and Shinnar[30] called such dispersions as "stable dispersions." Stabilization is effected in the case of the nonionic polymeric agents such as the one used in this study by the steric stabilization mechanism.[31] In these dispersions the drop sizes even at high dispersed phase volume fractions will be governed by the breakage process rather than the prevention of coalescence mechanism operative in the turbulence-stabilized dispersion. It is the noncoalescing conditions of this type that we are interested in here. Thus, eq. (6) will be expected to hold. The only effect of high ϕ will be the ensuing turbulence damping, and, therefore, only the constant in the equation will be different.

RESULTS AND DISCUSSION

Critical Surface Coverage

Table I gives the results of the critical surface coverage experiments. Measured values of d_{32} at 500 and 100 rpm are reported at different concentrations of the polymeric stabilizer F 50LV in the aqueous phase. At low concentrations of F 50LV it is seen that the average drop size increases when the speed is reduced from 500 to 100 rpm, indicating that coalescence is taking place. At concentrations of F 50LV above 0.05% the change in drop size is small enough to be within experimental error. The critical surface coverage

TABLE I
Sauter Mean Drop Sizes at 500 and 100 rpm at Various
Concentrations of F 50LV from Critical Surface Coverage Experiments

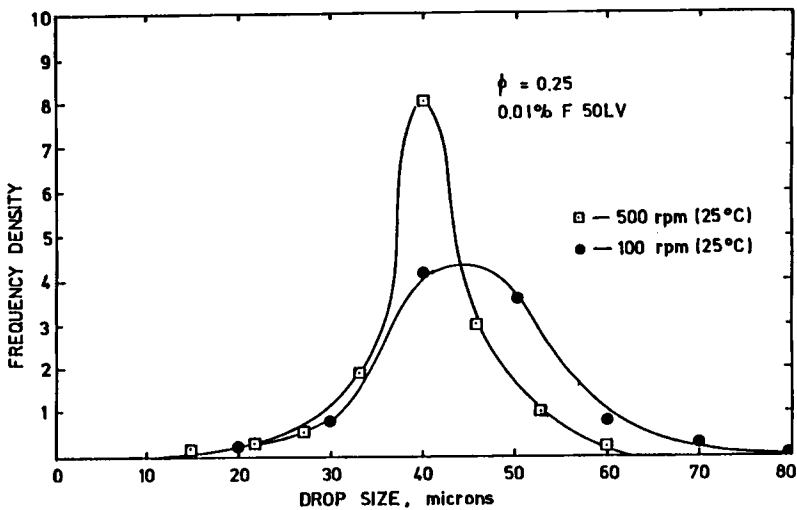| F 50LV (wt %)	d_{32} (μm)	
	500 rpm	100 rpm
0.005	67	79
0.01	45	52
0.05	48	49
0.1	48	46
0.2	47	48

Fig. 2.   Drop size distribution curve for 0.01% (wt) F 50LV with organic mixture at ϕ = 0.25 at 500 (□) and 100 (●) rpm (25°C).

may be calculated as

$$S_c = \frac{(1 - \phi)d_{32}}{\phi}C_c \qquad (11)$$

Where C_c is the critical concentration, which in this case is between 0.01 and 0.05% (wt). Using $d_{32} \approx 47~\mu$m, we get the critical surface coverage S_c to be between 1.2×10^{-6} and 2.35×10^{-7} g/cm^2. Figures 2 and 3 show the drop size distributions at both 500 and 100 rpm at two concentrations of F 50LV above and below the critical coverage. It is seen in Figure 2 that at 0.01% (wt)
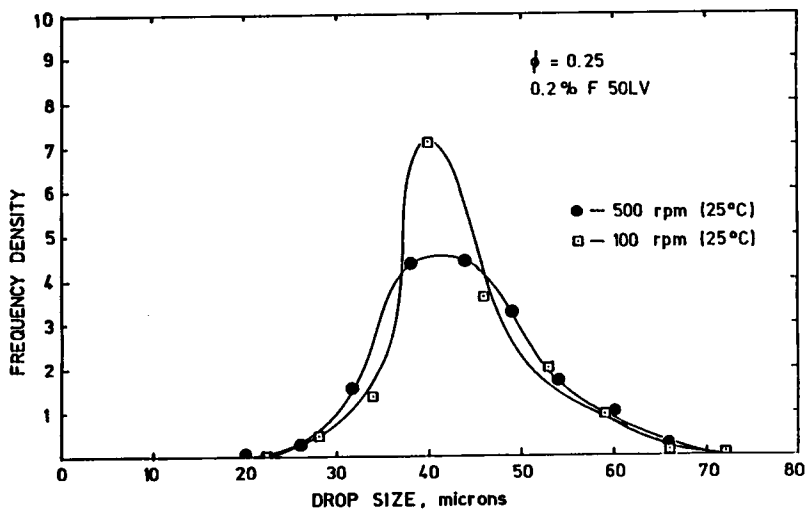

