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EXPERIMENTAL STUDY OF THE DRAG OF THE FOREBODY AND THE CYLINDRICAL PART OF THE HB-1 MODEL WITH AN UPSTREAM INJECTION OF A FLUID IN A SUPERSONIC FLOW

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Values of the gas-dynamic drag of the forebody and the cylindrical part of the HB-1 *test model in a supersonic flow have been separately measured using an internal strain-gauge balance. It is shown that an upstream injection of a fluid jet from the model forebody decreases the drag of both the forebody and the cylindrical part.*

The effect of an upstream injection of a thin jet of a fluid in a supersonic flow on the aerodynamic characteristics of bodies of various configurations was studied in [1]. It was found that the action of a fluid jet on an incoming flow results in a significant decrease in the drag not only for blunted bodies but also for pointed configurations.

It is known that the drag of bodies in supersonic flows is a sum of the drag of the model forebody (wave drag), the drag of the cylindrical part (friction), and the base drag. The question arises of what effect the injection of a fluid has on each component. For these studies an HB-1 (modified) model has been manufactured. The forebody and the cylindrical part are mounted separately on two independent single-component strain-gauge balances that measure the axial load. A sketch of the model is shown in Fig. 1. The forebody 1 is located on a strain-gauge balance 2, and the cylindrical part 3 is mounted on a strain-gauge balance 4. The strain-gauge balances and the base part of the model 6 are located on sting 5 attached to a standard balance of the T-313 wind tunnel at the Institute of Theoretical and Applied Mechanics, Siberian Division, Russian Academy of Sciences. Channel 8 for fluid injection passes along the axis of the sting; therefore, the reactive force of the jet and the pressure force of the flow on the end-face part of nozzle 7 for fluid injection were not reflected in the strain-gauge balance data but affected the value of the total drag of the model that was measured by a standard balance of the wind tunnel.

The basic difficulty in using a strain-gauge balance in an aerodynamic experiment is to take into account the "temperature drift of the zero point." This is associated with thermal deformations of the elements of the model construction which are induced by unsteady heat exchange of the model with the ambient flow. Temperature-sensitive resistors were placed on constructive elements of the strain-gauge balance to measure the temperature of the latter. It was impossible, however, to bring the balance elements and the temperature-sensitive resistors into spatial coincidence. As a result, this led to a hysteresis effect in the dependence between the data of the strain-gauge balance and the temperature-sensitive resistors for the case of heating and cooling of the model. The character of this dependence was studied in special calibration tests with modeling of the variation of the strain-gauge balance temperature in aerodynamic experiment. As a result, we obtained a steady-state dependence of the zero point of the strain-gauge balance versus temperature and a dynamic component proportional to the time derivative of the strain-gauge balance temperature. This made it possible to plot the true "temperature drift of the zero point," which was taken into account in processing of experimental data.

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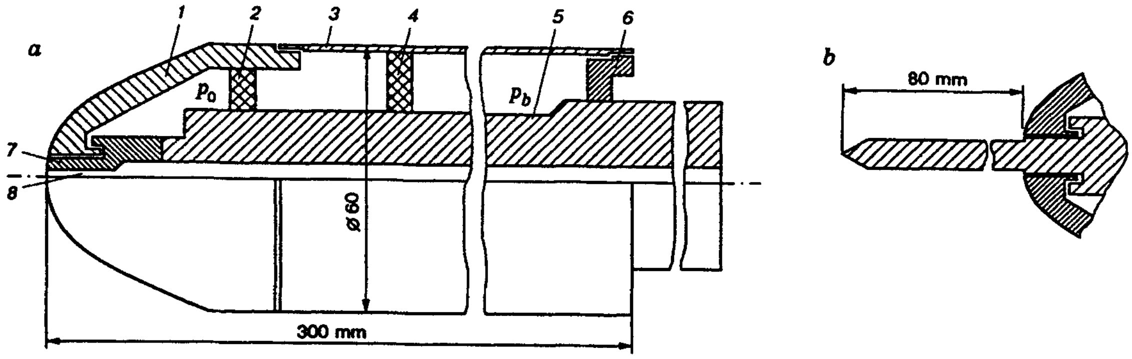

Fig. 1. Model construction in experiments with fluid injection (a) and with a spike (b): 1) forebody; 2) strain-gauge balance for the forebody; 3) cylindrical part; 4) strain-gauge balance for the cylindrical part; 5) sting; 6) base section; 7) nozzle; 8) channel for fluid injection.

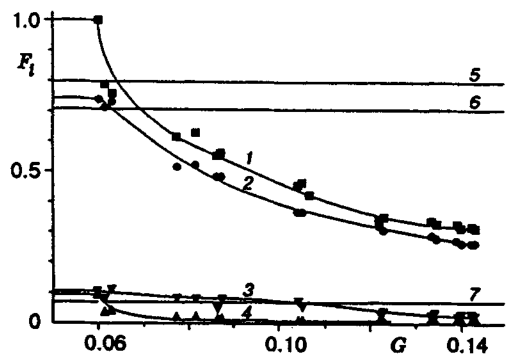

Fig. 2. Experimental dependence of the drag of the forebody and the cylindrical part of the model on the relative flow rate of the fluid G: 1) total drag of the model with fluid injection, measured by the standard aerodynamic balance (F_1); 2) drag of the forebody, measured by the strain-gauge balance (F_2); 3) drag of the cylindrical part, measured by the strain-gauge balance (F_3); 4) allowance due to internal flow around the forebody, calculated from the measured data on internal pressure (F_4); 5) drag of the model with a spike, measured by the standard balance (F_5); 6) drag of the model forebody with a spike (F_6); 7) drag of the cylindrical part of the model with a spike (F_7).

The total drag of the model located in a flow with the Mach number $M = 4$ was measured by a standard balance of the T-313 wind tunnel. To take into account the internal flow, we determined the internal pressure in the model forebody p_0 and near the base part p_b (Fig. 1a). The values of the drag of the HB-1 model were compared for three regimes: without the action on the flow, with the injection of a fluid jet, and with a thin spike. The fluid (75% solution of ethanol in water) was injected upstream from the forebody of the model through nozzle 7. The nozzle diameter (2.4 mm for the mid-section diameter of 60 mm), which was chosen in accordance with the results of [1], corresponded to the maximum decrease of the drag. The effect of the base pressure was ignored in the experiment, since for $M = 4$ (according to standard measurements) the base-pressure value does not exceed 0.1% of the total drag of the model, which is significantly smaller than the total error of experiment.

The measurements revealed that the fluid injection with a relative flow rate G of about 0.14 decreased the drag of the model forebody (F_2) by a factor of 2.8 and the drag of the cylindrical part of the model (F_3) by a factor of 3.2 (Fig. 2). The ratio of the flow rate of the fluid injected upstream from the body and the flow rate of the gas of the incoming flow through the mid-section of the model was determined from the conditions proposed in [1].

Thus, the decrease in the wave drag is related to a change in the shock-wave shape, and the decrease in the friction drag is, apparently, related to the boundary-layer reconstruction. This allows us to assume that even for bodies whose wave drag cannot be reduced by injecting a jet of a fluid or mounting a spike [2] the total gas-dynamic drag decreases due to a decrease in the friction drag, which is particularly important for bodies with a large aspect ratio and an ogival forebody.

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