DEEPLY PENETRATING WAVE PRODUCED IN ROTATING HELIUM II

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The properties of a deeply penetrating $S^{(-)}$ wave were investigated. This wave appears in rotating helium II during vibrations of a disc in it. The values of the parameter ν_S characterizing the tension of the vortex line, and the penetration depth of the $S^{(-)}$ wave, $\lambda_S^{(-)}$, were determined.

SMALL vibrations of a disc, superposed on its common rotation with helium II, generate a complex wave in the rotating helium II that is the sum of four simple waves of circular polarization (see, for example, the reviews[1-3]). Chief interest attaches to one of these waves, the so-called $S^{(-)}$ wave, the penetration depth of which exceeds the penetration depth of the other three for $2\omega_0 < \Omega$ (ω_0 is the angular velocity of rotation, Ω the frequency of the vibrations). Only this wave, which is unique, the penetration depth of which exceeds the wavelength, appears in resonance phenomena associated with the spacing of a definite number of half-waves (or quarter-waves) over the distance between the vibrating and reflecting surfaces. Such phenomena were observed (only for the condition $2\omega_0 < \Omega$) by of Hall[4,5] and Andronikashvili and Tsakadze.[6]

The wavelength $L^{(-)}$ and the penetration depth $\lambda_S^{(-)}$ of this $S^{(-)}$ wave are determined for relatively weak mutual friction by the formulas

$$L_s^{(-)} = 2\pi\sqrt{\frac{\nu_s}{\Omega - 2\omega_0}}\left(1 - \frac{1}{4}\frac{\rho_n\Omega}{\rho(\Omega - 2\omega_0)}B'\right), \tag{1}$$

$$\lambda_s^{(-)} = \frac{4\rho\sqrt{\nu_s(\Omega - 2\omega_0)}}{\rho_n\Omega B}, \tag{2}$$

where $\nu_S = \epsilon/\rho_S\Gamma$, ϵ is the tension of the vortex line, Γ the quantum of circulation, equal to $2\pi\hbar/m$, m the mass of the helium atom, B and B′ the coefficients of mutual friction. In the already mentioned researches[4-6], the resonance phenomena were used for the measurement of $L_X^{(-)}$ and the determination of the parameter ν_S, which led to the following results

$$\nu_s = (8.5 \pm 1.5)\cdot 10^{-4}\ \text{cm}^2/\text{sec}[^4],\quad \nu_s = 8\cdot 10^{-4}\ \text{cm}^2/\text{sec}[^6],$$
$$\nu_s = (9.7 \pm 0.3)\cdot 10^{-4}\ \text{cm}^2/\text{sec}\ [^5].$$

In our work, which was carried out by means of a somewhat different variant, the same quantity was investigated, and also the penetration depth $\lambda_S^{(-)}$.

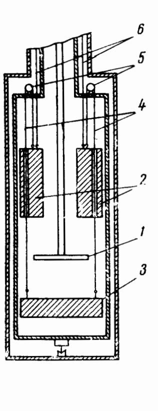

FIG. 1. Scheme of apparatus; 1—vibrating disc, 2,3—planes bounding the liquid, 4—steel wires, attached through block 5 (actually, the number of blocks was three, although only two are shown in the drawing); 6—steel wires, serving to move planes 2 and 3.

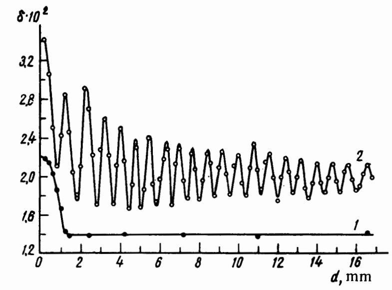

FIG. 2. Dependence of the logarithmic damping decrement of the vibrations of the disc on the distance between it and the bounding liquid surfaces. Curve 1—motionless helium; curve 2—rotating helium $\omega_0 = 0.048\ \text{sec}^{-1}$.

We used the following apparatus: a vibrating disc was placed between two fixed planes and attached to an elastic steel wire, which was passed through a block (see Fig. 1). By means of the wires, a pull could bring the planes closer to the disc or further away from it. In this case, the distance between the vibrating disc and each of the planes d_1 and d_2 could be made equal to within 0.01 mm ($d_1 = d_2 = d \pm 0.01$ mm). Steps were taken to keep a strict parallelism between the planes.

The logarithmic damping decrement of the vibrations of the disc was determined, at a constant temperature T = 1.35° K and rotational velocity $\omega_0 = 0.048/\text{sec}^{-1}$, as a function of the distance d, measured by means of the cathetomer KM-6. The frequency of vibration of the disk was also constant and equal to $\Omega = 0.447\ \text{sec}^{-1}$.

The results of the experiment are shown in Fig. 2. The reduction of the resulting data shows that, under the conditions of the given experiment ($\omega_0 = 0.048\ \text{sec}^{-1}$, $\Omega = 0.447\ \text{sec}^{-1}$, T = 1.35° K)

$$\lambda_s^{(-)} = 1.684 \pm 0.034\ \text{cm},$$

$$L_s^{(-)} = 0.316 \pm 0.004\ \text{cm}.$$

At such an accuracy of measurement of $L_S^{(-)}$, the correction term in Eq. (1) would have significance under the condition $B' \gtrsim 0.55$. Inasmuch as $B' \ll 0.55$ at T = 1.35° K from the calculations of Iordanskiĭ[7], the correction to Eq. (1) due to mutual friction was not taken into account, and the expression $L_S^{(-)} \approx 2\pi\sqrt{\nu_S/(\Omega - 2\omega_0)}$ was used for the calculation of ν_S; as a result,

$$\nu_s = (8.83 \pm 0.25)\cdot 10^{-4}\ \text{cm}^2/\text{sec}$$

So far as Eq. (2) is concerned, the value of $\lambda_s^{(-)}$ computed by use of it amounts to 1.7 cm, in complete agreement with the experimental result.

In the calculations, the coefficient of mutual friction that we used was taken from the work of E. Lifshitz and Pitaevskiĭ.[8]

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