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MODELING OF AERODYNAMIC NOISE OF QUADROTOR TYPE AEROTAXIS

Statement of the problem

The models describing the flow field around the quadrotor blades include the model of nonlinear vortices in lattices, the Reynolds-averaged Navier-Stokes equation (RANS, URANS), the large eddy simulation method (LES), as well as the direct numerical simulation (DNS) of the system of aerodynamic equations. Gutin's model [1] is used to describe the noise of the quadrotor rotation, and the Fowkes-Williams-Hawkings equation [2] in the formulation of Farassat [3] is used to model the noise taking into account various sound sources. However, these approaches have certain drawbacks that limit the application of these models. The following paper uses a modern approach to modeling noise of aerodynamic origin based on the 3-dimensional non-stationary equation of sound propagation from a thin blade in the potential approximation [4].

Statement of the main materials of the study

To study the rotor rotation noise of quadrotors, it is necessary to distinguish small acoustic disturbances of the flow. Therefore, we use the potential flow model described by the system of equations of motion in potential form [4], Bernoulli's equation and border condition equation. This is a mathematical model of the generation of rotation sound generated by the joint operation of aerotaxi rotors.

On its basis, the calculation of the near and far sound fields were performed. A new model for calculating the long-range sound field of a quadrotor type aerotaxi is proposed, which takes into account the mutual formation of the resulting sound field from the joint operation of 4 propellers.

As a test configuration we assumed blade radius R = 3 m with a chord 0,3 m. In cross-section, the blade has a NASA parabolic profile.

Fig. 1 and fig. 2 are examples of graphs obtained in the scope of our study.

In our studies, we discovered that thick blades disturb flow much less than thin blades. Maximum Cp achieved on high Mach numbers and thicknesses. In such cases, additional zones of sound generation appeared in two places nearer to the airfoil tail. At the same time, they are more pronounced for Mach number than for Mach number. Also, we discovered that increasing the relative blade thickness to the value of 0.1, resulted in a significant increase in the generated noise level in far field to 95 dB. At the same time, the pattern of distribution of the peaks in the sound wave changed slightly: the peaks became more pronounced. With increasing distance from the control surface, the local areas of the maximum pressure level significantly decrease, levelling out with the overall sound pressure level.

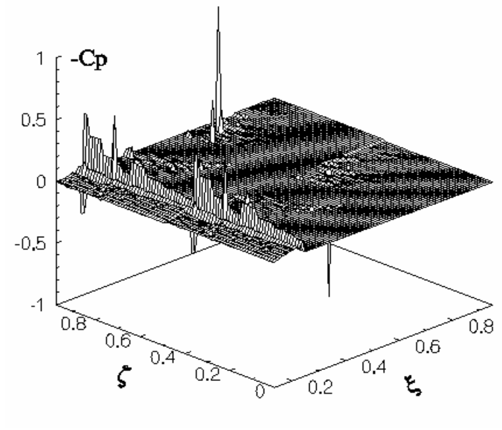

Fig. 1. Cp(ξ,ζ) distribution if $M = 0{,}1$, $\delta = 0{,}06$, $\Omega R = 220$ m/s

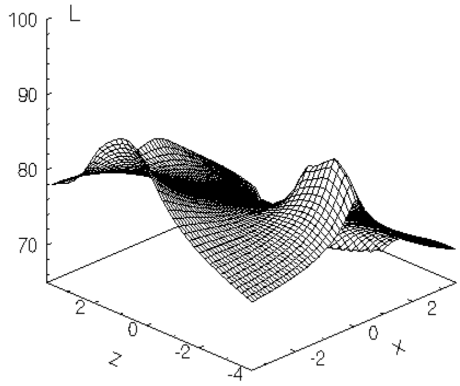

Fig. 2. Far sound field pressure level distribution L(x,y) (in dB) if $M = 0{,}1$, $\delta = 0{,}06$, $\Omega R = 220$ m/s

Conclusions

The problem of generating rotational noise by the blades of a quadrotor-type air taxi is formulated and numerically solved in the potential approximation. The characteristics of the near and far sound fields are studied. In particular, the pressure coefficient and the sound pressure level in the far sound field are calculated, and the frequency content of the generated sound wave spectrum is investigated.

The total level of generated rotational noise is in the range of 70 dB – 102 dB, which is quite close to the results of studies of a quadrotor air taxi, and is also close to an air taxi with an aircraft-type propeller arrangement.

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