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Numerical studies of side slip effect on stability of airplane with propeller and the high aspect ratio wing

© O.V. Pavlenko,[1,2] E.A. Pigusov,[1,2] A. Santhosh,[2] Thang Ngoc Trinh,[2]

[1]Zhukovsky Central Aerohydrodynamic Institute,
140180 Zhukovsky, Moscow oblast, Russia
[2]Moscow Institute of Physics and Technology,
141701 Dolgoprudny, Moscow oblast, Russia
e-mail: olga.v.pavlenko@yandex.ru, pigusoff@gmail.com

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The results of numerical studies of effect of the slip angle (crosswind) on the on stability of airplane with propeller and the high aspect ratio wing are presented. Increase the slip angle from 0 to 20° are change aerodynamic and moments characteristics of airplane due to the deterioration of the power plant and the asymmetric blowing by the pulling propellers. Numerical studies were carried out using the numerical code for the Reynolds-averaged Navier–Stokes equations.

Keywords: pulling propeller, high aspect ratio wing, slip angle, moments characteristics, CFD methods.

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A side wind substantially impacts an aircraft flight, since it increases downwashes and change the local slope of the wing.

This paper uses the example of an airplane with airscrew propellers at the ends of the wing of extra-long elongation [1,2] to consider the impact of the side wind at its moment characteristics. For this purpose, using the software based on solving Reynolds-averaged Navier-Stokes equations, numerical research was completed on the impact of the side wind on the flow about wing of extra-long elongation ($\lambda = 23$) with centralized mechanization $\delta = 0$ in the aerocruise mode and takeoff position $\delta = 15°$, when all flaps ans ailerons are deflected by one and the same angle, with the rotating screws at its ends at the zero angle of attack at the incident flow velocity $V = 50$ m/s and Reynolds number $\mathrm{Re} = 0.35 \cdot 10^6$. The design model of the airplane includes a high-lift straight wing with an airfoil of relative thickness $\bar{c} = 15\%$ and a chord $b = 0.106$ m, with engine nacelles installed at the ends with the diameter of 0.35 m with propelling two-blade air screws with diameter of 0.22 m, and rotation frequency $N = 15000$ rpm. (fig. 1). Air screws of oppositely directed rotation — towards the hull. The calculations are performed at the screw load value of $B = 0.5$. The screw thrust coefficient at zero angle of attack and slide $\alpha = 0.06$, relative pitch ratio $J = 0.44$. Numerical investigations were performed using ANSYS FLUENT program, based on the solution of Reynolds-averaged Navier-Stokes equations, on a structured computational grid containing around 20 mln cells. When modelling in the boundary layer region, the height of the first grid cell near the wing surface was chosen such that the boundary layer could accommodate a sufficient number of cells to calculate the near-wall function and the value of the parameter y^+ in the first near-wall node did not exceed unity (in these calculations with the propeller $y^+ \le 0.82$. A $k-\varepsilon-$*realizable* turbulence model with improved modelling of turbulence parameters near the wall and taking into account the influence of pressure gradient and compressibility effects is used in the calculation. This turbulence model allows making quite accurate forecasts of boundary layer characteristics at high gradients of pressure, separating and gyrating flows [3], and the near wall region uses a single-parameter turbulence model adapted to flows with small Reynolds numbers. The equations solved in the calculation process were approximated using finite-volume schemes of the second order of accuracy. It should also be noted that this turbulence model is suitable for calculations on a coarse mesh with a small number of cells. More detailed information about the investigated airplane model, and mesh independence are provided in paper [4].

A yawing flight in such an airplane causes higher rolling and yawing moments due to the differences in the flow

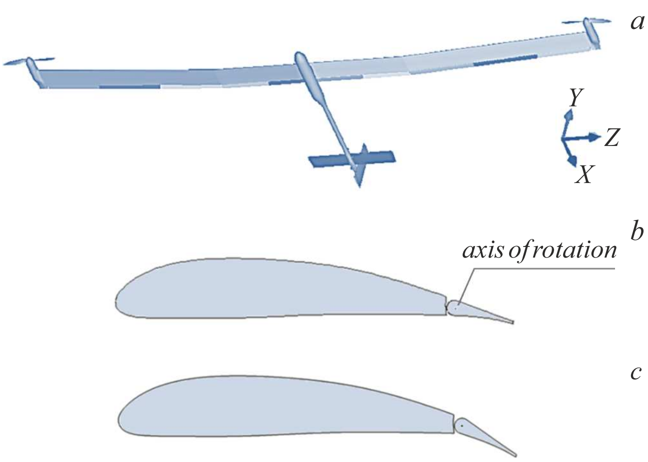

Figure 1. Design model of airplane: a — general view, b — wing section $\delta = 0$, c — wing section $\delta = 15°$.

