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Examination of gas-liquid diffusion by using the interference fringes *

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1. Introduction

In the interference (classical and holographic) method the phase shift between the object wave passing through the examined phase object and the reference wave is measured. In the classical interferometry the two-beam interferometers (of Mach–Zehender, for instance) are exploited to examination of the phase objects, while the holographic interferometry may be realized by using double-exposure holography or the real time holography methods. Interferometers (both classical and holographic) may be adjusted either for the fringes of equal thickness or the fringes of infinite width [1–3].

In the seventies there appeared a number of works devoted to the examination of diffusion by the method of holographic interferometry. The diffusion of liquid-liquid type was examined by using the method of double exposure holography in the field of zero order interference fringe [4], [5] or by the equal thickness interference fringes [6], while the gas-liquid diffusion was investigated in the real-time systems [7–9].

In the present paper the gas-liquid diffusion was examined with the help of interference fringes of equal inclination. In contrast to the paper [9], where the process of gas to liquid diffusion was examined, in our experiment first the diffusion of gas to liquid was observed then the gas from the space above the liquid was removed and the diffusion of gas further into the liquid and back to the air was registered.

2. Experimental setup

In the experiment we used the Mach–Zehender interferometer composed of the mirrors of the ZHL holographic system of PZO, Warsaw, production. The optical

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scheme of the interferometer together with the cuvette filled with water and located in one of its branches and the apparatus serving to transmit the gas above the water in the cuvette are shown in Fig. 1.

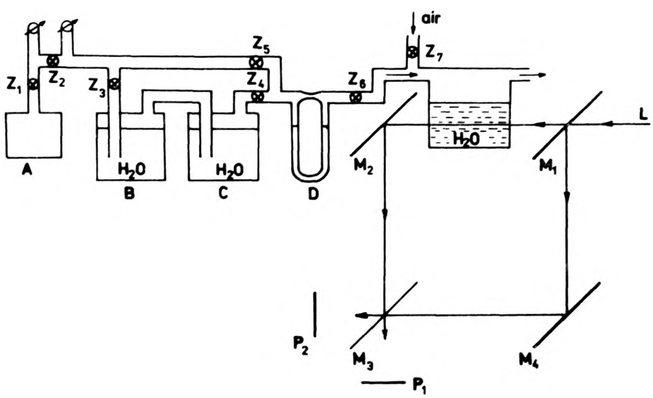

Fig. 1. Experimental setup for examination of gas-liquid diffusion. A – vessel with gas (argon), B, C – vessel with liquid (water), D – manometer, Z_1–Z_7 – gas cocks, M_1, M_3 – mirrors of 50% transmission, M_1, M_4 – mirrors of 0% transmission, P_1, P_2 – recording planes of interference images, L – light beam from the He–Ne laser

The interferometer may be adjusted for the infinitely wide interference fringe or for the fringes of equal thickness. When removing the mirror M_3 (Fig. 1) and changing the inclination angle of the mirror M_4, the object and reference waves may meet each other at the plane P_1, and then the hologram be recorded. The "dry" gas allowed to flow above the liquid in the cuvette when the cocks Z_1–Z_6 were opened, the remaining ones being closed. The wetted gas was obtained by letting it through vessel filled with distilled water (B, C, Fig. 1). Then the Z_1–Z_6 cocks were open while the others closed.

3. Concept of measurement and results of experiment

The existence of the concentration gradient of the diffusing component is the condition of diffusion. The mass diffusing from the medium of higher concentration of diffusing component to the medium of lower concentration gives rise to the gradient of refractive index in the direction of diffusion (first and second Fick laws for stationary and nonstationary diffusion, respectively [10]).

The idea of measurement consists in examination of the diffusion process by a continuous observation of the refractive index gradient made in two stages in the diffusion region. In the first stage the gas diffuses to the liquid during the fixed time. In the second stage the flow of gas is stopped, the space above the liquid filled with the air and the gas diffusion process is observed. This process occurs actually in two directions: deep into the liquid and to the air above the fluid from the diffusion region in the liquid. During both the stages the shapes of interference fringes, which map the light refractive index distribution, are recorded. When the light refractive index distribution in the region of diffusion is known, then by using the least squares error method such a value of the diffusion coefficient may be found, for which the theoretical curve of the refractive index distribution agrees with the experimental curve. In Figs. 2a–d the results of one of the series of measurements of argon to water of 19.5 °C diffusion are shown in the case when the interferometer was adjusted to the fringes of equal thickness, while one of the