Fig. 3.   Drop size distribution curve for 0.2% (wt) F 50LV with organic mixture at ϕ = 0.25 at 500 (●) and 100 (□) rpm (25°C).
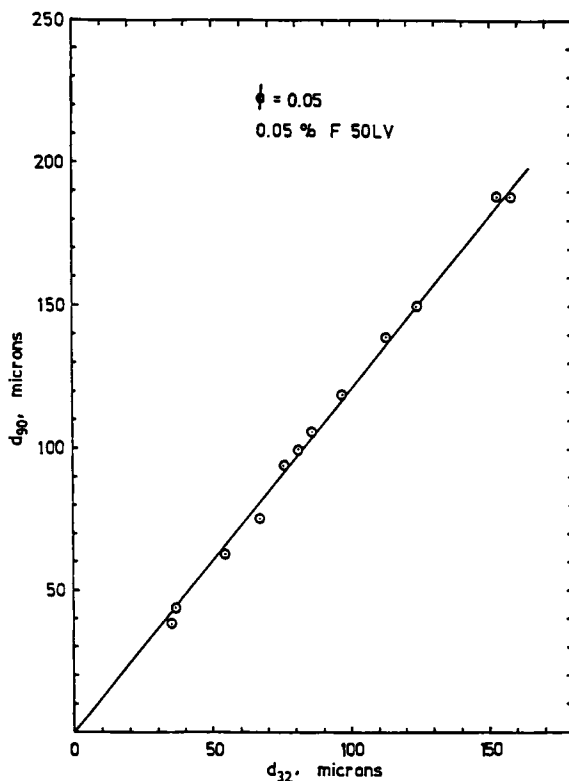
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Fig. 4. Comparison of d_{90} with d_{32} for 0.05% (wt) F 50LV at various agitation speeds ($\phi = 0.05$).

concentration of F 50LV there is a distinct rightward shift when the agitation speed is reduced indicating coalescence. While, in Figure 3 at 0.2% (wt) F 50LV, coalescence is not detected. Since no coalescence occurs upon reduction of turbulence levels, the dispersion is not a "turbulence-stabilized dispersion" but a "stable dispersion" in the terminology of Church and Shinnar[30] (see above). After agitation was finally stopped, it was noted that, although creaming occurred, no organic phase appeared at the top even after 4 days, confirming that they were indeed stable dispersions. This was further verified by conducting an incident light interferometric study in which the film thinning phenomena was observed using this system. The film was found to be stable.

Drop Breakage

Figure 4 shows a plot of d_{90} vs. d_{32} at various agitation speeds for 0.05% (wt) F 50LV at low volume fractions ($\phi = 0.05$). The diameter d_{90} implies that 90% of the drops are smaller than this size, and, thus, this is a good measure of d_{max}. It is seen that the relationship between d_{90} and d_{32} is indeed linear and that $d_{90} = 1.21 d_{32}$ indicating a rather narrow distribution.

