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INTERFEROMETER INVESTIGATION OF THE CONVECTIVE STABILITY OF A GAS IN HORIZONTAL CHANNELS HEATED FROM BELOW

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The stability of the temperature field of a gas layer under natural and forced convection in horizontal channels heated from below is experimentally investigated by the method of holographic interferometry.

A horizontal layer heated from below in which thermal convection occurs is an example of instability and the transition to turbulence [1]. Interferometric methods of visualization [2] that permit investigation of a medium with different physical characteristics, from polymer solutions [3] to gases [4], are used to study the temperature fields in such layers.

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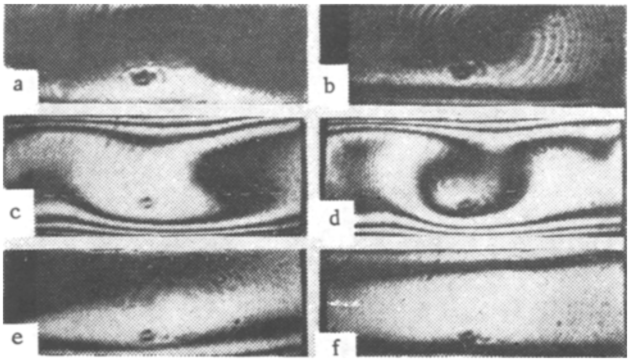

Fig. 1. Interference patterns of temperature in a channel during natural convection. a) $\Delta T = 7°$; b) 10°; c) 22°; d) 24°; e) 20°; f) 12°C.

The stability of a temperature profile under natural and forced convection in plane channels was studied in an experimental installation that is a holographic interferometer assembled on the basis of a SIN interferometer table. Continuous observation of the interference pattern obtained by a real time method was realized by using television apparatus. During the experiment the television signal was recorded continuously on a video magnetic tape recorder, and the most characteristic interference patterns of the temperature field profile within the channel were photographed. Compared with the traditional interference methods, the holographic interference scheme permits reducing demands on the optical elements of the scheme, easy rebuilding for different recording methods, and obtaining information in a form convenient for subsequent processing [5].

The holographic scheme was adjusted to obtain interference fringes of infinite width for more graphic visualization of the temperature field in investigations of the natural convection in a plane channel since lines of equal blackness in the interference pattern are isotherms. The height h of the plane channel was selected equal to 0.025 m in conformity with the recommendations in [1, p. 132] and the size of the working areas of the flat metal plates, its generators, was 0.2 × 0.4 m.

Represented in Figs. 1a-c are photographs of the television images of the interference patterns of the temperature field corresponding to different heating times for the lower plate. Stages in the loss of stability of the temperature field and the formation of convective arches whose horizontal dimension diminishes to reach the theoretically predicted configuration [1] in the steady state (Fig. 1d) are observed in the photographs. The results obtained for the steady state are in complete agreement with the experimental data presented in [4]. Upon cooling the channel (Figs. 1e and f) the return of the temperature field to the initial position occurred through a state different from those characteristic for the heating mode.

To investigate the possibility of studying the temperature field stability under forced convection conditions, it turned out to be expedient to adjust the holographic interference scheme to fringes of finite width, which permitted determination of more abrupt deformations of the temperature field inherent in this kind of convection.

A channel formed by plates of complex shape (Fig. 2) was the object of the study, where the height h of the channel section was 0.01 m, and the origination of significant naturally convective flows was eliminated for the same temperature drops for which they were observed in the plane channel while the channel shape afforded the opportunity of investigating inhomogeneity of the temperature gradient. The sequence for obtaining images of finite-width fringes was the following. Initially, exactly as in the natural convection tests in the plane channel, steady temperature profiles in a channel heated from below (Fig. 2a) were obtained. Then this state of the temperature field was recorded on a hologram and was the reference. Interference fringes of infinite width corresponding to the temperature gradient were not observed (Fig. 2b) in observing the heated channel through the hologram. The necessary initial interference pattern of finite width fringes (Fig. 2c) was shaped by changing the angle of laser beam incidence on the hologram. Photographs of the deformed initial interference pattern of the finite-width band are given in Figs. 2d and e for forced convection for Reynolds numbers of 300 and 3000, respectively. Comparison of the photographs of

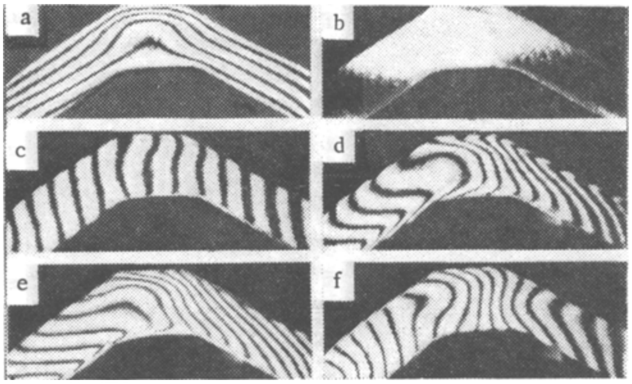

Fig. 2. Interference patterns of temperature fields in a channel during forced convection. a, b, c) Re = 0; d) 300; e) 3000.

these two flow regimes shows that a change in the temperature fields relative to the initial state causes a change in not only the configuration of the finite-width fringes but also a diminution of their contrast in the turbulent flow regime (Fig. 2e) because of the loss of stability of the temperature field. Relaxation of the temperature field to the initial state after cessation of air delivery to the channel is shown in Fig. 2f.

NOTATION

h, channel height; $Re = v_0h/\nu$, Reynolds number; ΔT, temperature drop between walls; v_0, gas velocity; and ν, kinematic coefficient of viscosity.

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