Summary

A series of model experiments is described on the development of fatigue patterns in an isotropic material (a powder aggregate) adhering to a deformable membrane subjected to cycles of strain whose amplitudes, relative phases and frequencies, are controlled in the two dimensions of the contact plane. At sufficiently large amplitudes, a pattern of ridges develops on the surface of the powder and their growth and subsequent fission can be observed in detail. The shape, height, periodicity, and orientation of these ridges are investigated in relation to the strain parameters listed above. The present experiments are only early steps in a novel approach to the problem of fatigue and failure and it is hoped that further development will widely extend the range of materials that can be tested by the flexible boundary technique.

References


From T. Wall & Sons, Ltd., Acton, London, W. 3 (England)

The Viscosity of Emulsions*)

By P. Sherman

With 1 figure in 2 details and 1 table

(Received April 22, 1960)

Introduction

The practical performance of emulsion products depends to a large extent on their flow properties. Thus the importance of correct formulation to obtain the desired viscosity for any particular working conditions.

The development of an equation that indicated the importance of factors influencing emulsion viscosity would facilitate greatly the formulation of these products.

An empirical expression of this type, could not account for the effects exerted by all possible factors without becoming very complex. However, some of these exert comparatively little effect so that they may be conveniently disregarded, without undue loss of accuracy, and attention focussed on those factors with major influence.

Several equations are to be found in published literature, but each suffers from the disadvantage that it holds only for the limited amount of practical data from which it was derived. None of the equations show wide application. Furthermore, no general agreement exists as to the principal factors that influence emulsion viscosity. The only point of similarity between these equations rests in the fact that they all indicate a linear relationship between emulsion viscosity ($\eta$) and the viscosity of the continuous medium ($\eta_0$).

Two principal trends of thought are apparent in the development of viscosity equations for emulsions.

The first assumes that small liquid droplets surrounded by an adsorbed layer of emulsifying agent, and dispersed in a fluid continuous medium, resemble suspensions of rigid particles (1). This view derives from the observations of Bond and Newton (2) who showed that droplets with radii less than a certain critical value behave like suspensions of rigid spheres

$$r = \sqrt{\frac{\sigma}{(\rho_1 - \rho) g}}, \quad [1]$$

where $r$ is the critical radius, $\sigma$ is the interfacial tension, and $(\rho_1 - \rho)$ is the difference between the densities of the two liquids.

*) Presented at the September, 1959, Meeting of the American Chemical Society, Division of Colloid and Surface Chemistry (Read by Dr. Paul Becher).
On this basis, equations developed for solid suspensions of spherical particles in liquid media – that have been investigated in great detail – are equally applicable to emulsions. Consequently the viscosity of the liquid forming the dispersed internal phase ($\eta_i$) does not require consideration.

The second trend regards emulsions as suspensions of deformable liquid droplets. Factors of importance now include $\eta_i$, and the nature and physical properties of the adsorbed layer of emulsifying agent at the oil-water interface.

Discussion

In general, factors exerting an influence on emulsion viscosity may be summarised under the following headings, provided the emulsions are always prepared in the same way, and no chemical interaction occurs between the emulsifying agent and the liquid phases.

Volume concentration of disperse phase ($\phi$). Effects arising from this in dilute and concentrated emulsions. Inter-particle interactions.

Viscosity of the external phase ($\eta_0$).

Viscosity of the internal phase ($\eta_i$).

Electroviscous effect.

The emulsifying agent; its chemical structure; the physical properties of the film adsorbed at the oil-water interface.

Size distribution of the dispersed globules.

Homogenisation.

A summary of this form is not wholly satisfactory since some of the factors are inter-dependent, as will be shown later.

The net result of the effects due to some of the aforementioned factors is believed to be an increase in effective droplet size, due to the development of an additional layer around the globules. Whilst no published equation takes account of any effect due to globule diameter this undoubtedly affects $\phi$ and $\eta$.

Dilute Emulsions

a) Influence of $\phi$, and Particle Interaction

Assuming that emulsion systems behave like suspensions of rigid spheres the simplest viscosity equation that can be applied is that due to Einstein

$$\eta = \eta_0 (1 + a \phi),$$

or

$$\lim_{\phi \to 0} \frac{\eta_0}{\eta_0 - \phi} = \lim_{\phi \to 0} [\eta] = a,$$  \hspace{1cm} [2]

where $a$ is a constant, value 2.5, and $[\eta]$ is the intrinsic viscosity.

This equation applies only to extremely dilute systems, in which no interaction occurs between the particles, that are assumed to be perfect spheres, and the distance between them is very large compared with their diameter.

Most systems of practical importance have values of $\phi$ greater than those for which equation [2] holds. For these, values of $a$ greater than 2.5 were found, and the general form of the equation had to be amended so as to include a power series of $\phi$.

$$\eta = \eta_0 (1 + a \phi + b \phi^2 + c \phi^3),$$  \hspace{1cm} [3]

where $b$ and $c$ are constants. This allows for increased interaction between the particles with increasing $\phi$.

Some typical values for these constants, derived from viscosity data for suspensions of solid particles and dilute emulsions, are given in table 1.

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<td>Roscoe (10)</td>
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b) Influence of $\eta_i$ on $\eta$

Assuming the disperse phase droplets to be deformable Taylor (15) modified Einstein's equation, on the basis of hydrodynamic theory, to show the influence of $\eta_i$ on $\eta$. He assumed that the droplets were so small that they remained spherical, that there was no slippage on the surface of the droplets, and that any film surrounding the droplets did not hinder the transmission of tangential stress from one fluid medium to the other.

$$\eta = \eta_0 \left[1 + 2.5 \phi \left(\frac{\eta_i + \eta_0}{\eta_i + \eta_0} - 1\right)\right].$$  \hspace{1cm} [4]