PASSAGE OF A SUBSONIC FLOW AROUND V-SHAPED WINGS

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In view of the problems involved in the design of hypersonic aircraft great interest has arisen in recent years as to the behavior of wings in fast supersonic flows. Two main approaches have been used: a study of hypersonic flow around traditional wings, and a search for new configurations with optimum aerodynamic properties. Aerodynamic [1, 2], heat-transfer [3], and stability investigations (for V-shaped wings in super- and hypersonic flows) belong to the latter category. Before attaining supersonic flight the aircraft has to overcome the range of subsonic velocities. In this connection it is important to study flow around V-shaped wings at $M < 1$. Little research has been devoted to flow around such configurations at subsonic velocities, principal attention having been directed at the study of rapid flow around aircraft configurations with V-shaped wings or tails. The results of analytical and numerical calculations allowing for the interference of transient aerodynamic forces acting on a V-shaped and mutiple-fin tail group in combination with the fuselage were presented in [4, 5]. An experimental study of V-shaped wings as regards the influence of the wing dihedral angle on the aerodynamic characteristics of a model aircraft was presented in [6, 7].

We studied the pressure distribution associated with flow around V-shaped wings by using a demountable construction which enables one half of the wing to be rotated relative to the other, varying the dihedral angle γ from 0 to 180°. The demountable wings were made in the form of flat triangular plates with leading edges sharpened from the outside (taper angle 15°). We tested a model of the wing with a sagittal angle of 55° or a vertical angle of $\beta = 35°$ (half-wing span 125 mm).

The inner surfaces of the wings were drained in several cross sections normal to the axis and in several conical sections. If we denote the distance from the axis of the model to the drainage point in a particular section by r_1, and the distance from the axis to the edge of the wing in the same section by R, then a fixed value of $r = r_1/R$ will correspond to points lying on a single straight line passing through the vertex of the model. A value of $x = x_1/L$ will correspond to points lying in a single section normal to the axis.

In order to study flow between the wings a total-pressure manifold was placed behind the model. Tubes were arranged in the symmetry plane of the wings at a distance of 20 mm from their trailing edge.

Experiments were carried out in an aerodynamic tube of sections 600 × 600 mm at Mach numbers M = 0.4, 0.6, and 0.8. The Reynolds numbers (referred to the wing span and determined from the parameters of the incident flow) varied from $2.5 \cdot 10^6$ to $4 \cdot 10^6$. The pressure on the surface of the models and the flow parameters in the working part of the apparatus were measured with the aid of a GRM-2 instrument. The relative mean square error in the determination of the pressure coefficient over the range M = 0.4-0.8 was 7-3%, respectively.

The pressure distribution in two cross sections (x = 0.5, section I; x = 0.9, section II) normal to the axis is presented in Fig. 1a ($M = 0.8$; $c_p = (p_i - p)/0.7M^2p$, where c_p is the pres-

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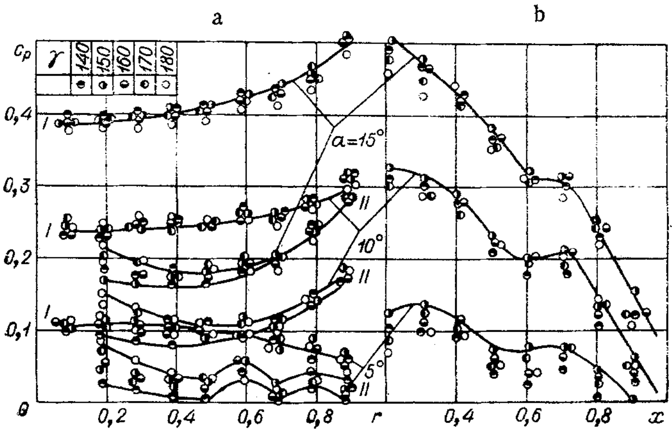

Fig. 1

sure coefficient) p_i is the pressure measured at the surface of the wing) p, M are the static pressure and the Mach number of the unperturbed flow). For M = 0.8 and an angle of attack $\alpha = 5°$ the pressure measured over the wing span increases slightly toward the axis, while for α = 10 and 15° it increases from the axis to the edge. For M = 0.4 and 0.6 the behavior of the pressure curves in relation to r is analogous. We see from the pressure distributions along the conical sections that the flow around V-shaped wings resemble that around triangular wings and cones, in that the pressure falls on passing down the flow (Fig. 1b, M = 0.6 and r = 0.6).

Let us consider the change in pressure as the wings successively come closer together (Fig. 2a, M = 0.8 and $\alpha = 15°$). In section I, situated close to the nose, the approach of the wings leads to a slight increase in pressure, both at the base (r = 0.2) and at the edge (r = 0.9). In the tail section (II) the pressure also rises close to the edge as the wings approach) but close to the axis there is a fall in c_p.

It is interesting to determine the effect of the velocity of the incident flow on the pressure distribution. We see from Fig. 3a ($\alpha = 15°$, $\gamma = 160°$) that a rise in Mach number from 0.4 to 0.8 is accompanied by a rise in c_p over the whole surface of the wings, which is illustrated by the pressure curves of sections I and II. Measurements of the total pressures in the symmetry plane of the wings, carried out in the same way as measurements at supersonic velocities [10], show that for every Mach number the value of the total pressure remains constant independently of the wing-dihedral angle or the angle of attack.

