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New directions and approaches to improve the efficiency of air propellers.

The modern trends and techniques of increasing the effectiveness of air propellers are considered. The application of tip vortex generators for combining the tandem propeller blades, in order to utilize the energy of finite vortices is proposed.

Introduction

An air propeller, known as a thruster for a long time, has been the only possible thruster in aviation for many years. The growth of the flight speed, the appearance of reactive, and then the turbofan engines significantly reduced the use of propellers. However, it should be noted that today the air propeller does not have economical competitors at moderate flight speeds ($M \leq 0,6$, and in the case of coaxial counter-rotating propellers – $M \leq 0,8$). Also, propellers and ducted propeller has no competitors in the application for aerofoil boat and hovercraft, which is necessary to reject large engine air mass with low speed not achievable jet engines. The main disadvantages of air propellers that restrict their use include low aerodynamic loading (limited number of blades), large diameters, need for a gear and blade rotation mechanism, significant tip losses (associated with the formation of tip vortices and their interaction between the yourself and with an airplane).

However, despite the inherent disadvantages recently started to manifest increased interest to propellers as thrusters. This is mainly due to the rapid development of subsonic unmanned aerial vehicles and methods of numerical gas dynamics, the application of which allows for better (optimally) design and research. Also, in recent years, the interest of designers to the "open rotor" system with multi-blade wide-chord counter-rotating propellers has grown considerably.

To sum up, it should be noted that the main trend of the last decade is the study, design and application of wide-chord, high-speed, high-rotation and high-performance propellers, as evidenced by various Western aviation development programs for the near future.

Background

The increase in the peripheral velocity of the propellers leads to a forced reduction in the diametric dimensions, which in turn reduces the thrust developed by the propeller. This circumstance requires the use of wide- chord blades, and the design of counter-rotating propellers. An intermediate position is occupied by tandem propellers, which were developed in the early 1950s, but were not widely used because they had a significant drawback - very large tip losses. These losses are primarily due to the interaction of tip vortices, which come down from the first and second rows of propeller blades. The problem of strength and vibration of the console tandem blades, which are the result of aeroelasticity effects and the design of the propeller, are not the last place. In general, despite the design and scheme of modern propellers, they have one common disadvantage - significant tip losses due to the presence and interaction of tip vortices. But the problem facing researchers and designers is to find ways and develop methods to reduce the level of tip losses to improve the effectiveness of air propellers.

Solutions to the existing problem go in many different ways. This depends on the structure and design of the propeller. For single-row propellers, the tip of the blade is specially profiled [1] to reduce the end losses, or a tip winglet [2] or a series of stationary blades located downstream behind the propeller is used to untwist the tip vortex [3]. For counter-rotating double-row propellers, use forward (for the first row of blades) and backward (for the second row) sweep, different diameters of the first and second rows, the optimal arrangement along the axis of the first and second rows of blades so that the second row of blades untwist the tip vortices created first blade row. For tandem propellers, the jointing of the first and second row blades [4] are used, which leads to a two times reduction in the number of top vortices, but along with this, the efficiency of the second row of blades also decreases, which is due to the structure of the tip vortices.

In general, the design of propellers with tandem blades has certain advantages over single-row and counter-rotating propellers. However, the almost complete lack of information, studies of tandem propellers, both with disconnected and combined blades, have led to the conduct of scientific research aimed at theoretical substantiation of the use of tip vortex generators.

Ideas and working hypotheses

The basic idea behind this is to integrate into one unit: tandem blades, end-plates or proplets, forward, backward, and double-swept blade. This integration will utilize all the benefits of each individual method. This will significantly reduce the level of acoustic emissions and increase the effectiveness of air propellers.

The main hypothesis is to use the energy of the tip and hub vortex, to increase the impulse of the main flow in the central part of the propeller blades. After transferring the energy of the tip and hub vortices to the main flow, their intensity will decrease significantly, which in turn will reduce the overall noise level. Structurally, this is achieved through the use of special vortex generators, which are installed in the hub and the tip parts of the blade. In order to provide the required stiffness and increase the aerodynamic load of the blades, it is proposed to use a second row of blades, which are connected to the first by hub and the tip vortex generators. Both blades in the hub have a common root, which allows you to apply a pitch change mechanism. The first and second sets of blades are made as double-swept blades.

In general, a two-row aerial screw with combined blades (Fig. 1) consists of a propeller hub (item 1) and evenly distributed circles of the blades (item 2), with a quantity from two or more. Each separate blade consists of a forward blade of a saber-shaped shape with a forward swep (Item 3) and a rear blade of a saber-shaped shape with a bakward swep (item 4) jointed in the tip part of the spiral vortex generators (item 5), but in the root portion of the spiral vortex generators (item 6), which connects the blades and smoothly passes into the conical shaft (item 7). With the help of a shaft, the blade is fastened to the corresponding grooves of the propeller hub.

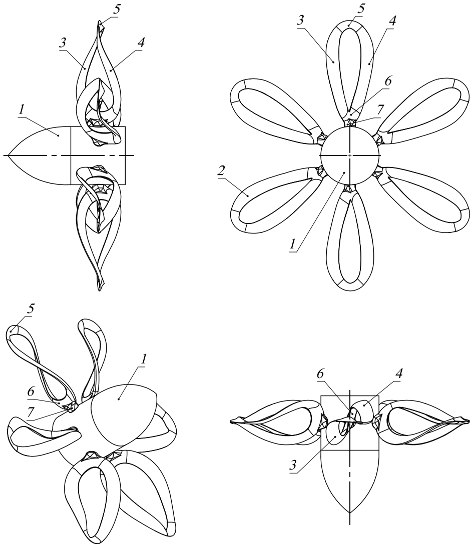

Fig. 1. Tandem propeller with jointed blades by tip vortex generator

Conclusions

A new constructional performance of the tandem propeller blades allows to achieve a number of advantages over existing schemes of propellers, namely: higher specific parameters (specific power, specific weight); high efficiency; lowered acoustic emission; propeller control system, as in a conventional single-row propeller; high stiffness and structural strength. Also, the propeller of this scheme can be used as a thruster for: airplanes, helicopters, ships, submarines, hovercrafts.

References

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