APPLICATION OF A WEDGE-TYPE FABRY-PEROT ETALON TO THE STUDY OF LOW-DENSITY AIR FLOWS

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A Fabry-Perot etalon with a wedge-shaped arrangement of the mirrors is applied to the study of low-density air flows. Interferograms of a gas flow past a cylinder at a pressure of $5 \cdot 10^{-2}$ torr are presented.

The utilization of a Fabry-Perot etalon for obtaining spectra of supersonic rarefied gas flows past models and calculating the densities at the models has been communicated previously in [1]. The mirrors of the etalon were adjusted parallel to each other, and were illuminated by a collimated monochromatic light beam. The central portion the system of interference rings was viewed by a small aperture, while the interference field had the form of a uniformly illuminated surface. The gas flow past the model was made to pass between the mirrors. A change in density at the model resulted in a change in the illumination of the interference field. The density field was calculated with the aid of a photometric resolution technique based on the dependence of the optical blackness density of the negative on the phase difference created by the nonuniformity being studied.

Another version of the application of a multiple-wave interferometer to the determination of the parameters of a gaseous medium situated between its mirrors is the use of nonparallel mirrors, i.e., of adjustment to fringes of finite thickness (rather than to fringes of infinite thickness, as used in [1]).

Earlier, a wedge-type Fabry-Perot interferometer was applied to spectroscopic investigations of various types. For example, Korolev [2] has used a wedge-type etalon for studying the fine structure of mercury lines; in [3, 4], a wedge-type interferometer was used as a spectroscope and as an interference monochromator. Tolanskii [5] used an etalon to study the topography of plane surfaces.

Fringes of equal width were used also for studying various nonuniformities located between the mirrors of an etalon. Post [6, 7], for example, used a three-plate interferometer with equidistant mirrors for obtaining the field of a heated wire loop and determining the stresses in a transparent model.

This paper discusses a new effective application of a Fabry-Perot etalon to the study of low-density gas flows.

A schematic drawing of the application of a wedge-type etalon to the study of nonuniformities in air flows is shown in Fig. 1. The gas was made to flow between two mirror-coated plates (reflection coefficient of 80%. The plates were arranged in such a way that their mirror surfaces formed a certain dihedral angle. The collimator section incorporated a low-pressure mercury tube (1) [8], light filter (2) with maximum transmission in the range between 5770 and 5790 Å, and lens (3) with a focal length of 300 mm. The registering section contained lens (5), aperture (6), and "Zenith" camera (7). The nozzle from which the gas flow was expelled and the model were placed between the plates. All the elements of the interference scheme were rigidly mounted on a common frame that was coupled to the camera. First, the etalon was adjusted to fringes of equal inclination in the conventional manner. The aperture then was made to view only the central portion of the interference pattern, while the corresponding angle was achieved by tilting one of the plates (4). The width and orientation of the fringes are defined by the values of the optical density and its gradient in the medium under study.

Figure 2 shows typical interferograms of the flow of a rarefied gas past a cylinder 10 mm in diameter, situated normal to the flow axis.

It can be seen from the interferograms that by varying the orientation of the fringes it is possible to obtain different displacements of the fringes in the same regions of the field for the same flow parameters. In Fig. 2a, for example, it is possible to determine

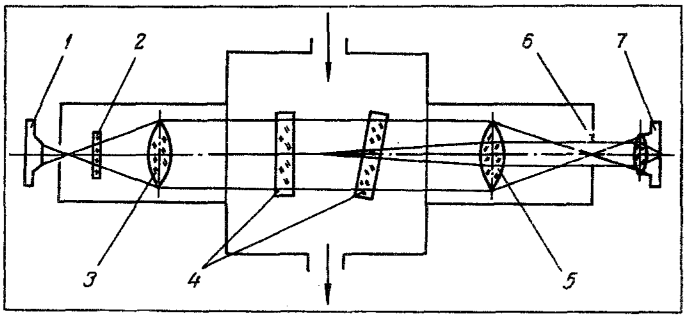

Fig. 1. Schematic drawing of the experimental equipment: 1) light source; 2) light filter; 3,5) lenses; 4) etalon plates; 6) aperture; 7) camera.

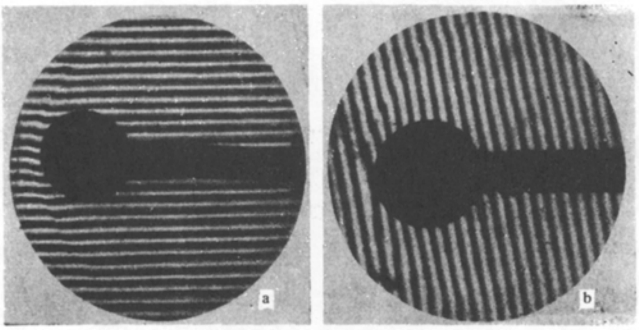

Fig. 2. Interferograms of a flow past a cylinder (Mach number $M \simeq 4$, static pressure of $5 \cdot 10^{-2}$ torr): a) adjustment to horizontal fringes; b) adjustment to vertical fringes.

a high degree of accuracy the parameters in the region of the forward stagnation point, in particular, the structure and magnitude of shock layer separation.

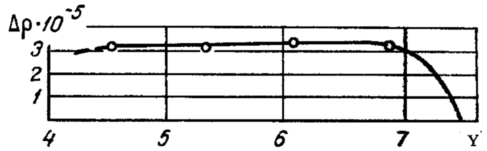

Fig. 3. Density distribution curve ($\Delta\rho$ in g/cm^3, Y in mm).

The common shock-wave front is clearly represented on the interferogram in Fig. 2b, particularly in the peripheral regions of the flow. This shows that optimal adjustment should be selected for studying any specific flow condition. A study of the interferograms reveals that the relative width of the fringes is rather large. This is attributed to the insufficient monochromaticity at a distance of 60 mm of the source employed in the experiments. In spite of this, the photographs obtained lend themselves to quantitative analysis; for this purpose, we used the conventional interferogram interpretation methods in twin-wave interferometry [9]. Figure 3 shows the density distribution over one of the cross sections of the flow behind the shock layer. The origin of the coordinates coincides with the forward stagnation point of the model, the X axis coincides with the axis (in our case X = 0.35 mm) of the model and the flow, while the Y axis is normal to this axis. The value of the density increment behind the shock calculated from formulas in the aerodynamics of continuous media is $\Delta\rho = 3.08 \cdot 10^{-5}$ g/cm^3, while its experimental value is $\Delta\rho = 3.2 \cdot 10^{-5} \pm 0.2 \cdot 10^{-5}$ g/cm^3. Processing of other cross sections behind the shock wave yields values that agree with the values given above within experimental and processing uncertainty. Thus, it may be assumed that the density behind the shock wave is constant for the flow parameters under consideration. In direct proximity to the model (0.2 to 0.25 mm), interpretation becomes difficult and requires development of special interferogram interpretation methods. The curve shown in Fig. 3 is also suitable for determining the shock wave thickness which may not be treated as infinitely thin. The shock wave thickness is roughly 0.3 mm, which constitutes several mean free paths of the gas molecules, calculated on the basis of the oncoming flow parameters.

The experimental results obtained may be considered to be in satisfactory agreement with the theoretical data. They demonstrate the applicability of the wedge-shaped Fabry-Perot etalon to aerodynamic studies of low-density flows, where conventional twin-wave interferometry methods prove to be insufficiently accurate. It is obvious that the measurement sensitivity can be increased by using more monochromatic light sources (such as gas lasers). This will make it possible to study highly rarefied gas flows.

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