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Technique of designing a ducted propfan for a turbofan engine

The work presents the developed technique of designing a ducted propfan for a turbofan engine with high and ultra-high bypass ratio.

Introduction

The struggle for a high level of aircraft efficiency prompts manufacturers of aircraft engines to improve the main components of engines, to create new engine schemes, to develop structural modifications of engine elements. One of the main trends in modern aircraft engine construction is the increase in bypass ratio. This leads to an increase in the fan and, accordingly, to an increase in the diametrical dimensions and the weight of the engine nacelle, that negatively affects the economy of the aircraft. One of the possible solutions to this problem is the use of an open rotor. This is the so-called Open Rotor engine. Along with the fact that these engines have high fuel efficiency, Open Rotor engines encountered another problem−the high level of noise generated by the open propfan [1].

A ducted propfan is a possible solution to the problem of reducing the noise generated by the propfan. When using a ducted propfan for an engine with high bypass ratio, the weight of the motor nacelle of such an engine will be significantly less than the weight of the nacelle of a classic turbofan engine, but at the same time there are significant advantages in terms of increasing the economy of the aircraft when using engines with high bypass ratio.

Analysis of previous research publications

In works [2-5], the results of the research of ducted propfans and propellers (props) are provided. In work [2], the authors established that the presence of a cowl allows increasing the efficiency of the propellers. The paper shows that the presence of the cowl contributes to the redistribution of the vortex flow in the peripheral part of the blade. The work [3] presents the research results of the flow in a ducted prop by the methods of numerical and physical experiments, the feasibility of using numerical experiments at the first stages of designing ducted propellers and propfans is proven. The authors of the work [4] present the results of optimization the shape of the blades of the ducted prop. It is shown that the application of optimization allows improving the characteristics of ducted propellers and propfans. In [5], the performance assessment of the ducted propfan of the turbofan engine with ultra-high bypass ratio was provided. According to the results of numerical modeling of the flow in a ducted and open propfan for a long-term turbofan engine with ultra-high bypass ratio, it was established that the cowl has a significant effect on the thrust increase of the propfan. For the range of rotation frequencies 1500...1650 rpm. at Mach numbers at the entrance from 0.54 to 0.8, the increase in thrust reaches more than 70%. The visualization of the flow in the inter-blade channels of the propfan in the study [5] shows that the presence of the cowl contributes to the improvement of the internal aerodynamics of the propfan.

A literature review shows that the presence of a cowl helps to improve the aerodynamics of the blade row of a propfan (propeller) and improves its characteristics. However, there is a need to develop a technique of designing a ducted propfan for a turbofan engine with high and ultra-high bypass ratio.

The purpose of the work is to develop a technique of designing a ducted propfan for a turbofan engine with high and ultra-high bypass ratio.

Research results

A technique of designing a ducted propfan for a turbofan engine with high and ultra-high bypass ratio consists of several consecutive operations. The algorithm of technique of designing a ducted propfan for a turbofan engine with high and ultra-high bypass ratio presents in fig. 1.

Let's consider in more detail the algorithm of the technique of designing a ducted propfan for a turbofan engine with high and ultra-high bypass ratio.

Block "Output data of engine core". To start the calculation, it is necessary to set the initial data: the operating mode, altitude, atmospheric parameters, the power produced by the engine to rotate the propfan, the air consumption in the engine core.

Block "Choosing of bypass ratio". During this operation, the bypass ratio of the considered gas turbine engine is set. When choosing this parameter, you should be guided by additional studies that show the range of the optimal bypass ratio, taking into account the economy and mass characteristics of the engine.

Block "Calculation of the diametrical dimensions of the ducted propfan". Based on the selected value of bypass ratio, the airflow rate at the entrance to the ducted propfan is calculated. Next, using the data from the selection of the calculation mode and atmospheric parameters, with the help of the flow equation, the cross-sectional area through which the air will be supplied is calculated. After that, the diameter of the hub and the peripheral diameter of the propfan are calculated. Then, the height of the prop blade is calculated.

Block "Theoretical gas-dynamic calculation of the propfan rotor". Based on the preliminary data for the initial data accepted in the first three blocks, a theoretical gas-dynamic calculation of the propfan rotor is made, the parameters are calculated for three cross-sections: hub, middle, peripheral.

Block "Creating of a 3D model of the propfan blade". Based on all previous obtained calculations−installation angles, calculation of aerodynamic profiles, blade height, hub and peripheral diameters, choice of blade shape−the propfan blade is installed. To build a 3D model of a propfan blade, a special software environment for 3D design and model drawing is used.