In order to determine the aerodynamic characteristics of V-shaped wings we carried out weight tests on five wing models excecuted in the form of two half-wedges with a sagittal angle of 70° ($\beta = 20°$). The dihedral angle was varied from 140 to 180°, and the dimensions (L = 155 mm, b = 34 mm, $\beta_1 = 28°$, Fig. 4) were the same in all the models. The tests were carried out on a mechanical balance for Mach numbers of M = 0.4, 0.6, and 0.8, the relative mean square error in the measurements of the aerodynamic coeffcients c_x, c_y, m_z being 10-5%, respectively. In calculating the aerodynamic characteristics we took the plan area of the wing as characteristic area. Figure 4 (M = 0.8) gives the resistance (drag) and lift coefficients, together with the aerodynamic quality of the models tested in relation to the angle of attack. We see from the test results that for M = 0.8 the drag coefficient of the model remains almost constant up to a value of $\alpha = 10°$, after which it starts increasing. Over the whole range of angles of attack studied the lift increases continuously, the zero value of c_y corresponding to an attack angle of $\alpha \approx 5°$. This is associated with the fact that the attack angle is reckoned from the conjugation line of the inner planes of the wings, and since the wings have a finite thickness when $\alpha = 0$ their outer surfaces make a certain angle with the direction of the incident flow, causing a negative lift. The maximum aerodynamic quality is achieved for attack angles of $\alpha \approx 15°$, which corresponds to a real attack angle of $\sim 10°$.

Considering the relationship c_x, c_y, $K = f(\gamma)$, we note that a change in the dihedral angle does not have any substantial influence on the aerodynamic characteristics (Fig. 2b,

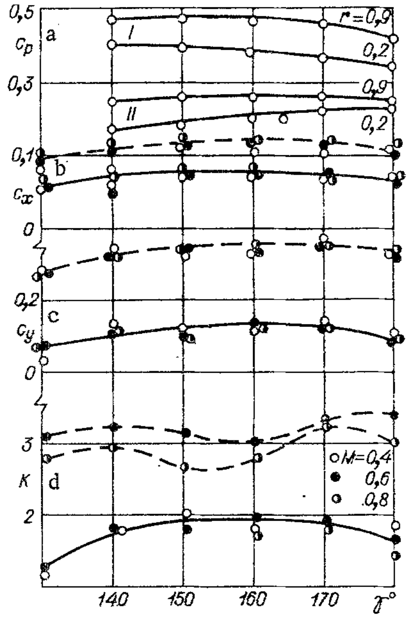

Fig. 2

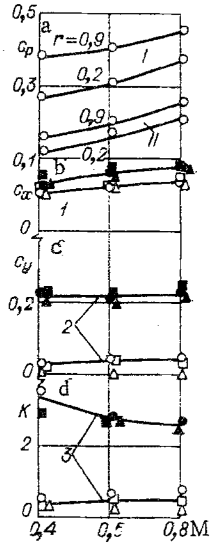

Fig. 3

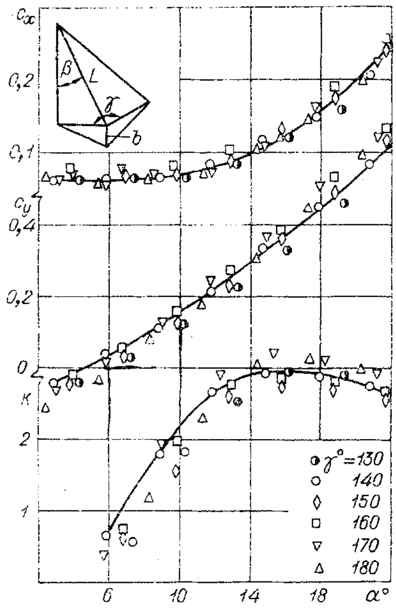

Fig. 4

α = 9 and 15°, continuous and broken curves, respectively). The values of the aerodynamic characteristics for Mach numbers of 0.4, 0.6, and 0.8 are shown in Fig. 3b (α = 6, 12° light and dark symbols; c_x, c_y, K denoted 1–3, respectively). We see that for all dihedral angles and for attack angles of over α = 12° the rise in the velocity of the incident flow causes an insignificant fall in the aerodynamic quality.

The advantages of a V-shaped wing over the equivalent triangular wing for hyper- and supersonic flight velocities in the sense of aerodynamic quality were established in [2]. In order to apply such a configuration to an aircraft it is essential to determine whether the V-shaped wing also satisfies lifting and quality requirements at subsonic velocities. The results of our experiments show that the values of c_y and K depend very little on the dihedral angle. Hence in the range M = 0.4–0.8 these characteristics of the V-shaped wing are analogous to those of the plane triangular wing. Thus, an aircraft with a V-shaped wing has quality advantages at hypersonic velocities and also satisfactory aerodynamic characteristics in subsonic flight.

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