Numerical Simulation of Strength and Aerodynamic Characteristics of Small Wind Turbine Blades

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Abstract. The main aim of this research is to develop effective methods to estimate strength and aerodynamic characteristics of small wind turbine blades for receiving the maximum aerodynamic quality. The aerodynamics of the wind turbine blades has been studied depending on their geometry and flow Reynolds numbers. Finite and boundary element methods have been used for numerical simulation. The two-dimensional hexagonal mesh has been generated for aerodynamics simulation, with thickening around the blade profile and the thin boundary layer adjacent to the airfoil. Modal analysis has been carried out. A discrete analogue of the wind turbine has been created to study the aerodynamic characteristics of wind turbine blades using the Shear Stress Transport turbulence model. The influence of the attack angle on the aerodynamic characteristics has been studied, and its critical value has been found. The comparison of results of estimating the aerodynamic characteristics using boundary and finite element methods has been accomplished.

Keywords: Small Wind Turbine, Blade, Finite Element Method, Shear Stress Transport Turbulence Model, Natural Frequencies, Mode Shapes, Aerodynamic Characteristics.

1 Problem Statement

Wind energy is a rapidly developing industry, and now it is considered as one of the most promising renewable energy sources. So, by the beginning of 2019, the total installed capacity of all wind generators (with 600 GWs or more generator power) exceeded the total installed capacity of nuclear power stations. As main advantages of producing electricity with wind turbines consists in absences of pollutant emissions into the atmospheric air. Besides, the operation of one wind generator with capacity of 1 MW reduces annual emissions into the atmosphere by 1,800 tons of CO_2.

Along with this, there are a number of negative factors in the use of wind power plants, which include instability of operation, relatively low output of electricity, high cost, certain danger to wildlife, noise pollution [1], etc.

Nevertheless, the special attention is now paid to developing small wind turbines (SWT) due to their capacity of efficient electricity supplying both isolated consumers, requirement was 180 kW per month. In the calculation process, the SHAWT producing 247 kW per month was obtained, which is enough for the stable energy supply, even in the case of less windy weather (average wind speed of 4 m/s). For this purpose, the modal analysis was accomplished, and aerodynamic characteristics of bade airfoil were estimated. A two-dimensional aerodynamic calculation of the wind turbine blade profile based on NASA 4412 airfoil, was carried out. As the results, the profile flow patterns, aerodynamic coefficients and their dependence on the angle of attack were obtained. Based on the results obtained, recommendations were given regarding the choice of the angle of installation of the blade in sections and its general appearance. The obtained results allow to receive the SHAWT with maximum coefficient of performance.Further, SMTs with twisted blades and different thickness along the blade length will be investigated by proposed approach.

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