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MATHEMATICAL MODELING OF THE BLENDED WING BODY AIRCRAFT FLOW-OVER IN CRUISE MODE

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ABSTRACT

Addressed is the cruise aerodynamic performance of a Blended wing body (BWB) aircraft in configuration with rear-mounted engines. The investigation of the BWB aerodynamic flow-over has been carried out by mathematical modeling based on Navier-Stokes equations numerical solution using a turbulence model with automatic resolution of the boundary layer. In the adopted problem statement the Navier-Stokes equations describe the viscous heat-conducting turbulent flow of a compressible medium in the region containing an aircraft of the above-mentioned type. Boundaries are at a sufficient distance from the aircraft, so as not to have influence on its flow-over. Computational grid consists of 10.6 million cells and thickening occurs near solid walls for an accurate description of the boundary layer.

Keywords: Blended-Wing-Body Aircraft, aerodynamic performances, flow-over, viscous flow, aerodynamic effectiveness

INTRODUCTION

In most work devoted to BWB investigations, the engine installed near the trailing-edge assembly of the wing, directly on its surface, is studied. The drawback of this solution is that the boundary layer, which builds up on the wing surface, separates across the full width of the wing and has a vortex-type turbulent pattern. It results in heavy losses of the total pressure and in significant nonuniformity of fluid dynamics parameters throughout the flow. When entering the intake, the distorted flow introduces heavy distortions in the engine operation that leads to the engine thrust decrease and fuel flow increase.

This work sets a problem of improving the aerodynamic effectiveness of the design. The solution of this problem was obtained at certain moving of the engine nacelle away from the wing surface (Slobodkina, 2015). The placement of the engine nacelle near the rear of the wing surface at a specified distance between its lower point and the wing surface provides the generation of a transonic flow in this area and forms the maximum flow uniformity at the intake as well. This result can be explained by the fact that in this case the engine exhaust causes an ejection effect contributing to flow scattering under the nacelle. The boundary layer that builds up on the aircraft surface is stable, it does not separate from the surface and does not increase the aircraft drag coefficient. The obtained uniform flow at the intake provides the proper engine operation in the specified mode.

If the nacelle intake is placed at a distance that is shorter than the mentioned ratio, then the supersonic flow area appears between the wing and the intake that ends with a series of shock waves. The interaction of these shock waves with the boundary layers on the surface of the wing and the intake results in flow layers separation with intensive vortex generation that leads to heavy losses of the total pressure.

In case the intake is moved away from the wing surface at a longer distance than the mentioned one, then the intake inlet section is in the slow flow that is confirmed by generation of a well-marked boundary layer on the intake walls. These features of flow-over have an impact on the aircraft performances.

The key characteristic (the lift-to-drag ratio) of an aircraft is the ratio of a lift force coefficient Cy to a drag coefficient Cx which represent forces acting on the aircraft when it flies that are related to a ram air oncoming onto the aircraft. Depending on the aircraft purpose, the value of the lift-to-drag ratio Cy/Cx of the modern aircraft reaches 14 - 15. Due to the efficient aerodynamic configuration of the nacelles on the BWB its Cy/Cx is ≥ 20.

RESULTS AND CONCLUSIONS

1. Flow-over the "Blended Wing Body" (BWB) aircraft equipped with powerplants has been investigated at variation of the following parameters:

- angle of attack;
- spacing between the engine nacelle and the wing surface;
- consumption of suction air and location of the air suction area near the engine inlet on the wing surface.

The investigation was carried out using mathematical simulation by integration of the equations governing an unsteady three-dimensional turbulent air flow generated by aircraft motion in cruising (M=0.83, H=11km).

2. The calculation results showed that:

- the optimal angle of attack is an angle of 5 degrees;
- the optimal spacing between the engine nacelle and the wing surface is the spacing L=0.75m = 0.39D;
- the optimal air suction area must be located ahead of the engine inlet, suction air consumption is ~25-50 kg/s.

3. The variation of an angle of attack led to the following conclusion:

- The Cy/Cx ratio increases 5.6 times for the engine nacelle located close to the wing at variation of α from 2.5 up to 5 degrees, and for the engine nacelle located at spacing L=0.75 m this ratio increases 5.8 times and reaches 20.6 that is by 10.75% more than for the engine nacelle located close to the wing.

4. The calculations taking account of influence of suction air on the flow parametrs led to the following conclusions:

- Air should be sucked in the boundary layer ahead of the air intake.
- In the case of an angle of attack equal to 5 degrees, for the engine nacelle located close to the wing the Cy/Cx ratio increases by 3.2% when suction air consumption is 10 kg/s; the Cy/Cx ratio increases by 7% when suction air consumption is 25 kg/s; the Cy/Cx ratio increases by 14% when suction air consumption is 50 kg/s and practically reaches the value obtained for the engine nacelle located at spacing L=0.75m, i.e. in this case Cy/Cx=21.2.
- When the angle of attack is 2.5 degrees the suction air consumption scarcely influences the Cy/Cx value.

5. As a result of calculations it was determined that the increase in Cy/Cx ratio in all the investigated cases is explained by considerable drop in drag under the action of the following influences: the increase of spacing between the engine nacelle and the wing in the over-the-wing configuration (up to the optimal value); the increase of α (up to the optimal value) as well as the increase of suction air consumption up to the limiting value. The lift value varies insignificantly at all three influences.

Then, the Cy/Cx ratio that characterizes an aircraft aerodynamic efficiency - BWB + powerplant can be increased by two ways reaching practically the same result at α=5 degrees:

- by installation of the engine nacelle at spacing L=0.75м = 0.39D;
- by boundary layer suction near the air intake entry for the engine nacelle installed on the wing.

In the first case there are additional problems with the BWB trim; in the second case, when the engine nacelle is installed on the wing, the substantial energy demands are required for air suction.

CONCLUSION

The investigation of the BWB gas-dynamic flow-over pattern has been carried out for two configurations of the aircraft: with a powerplant consisting of two engines and with a distributed powerplant. In both cases the powerplants are placed in the rear part. The flow in cruise was considered at H=11,000 m, M=0.83 and angles of attack equal to 2.5 and 5 degrees with nacelles placement at the distances corresponding to the mentioned in (Slobodkina, 2015).

REFERENCES

[1] Slobodkina F.A. The Russian Federation Patent of invention № 2605653. The way of engine arrangement on the BWB aircraft. Priority date August 28th, 2015. Duration of the patent - up to August 28th, 2035.