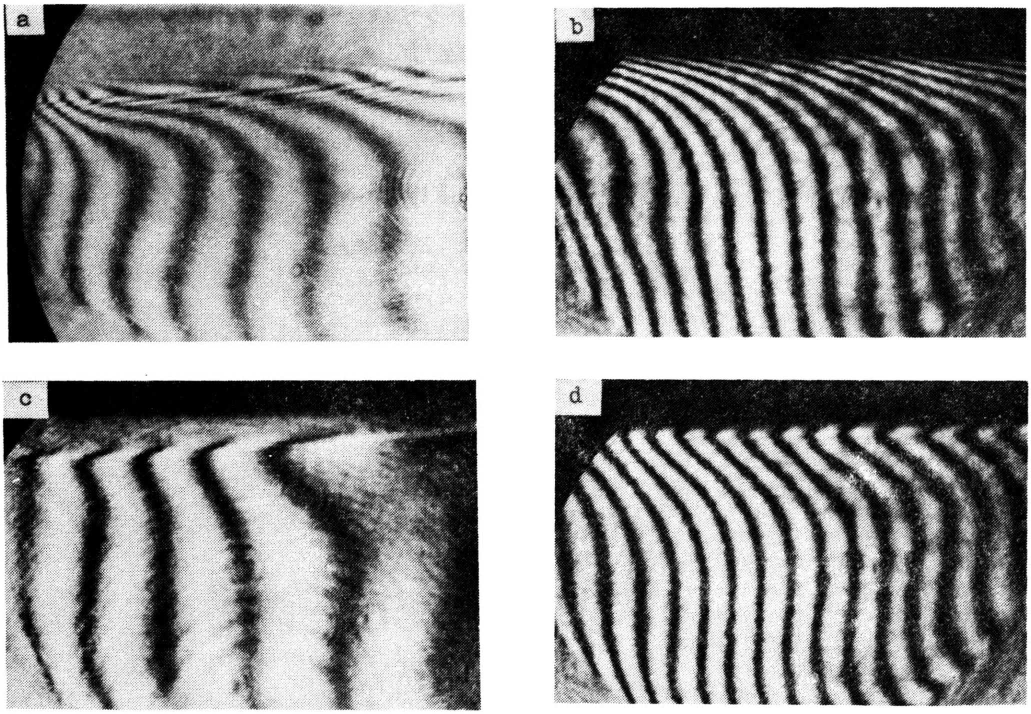

Fig. 2. Interferograms showing the refractive index distribution in the diffusion region (interferometer adjusted to the fringes of equal thickness). **a**, **b** – first stage of diffusion (**a** – wetted argon, **b** – dry argon), **c**, **d** – second stage of diffusion (**c** – continuation of the process for wetted argon, **b** – dry argon)

results obtained in the case when interferometer was adjusted to fringes of infinite width is presented in Fig. 3. Figure 4 shows the theoretical curve with the marked experimental points. This curve was obtained by minimizing the functions

$$\sum_{1}^{N}\left[XN(k)-\frac{n_2-n_1}{\sqrt{\pi}}\int_{-\infty}^{X(k)/\sqrt{2Dt}}\exp(-x^2)\,dx+n_1\right]^2$$

where $XN(k)$ denotes the refractive index distribution in the diffusion region obtained experimentally for given diffusion time t; n_1, n_2 are the refractive indices of the diffusing component and fluid, respectively; X is the depth of diffusion.

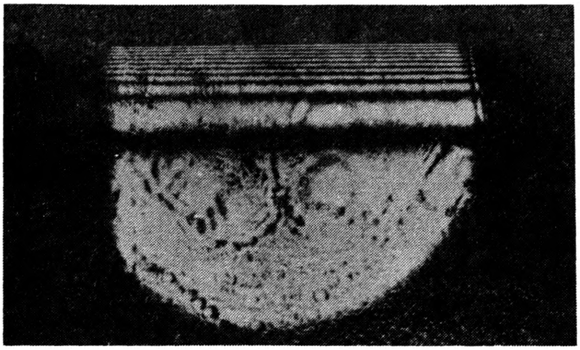

Fig. 3. Refractive index distribution in the diffusion region (interferometers adjusted to the infinitely wide fringe)

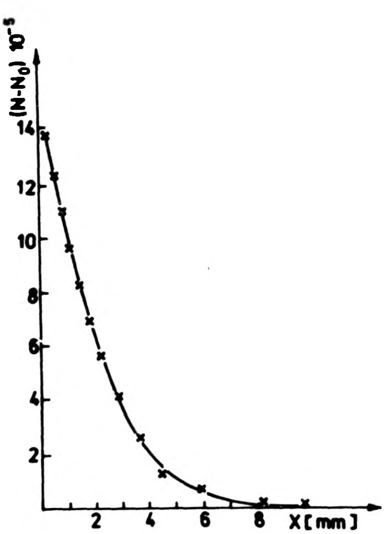

Fig. 4. Theoretical distribution of the refractive index N in the region of diffusion (N_0 light refractive index in water) × – experimental points

The average value of the diffusion coefficient D for a dry argon at 19.5° C was $D = 3.83 \times 10^{-5}$ cm^2/s, while for the argon wetted to the 60% relative moisture $D = 5.61 \times 10^{-6}$ cm^2/s.

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