

ON THE CAUSES OF THE BULGING OF A LIQUID SURFACE UNDER THE ACTION OF ULTRASOUND

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Fig. 1

Figure 1: Fig. 1

Abstract**Full Text****PHYSICS****L. D. ROSENBERG and L. O. MAKAROV****ON THE CAUSES OF THE BULGING OF A LIQUID SURFACE UNDER THE ACTION OF ULTRASOUND***(Presented by Academician N. N. Andreev, January 3, 1957)*

The effect of bulging of a liquid surface under the action of ultrasound has long been known and is widely used by experimenters for a qualitative estimate of the intensity of radiation. It is usually assumed that the cause producing this bulging is radiation pressure. Thus, in the experiments of Hertz and Mende ⁽¹⁾ it was shown that the direction of bulging at the interface of two immiscible liquids does not depend on the direction of the flow of sound energy, but is determined by the difference of the radiation pressures in the two liquids, which in turn depend on the corresponding values of the velocity of sound propagation.

As is shown in the present note, radiation pressure is not the only cause of bulging. The same effect can also be produced by the so-called acoustic wind, whose velocities in water, as was shown in ⁽²⁾, may reach 0.5-1.0 m/sec.

Radiation pressure is one of the ponderomotive forces of the sound field and, consequently, propagates with the velocity of sound; with the same velocity, naturally, there also propagates in space the onset of all perturbations caused by this force. Acoustic wind, however, belongs to the group of hydrodynamic effects. Therefore, in order to separate these phenomena in time it is convenient to study the process by which bulging is established.

Fig. 1

The experimental arrangement is shown in Fig. 1. In a flat glass cell, $50 \times 50 \times 15$ mm in size and made of optical glass, a layer of water was placed and, above it, a layer of transformer oil. Through an opening in the rubber bottom of the cell the end of an exponential concentrator was introduced, excited by a magnetostrictive emitter operating at a frequency of 24 kc. The diameter of the end of the concentrator was 8 mm; the distance from its cut end to the oil-water interface was about 10 mm.

Fig. 3

Figure 2: Fig. 3

To investigate the process, high-speed cinematography was used, carried out with a Zeiss "Zeit-lupe" camera at a rate of 2000 frames per second on standard 35-mm motion-picture film. The direction of the filming axis was perpendicular to the plane of Fig. 1.

At the moment the sound was switched on, vigorous formation of small bubbles began at the end of the vibrator; the acoustic wind carries these bubbles

upward, and at the end of the vibrator new ones are continuously formed. The velocity of displacement of the leading edge of the bubble cloud, although it is determined by the velocity of the acoustic wind, apparently is not equal to it.

Figure 2a shows the picture at the moment before the sound is switched on: an immobile air bubble sits at the interface; the cut of the vibrator coincides with the lower boundary of the frame. In Fig. 2b, corresponding to the time $0.8 \cdot 10^{-2}$ sec.,

Fig. 3. 1 –interface between oil and water; 2 $-V = 0.42$ m/sec; 3 $-V = 0.64$ m/sec; 4 $-V = 0.89$ m/sec.

after the sound is switched on the cloud has already traveled about half the distance to the interface. If one assumes that the cause of the swelling is radiation pressure, then the swelling should begin after a time of the order of 10^{-5} sec. However, in Fig. 2b no traces of deformation of the interface are found. They begin to appear only after $1.2 \cdot 10^{-2}$ sec., when the leading front of the cloud approaches the interface; only after $1.5 \cdot 10^{-2}$ sec. does a distinct swelling form (the dark round bulge in Fig. 2c).

In Fig. 3, which shows the dynamics of the phenomenon, data are given that were obtained as a result of frame-by-frame processing of the motion-picture film. Time, counted from the moment of appearance of the first bubbles, is plotted along the abscissa; distance is plotted along the ordinate. The horizontal line corresponds to the position of the water-oil interface. The dots indicate the position of the leading front of the cloud. It is seen that all the points lie well near a straight line corresponding to a propagation velocity of 0.64 m/sec. Deformation of the interface begins after 11 m/sec, and the corresponding points (marked by crosses), when the process has already developed, also lie well on a straight line corresponding to an interface velocity of 0.42 m/sec.

For verification, the following qualitative experiment was performed: the vibrating end of the concentrator was introduced not from below (into the water), but from above (into the oil). In this case, in contrast to the experiments of Hertz and Mende, the direction of swelling changed its sign.

Thus, it may be regarded as proven that under the conditions of the present

experiment we observed swelling of the interface between two liquids caused not by radiation pressure, but by acoustic wind.

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