Figure 5 shows a plot of d_{32} vs. N for 0.05% (wt) F 50LV at $\phi = 0.05$. Also shown on the plot is the best-fit straight line with theoretical slope of $-6/5$
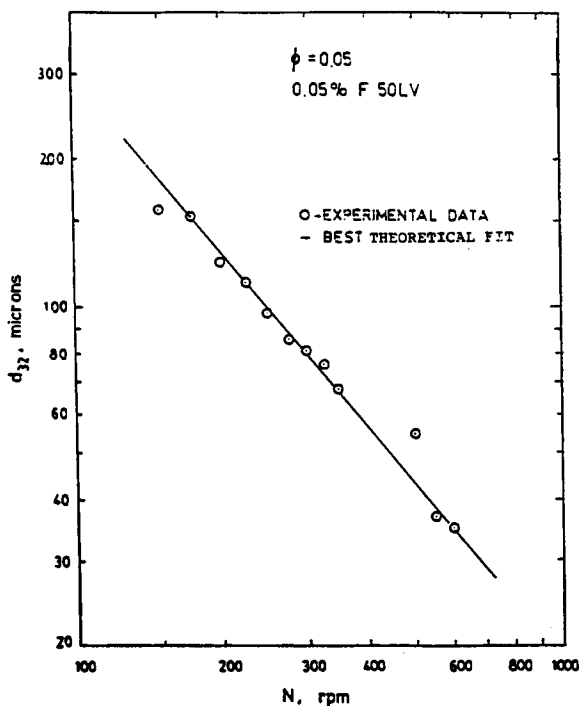
Fig. 5. Sauter mean drop sizes vs. N for 0.05% (wt) F 50LV at $\phi = 0.05$: ($\odot$) experimental data; (—) best theoretical fit.

as per eq. (9), indicating that the McManamey[27] formula and not the Leng and Quarderer[4] formula is applicable for our system, which is not surprising since we have used the turbine impeller. (The surface coverage in these experiments was above critical and Reynolds number was greater than 10^4). The interfacial tension between the organic mixture and 0.05% F 50LV aqueous solution was 10.3 dyn/cm, and the continuous phase density was 1.005 g/cm^3. Using these data, by least-square fit of eq. (9) to the d_{32} vs. N data, it was found that

$$d_{32} = 0.0654(\sigma/\rho_c)^{3/5} N^{-6/5} D^{-4/5} \tag{12}$$

in cgs units at $\phi = 0.05$.

At high dispersed phase volume fractions, $\phi = 0.2$ under noncoalescing conditions [0.2% (wt) F 50LV], we found that the relationship between d_{90} and d_{32} is again linear and that $d_{90} = 1.13 d_{32}$, indicating an even narrower distribution. Figure 6 shows a plot of d_{32} vs. N for 0.2% (wt) F 50LV at $\phi = 0.2$. Also shown is the best-fit straight line with theoretical slope of $-6/5$. The agreement again is good. The interfacial tension between the organic mixture and 0.2% (wt) F 50LV aqueous solution was 8.7 dyn/cm and the continuous phase density was 1.03 g/cm^3. Using these data by least-square fit of eq. (9) to the d_{32} vs. N data, we find

$$d_{32} = 0.102(\sigma/\rho_c)^{3/5} N^{-6/5} D^{-4/5} \tag{13}$$

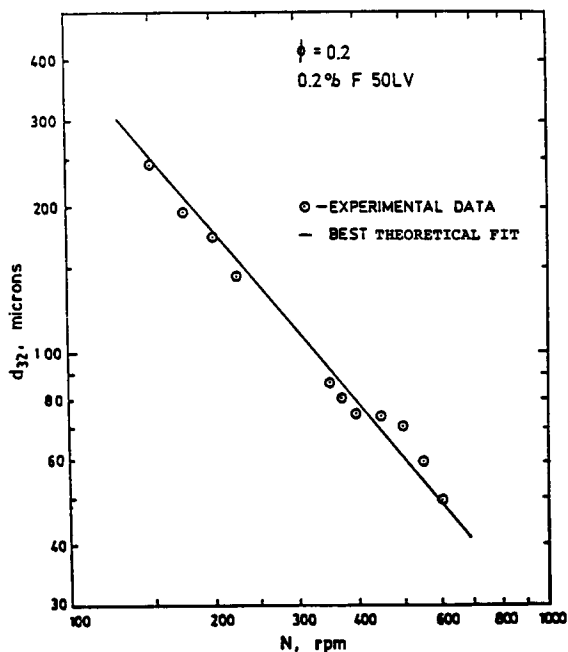(in cgs units) at $\phi = 0.2$.

