# STUDY OF AXISYMMETRICAL DISCONTINUOUS FLOWS WITH THE INTERFERENCE METHOD

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In studying discontinuous flows with the help of an interferometer, it is first necessary to establish the correspondence between the interference bands on both sides of the image of the discontinuity. The well-known experimental method — obtaining an auxiliary pattern in white light — cannot always be realized. A computational method for identifying bands, described in detail in [1], was proposed comparatively recently. We shall use this method in the form described in [2], where the difference in the variation introduced by the object is viewed as a function of the variable $\alpha = \sqrt{1 - (y/R)^2}$. Here y is the instantaneous coordinate in the working cross section, measured from the axis of symmetry. R is the radius of the cross section (coordinate of the image of the shock wave). The segment $\alpha R$ constitutes one-half the geometric length of a ray path in the inhomogeneity.

As shown in [2], the path difference $\Delta N$ is an odd function of the argument $\alpha$ and can be approximated by the polynomial

$$\Delta N = a_1\alpha + a_3\alpha^3 + \cdots,$$

$a_{1,3}$ are constants.

First, some reference difference $\Delta N_{ref} = a_0 + \Delta N$ is found from the interferogram, where $a_0$ is an unknown integer correction. It is determined by extrapolating the function $\Delta N_{ref}$ in the vicinity of the point $\alpha = 0$; the quantity $\Delta N_{ref}(0)$ obtained is rounded off to the nearest integer, which is taken as the correction sought.

We present below the results obtained for an object with a shock wave having a variable intensity. In practice, it turned out that analysis of the data from cross sections in regions with a strong and weak shock wave give a different enumeration of bands. As will be shown below, it seems that this occurs due to small systematic errors in determining the radius R.

Figure 1 shows an interferogram of the flow behind a shock wave obtained on a polarization interferometer [3]. The shock wave is formed by detonating a solid explosive in a cylindrical channel with a diameter of 34.2 mm; the channel goes over into a conical nozzle at a distance of 1.4 m from the point of the explosion. Figure 2 shows the configuration of the channel and the working cross sections, parallel to the nozzle exit. The diameter of the cylindrical channel is taken as a characteristic dimension. The working gas is air at room temperature and a pressure of 580 GPa.

It is easy to enumerate the bands in this case due to the fact that the photograph contains a region where the intensity of the shock wave is quite low: the diffracted part of the shock wave to the left of the nozzle exit. The conditions permitting establishing a direct correspondence between the perturbed and unperturbed bands are satisfied here [4]. The values of the true path difference are presented for several sections in Fig. 3a; it is evident that the enumeration of bands using the method in [2] would result in an error of one unit for some of the sections. The systematic nature of the error permits establishing the reason for it and thereby practically eliminating it.

The displacement of the path difference function observed in Fig. 3a could be caused either by the effect of refraction near the shock wave or the error in measuring the radius of the working cross section. The first reason could lead to displacement of the interference bands. It is natural to expect that this displacement will increase with the intensity of the shock wave; however, the graphs constructed do not show this (the intensity of the shock wave is manifested in them in the rate of growth of the path difference). The second of the reasons mentioned above can be easily checked. The dependences shown in Fig. 3b were

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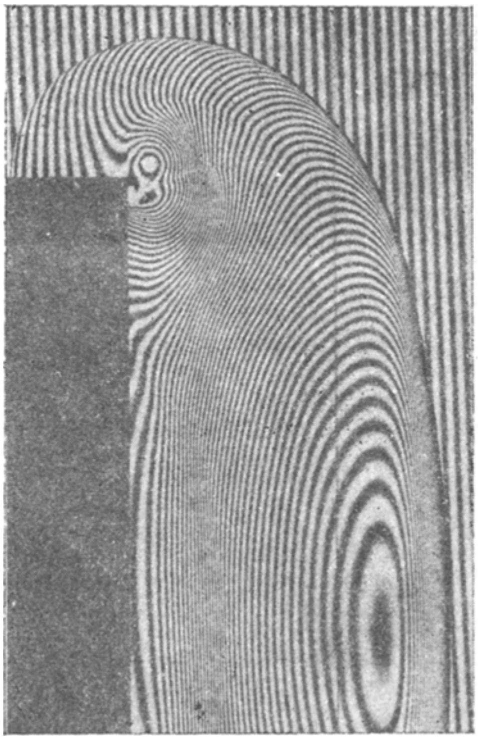