Block "Selection of blades number for the blade row of the propfan". Based on the theoretical gas-dynamic calculation, choose the number of blades of the ducted propfan rotor.

Block "Creation of a 3D model of the blade row for the propfan rotor". Having data on the geometry of the blade and the number of blades, the shape and parameters of the spinner are selected and a 3D model of the blade row for the propfan rotor with the spinner is created.

Block "Flow simulation in the ducted propfan". Using all the data that was obtained, simulation of the flow in the ducted propfan is carried out in the calculation mode. Flow simulation in the propfan rotor is carried out in the calculation mode of operation in a special software environment.

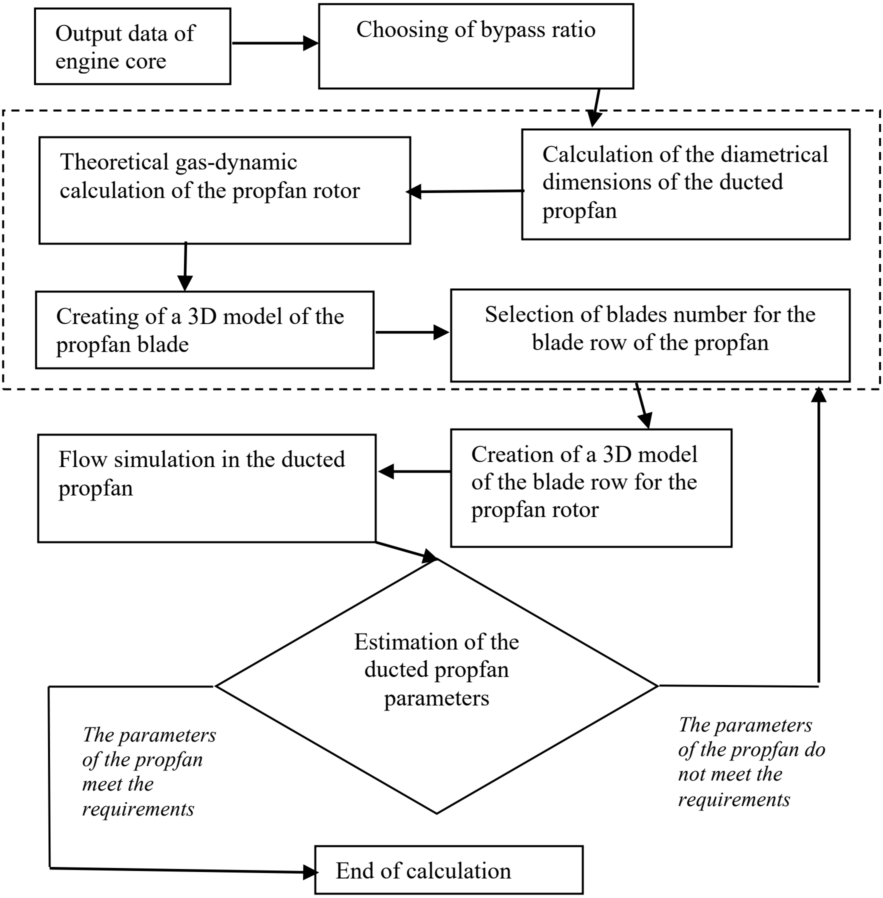

Fig. 1. Algorithm of technique of designing a ducted propfan for a turbofan engine with high and ultra-high bypass ratio

Block "Estimation of the ducted propfan parameters". According to the results of the flow simulation, the parameters of the ducted propfan are evaluated.

Based on the evaluation, a comparison is made between the given degree of pressure increase and the one obtained as a result of the calculation, the given effective operation of the propfan and the obtained one, the given efficiency and the obtained efficiency of the propfan, the given power and thrust of the propfan and the obtained power and thrust of the ducted propfan. If the obtained parameters of the ducted propfan meet the requirements, then the calculation ends and the received ducted propfan must be examined for other characteristics. If the obtained parameters of the ducted propfan do not meet the requirements, then the calculation goes to the system of blocks for the selection of geometric parameters of the blade, blade row, selection of the number of blades, etc.

Conclusions

The work presents the developed technique of designing a ducted propfan for a turbofan engine with high and ultra-high bypass ratio. The technique of designing a ducted propfan takes into account the influence of the shape of the blade, the number of blades and bypass ratio of turbofan engine.

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