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Experimental study of strong deformations of liquid layer caused by the solutocapillary stresses

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It is well known that surfactant spreading along the free surface of a thin horizontal liquid layer initiates a solutocapillary flow, which causes deformation of the surface. At a certain ratio of the layer thickness to surfactant concentration this deformation evolves into the layer rupture. In this work, we study experimentally the evolution of rupture of a viscous fluid layer depending on the physical-chemical properties of its substrate. Specifically, consideration is given to two cases: behavior of a horizontal fluid layer on a solid wettable or non-wettable substrate and behavior of a two-layer system consisting of insoluble fluids. In all cases the liquid system was placed into a cylindrical cuvette with a flat bottom. Then a droplet of a surfactant was applied to the center of the liquid surface with the help of a dosing pipette. For systems with a solid wettable substrate the layers were formed of aromatic hydrocarbons (hexane, heptane, decane, tridecane). The behavior of a fluid on the non-wettable substrate was investigated by considering a water layer on fluoroplastic substrate. For generation of the two-layer systems we used two pairs of fluids - "water-carbon tetrachloride" and "decane-water". Isopropyl alcohol was taken as a surfactant.

The analysis of the layer rapture dynamics showed that its diameter depends on time, the volume of the introduced droplet, the layer thickness, the cuvette diameter, the difference in surface tension values between the surfactant and the layer fluids and also between the fluids of the two-layer system. It was found that in the case with a wettable substrate, rupture diminishes and gradually disappears as the surfactant dissolves. It was shown that the critical thickness of the layer at which its deformation reaches the layer bottom is practically insensitive to the quantity of the applied surfactant and is defined by the surface tension difference at the surface. In the case of a two-layer system, the behavior of the fluid layer is specified to a greater extent by the properties of the fluid and substrate. It was found that at a certain combination of physical-chemical properties of both fluids rupture of the upper fluid retains after complete dissolution of the surfactant. A key factor determining the behavior of rupture is the surface tension at the interface. The occurrence of stationary rupture is also possible in the case of a layer on the non-wettable substrate. However, unlike the two-layer system the maximal thickness of the broken layer proved to be considerably smaller.

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