Fig. 6.   Sauter mean drop sizes vs. N for 0.2% (wt) F 50LV at $\phi = 0.2$: ($\odot$) experimental data; (—) best theoretical data.

If we assume that the numerical constant in eqs. (12) and (13) is a linear function of ϕ, as has been done by several investigators (see the review by Coulaloglou and Tavlarides[29]) we can write a single equation:

$$d_{32} = C_1(1 + C_2\phi)(\sigma/\rho_c)^{3/5}N^{-6/5}D^{4/5} \tag{14}$$

(in cgs units). We, thus, obtain C_1 and C_2 as $C_1 = 0.053$ and $C_2 = 4.6$.

The constant C_1 determines the value of d_{32} when $\phi \to 0$. Even in the absence of suspension stabilizers, the case of $\phi \to 0$ corresponds to the break-age process since the interdroplet collisions are very few and as such coalescence is negligible. Thus, the constant C_1 is determined by the breakage process, whether the suspension stabilizers are present or absent. The value of C_1 obtained here in the presence of suspension stabilizers is in excellent agreement with those reported by other investigators reviewed by Coulaloglou and Tavlarides,[29] who studied drop dispersion in the absence of suspension stabilizers. This lends support to the contention of Davies[24] that the interfacial viscoelastic films of polymeric suspending agents cannot significantly damp the turbulence levels; therefore, the breakage process is unaffected by the presence of any suspension stabilizers.

The constant C_2, on the other hand, is a measure of the effect of dispersed phase volume fraction on drop dispersion. As pointed out by Delichatsios and Probestein,[7] it is a measure of coalescence and of turbulence damping due to the presence of a dispersed phase. In the absence of suspension stabilizers, then, C_2 is expected to be high since most interdroplet collisions result in

coalescence. (The discrepancy between the various literature values was attributed by Delichatsios and Probestein[7] to trace surface active impurities entering the system inadvertently.) Under the noncoalescing conditions employed in this work, the constant C_2 reflects only the damping of turbulence intensities by the dispersed phase, in which case it should be close to unity.[7,8] The somewhat higher value of C_2 found here may be because only two different dispersed phase volume fractions (the minimum necessary to solve for C_1 and C_2) were studied.

SUMMARY AND CONCLUSIONS

In situ photomicrographic technique was used to monitor size distribution of suspended oil drops in stirred tank. It was shown that polymeric suspension stabilizers, when used in sufficient quantities, can stabilize the dispersion against coalescence. Experiments were performed to determine the critical surface coverage of a hydroxypropyl methylcellulose product F 50LV of the Dow Chemical Co. The critical surface coverage was found to lie between 2.35×10^{-7} to 1.2×10^{-6} g/cm^2. When the concentrations of F 50LV used are such that the surface coverage is above the critical value, drops presized at 500 rpm do not show any tendency towards coalescence when the agitation speed is reduced to 100 rpm.

By using high concentrations of suspending agents so that the surface coverage exceeds the critical value, it is possible to study the breakage mechanism even at high dispersed phase volume fractions without further complications arising from coalescence. The effect of high dispersed phase volume fractions under noncoalescing conditions is then only due to the damping of turbulence by the dispersed phase. The correlation obtained for the Sauter mean drop sizes at low dispersed phase volume fraction ($\phi \rightarrow 0$), as reflected by the value of the constant C_1 of eq. (14), is in good agreement with those reported in the literature. This is in accordance with our expectation that the presence of suspending agents should not affect the breakage process. For the turbine impeller used in the study we have shown that the use of volume swept by the impeller as suggested by McManamey[27] to calculate the power input per unit mass is the correct approach. Turbulence damping at high ϕ as reflected by the value of the constant C_2 of eq. (14) seems to be higher than expected, although more data are needed before conclusions can be drawn. Since the value of the constant C_2 of eq. (14) reflects only turbulence damping in the case of noncoalescing dispersions, they may serve as useful tools in the study of the damping of turbulent intensities in two phase systems if utilized in carefully planned, extensive investigations on the effects of dispersed phase volume fractions on drop sizes.

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