Fig. 1

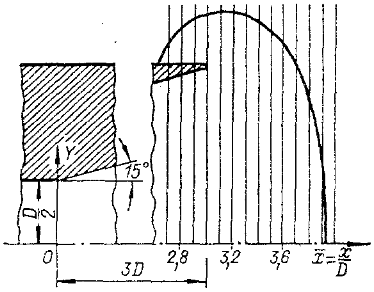


Fig. 2

obtained after introducing a small change in the quantity R: the path difference functions now appear more ordered and all of them pass through the origin of coordinates. In all cases, the radius had to be decreased; the magnitude of the correction for different cross sections turned out to be in the range 0.2–0.3 mm. This error is entirely plausible if we take into account the fact that the resolution of the optical system is about 10 lines/mm. The systematic nature of the error suggests that the image of the shock wave is slightly washed out due to inaccurate focusing of the photographic apparatus. This is supported by the following argument. The magnitude of the correction in this case must depend on the inclination of the shock wave relative to the working cross section. And, indeed, it increases with distance from the nozzle exit and in the section $\bar{x} = 3.9$ (see Fig. 2), it exceeds 1 mm.

The error in determining the radius of the cross section affects the determination of the intensity of the external shock wave. We shall demonstrate this for the section $\bar{x} = 3.3$. Figure 4 presents the results of calculations of the density for a small section adjacent to the shock wave in the section $\bar{x} = 3.3$. The dimensionless distance $\zeta$ from the axis of the flow in units of the cross section radius is marked along the abscissa axis. The density is scaled to its value in front of the shock wave. The density was calculated both from the measured values and from the smoothed values of the path difference using Shardin's zonal method. As is evident, the calculation using the measured values of the path difference and

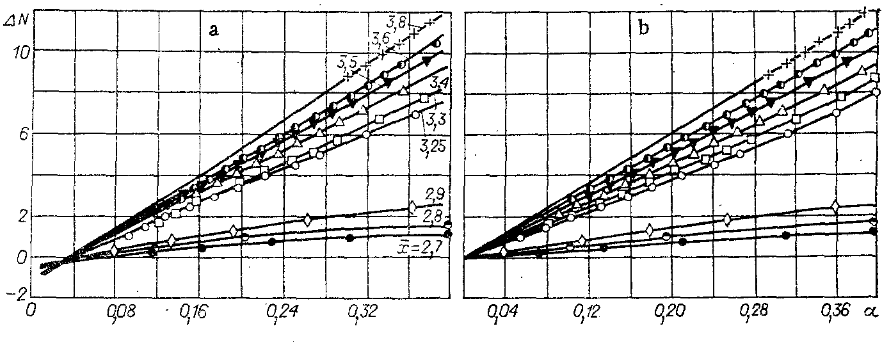


Fig. 3

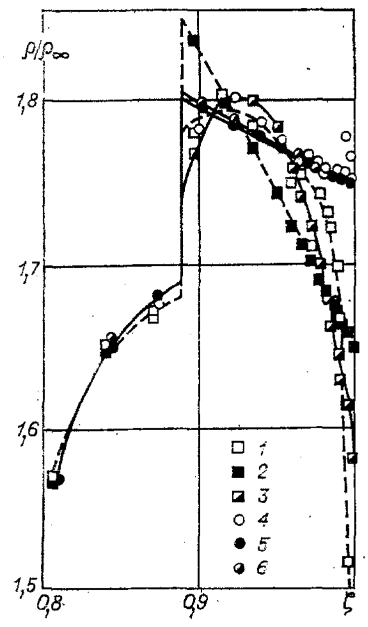


Fig. 4

the radius of the section (curve 1) gives a dependence that drops steeply toward the front of the shock wave and practically eliminates reliable determination of the shock wave intensity. An attempt to approximate the experimental values of ΔN by polynomials of third (points 2) and fifth (points 3) degree α give very different results. In addition, this affects the intensity of the stagnation wave, which in the section examined has the coordinate $\zeta = 0.89$. This wave arose with the rotation of the flow at the edge of the nozzle. The values of the density found after correcting the magnitude of the radius of the section without smoothing the path difference are indicated by points 4. Appreciable random deviations, generally not exceeding 2%, are observed only near the shock wave ($\zeta > 0.99$) and with $\zeta = 0.9$. Smoothing with the same polynomials as in the first case gives close results (points 5 and 6).

