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THE EFFECTIVENESS OF HIGH-ALTITUDE UAV PROPELLERS

Recently, high-altitude unmanned aerial vehicles have been attracting increasing interest due to their undeniable functional capabilities, which in many ways complement or even replace expensive satellite systems, in particular atmospheric research, telecommunications, the Earth surface sensing, and, especially given today's realities, reconnaissance and monitoring of battlefields and borders.

High-altitude UAVs also have undeniable advantages in terms of efficiency and ease of operation, as well as the ability to interact with global satellite systems and, to a certain extent, replace them in crisis situations.

Electric propellers are mainly used as propulsion systems in high-altitude UAVs. Both the altitude and duration of flight depend on the design and aerodynamic quality of the propellers.

At high altitudes, the efficiency of propellers decreases due to low Reynolds number flow conditions. In addition, the propeller design is optimized for maximum cruise efficiency, which makes its operation at low altitudes and during climb problematic.

The biggest problem in designing stratospheric propellers is their excessive diameter, weight, and blade shape.

The problem can be solved by using double-row tandem blades (Figure 1).

This significantly reduces the diameter of the propeller and increases its aerodynamic stability. If a toroidal-spiral tip is used, the rigidity and strength of the structure are increased while reducing tip losses.

Given the thinness of both the blade and the tip, the profiling of the connecting tip is simplified and basically comes down to cutouts in the trailing edge of the connecting tip of a constant thickness (as a rule). In this case, the profiled cutout is made in the area of the transition of the connecting tip to the blade of the next row (downstream). In the same way, vortex formation is reduced in the sleeve part of the blade, i.e., by a profiled cutout of the trailing edge.

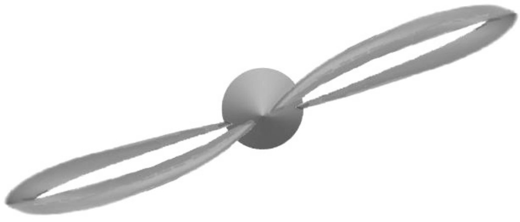

Figure 1 – Blade of a tandem propeller of a high-altitude UAV with a toroidal-spiral connecting tip.

Considering that the surface acoustic power level (SPL) mainly depends on the blade rotation frequency, since it is related to the rotation speed of the blade tip cross-section to the sixth power [1, 2], a significant reduction in the diameter of the propeller will also lead to a reduction in the vortex noise generated by the blade tip.

$$SPL=10\log\frac{kA_b(V_{0,7})^6}{10^{-16}},$$

where: k – the proportionality constant; A_b – the area of the blade; $V_{0,7}$ – velosity at 0,7 radius.

At the same time, based on the altitude of the UAV, this issue is only relevant during takeoff and climb phases.

The performance of the propeller directly depends on the diameter of the propeller [3, 4]. In the case of double-row (tandem) blades, a sharp decrease in the overall diameter of the propeller (compared to a single-row propeller) is compensated by the performance of the second row of blades. In addition, it should be noted that the blades of a single-row propeller are almost completely covered by the flow separation, while in a tandem propeller, the second row operates in a non-separated mode.

The increased level of tip losses caused by the separation of the flow from the tips of the first row blades and the creation of a torus-like tip vortex is compensated by the profiling of the connecting toroidal-spiral tip. That is, the main advantages of a double-row propeller with a connecting blade tip (reduced diameter, increased strength and stability of the structure) not only compensate for its disadvantages, but also, with the correct profiling of the blade and the connecting toroidal-spiral tip, as well as the mutual arrangement of both rows of the propeller, allow for a significant increase in propeller performance against the backdrop of increased strength and stability of the structure.

From this point of view, counter-rotating propellers with double-row blades connected by toroidal-spiral tips are of considerable interest. Such propellers allow for almost twice the thrust, although the mechanism of interaction between the end vortices of the connected blades requires detailed study.

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