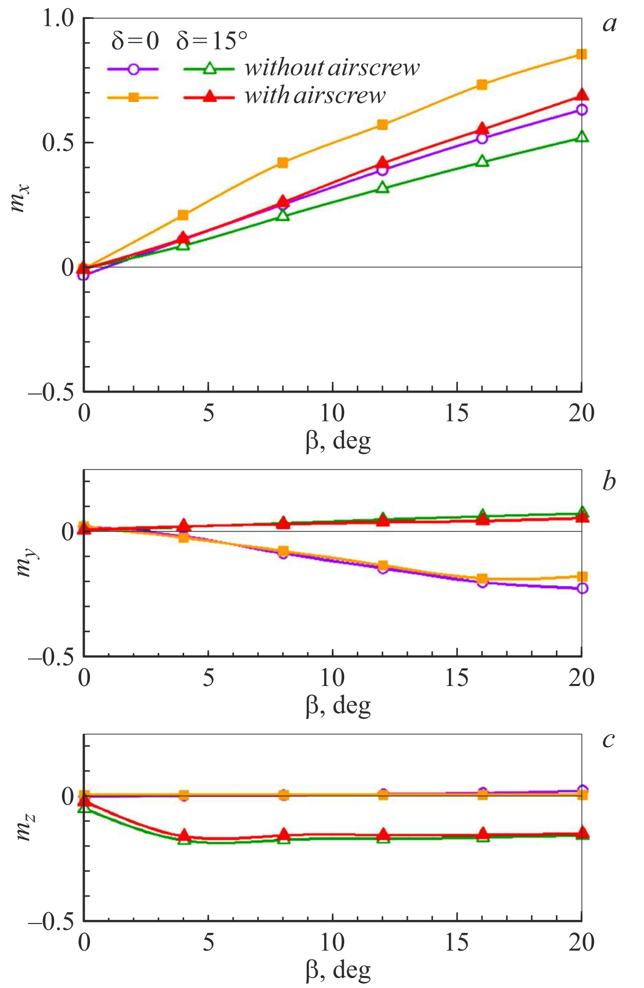

Figure 2. Dependences of moment characteristics of the airplane on the angle of slide: *a* — rolling moment coefficient, *b* — yawing moment coefficient, *c* — pitching moment coefficient.

around the air screws installed at the ends of the wing, and has practically no effect on the pitching moment (fig. 2). A diverted high lift device and absence of the rotating air screws contributes to more stable condition of the airplane model in roll (fig. 2, *a*). Such effect at the moment characteristics of the airplane with the increased angle of slide arises due to the asymmetric pressure distribution at the ends of the wing with long elongation developed by the blow with the screws.

The numerical investigations showed that the most effect from the angle of slide β increase from 0 to 20° is provided at the rolling moment m_x of the airplane with the non-diverted high-lift device and air screws at the ends of the wing in operation. Thus, when the angle of slide increases to $\beta = 4°$, the rolling moment derivative of such airplane model by the angle of slide is $m_x^\beta = 0.0538$, and of the airplane with the diverted high-life device and screws at the ends of the airplane — $m_x^\beta = 0.0303$. When the air screws at the ends of the wing are in operation, the diversion of the high-lift device in its entire spread by $\delta = 15°$ increases the airplane stability in roll: at $\beta = 4°$ by 44%, and in the range of the larger angles of slide at $8° \leq \beta \leq 20°$ approximately by a quarter. In case of absence of the screws, the diversion of the high-lift device also reduces the rolling moment, but to a lesser degree. The transverse stability deteriorates with the increase in the angle of slide as a result of asymmetric blowing of the wing with the propelling air screws.

Diversion of the wing high-lift device improves the transverse stability and increases the pitching moment for the nose-down pitch.

Conflict of interest

The authors declare that they have no conflict of interest.

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