The results of the calculation of the density for all cross sections indicated in Fig. 2 are given in Fig. 5. The dependences of the dimensionless gas density behind the shock wave (curve 1) and along the axis of the flow (curve 2) for all working cross sections are shown in Fig. 6. The sharp rise in density near $\bar{x} \sim 3.27$ on the axis of the flow is explained by the presence of the flow drift of the contact discontinuity, which formed as a result of the diffraction of the shock wave passing from the cylindrical channel into the conical nozzle. The stagnation wave arising in this case at the moment of photographing is located inside the conical nozzle.

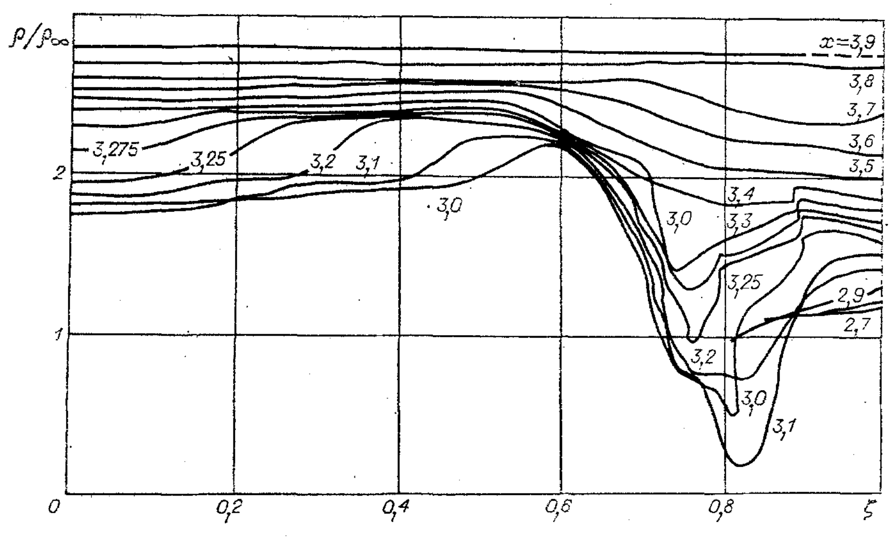


Fig. 5

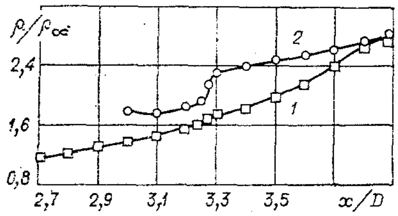

Fig. 6

The data presented, in our opinion, could be of interest to anyone concerned with numerical investigations of such flows. For this reason, we shall present additional information on the initial and boundary conditions. The Mach number of the shock wave at the throat of the conical nozzle equalled 3. When the shock wave moved a distance equal to three times the transverse dimensions of the channel, the density in the section x = 0 decreased approximately linearly by about 12% from its value behind the shock wave with M = 3. The pressure decreases over the same time approximately by 15%. These data were obtained in a flat channel with equal area of the transverse cross section with other conditions remaining the same by interference measurements and with the help of a piezoelectric sensor. The observation of a fanlike refraction structure with flow past the edge of the dihedral angle in the same channel [5] leads to the conclusion that the Mach number of the comoving flow in the throat of the nozzle (x = 0) does not change significantly. The data presented permit assuming that the velocity of the comoving flow at a short distance behind the shock wave is constant in the first approximation.

Calculation of the flow assuming that the boundary conditions in the section x = 0 are identical and equal the initial conditions would give, in all probability, satisfactory agreement with the results presented in Fig. 5 and 6. In this sense, the flow behind the shock wave in a flat expanding channel could serve as a close analogy. The calculation and experimental data for such a flow are presented in [6]. They correspond to the conditions enumerated above and agree well with one another.

## LITERATURE CITED


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