Chapter 11

Computational Analysis of Symmetric and Cambered Blade Darrieus Vertical Axis Wind Turbine With Bio-Mimicked Blade Design

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ABSTRACT

Vertical axis wind turbine suffers from low performance, and the need for improvement is a challenge. This work addresses this problem by using computational fluid dynamics. This chapter aims to analyze and compare symmetric and cambered Darrieus turbine. These analyses are usually carried for straight leading-edge blades, and cambered resembles more the natural shape of the wing of birds and other aquatic mammals, which helps them generate extra lift during movement. Moreover, recent studies suggest better performance was observed for NACA0018 symmetric aerofoil blades, and a similar trend has been observed for NACA2412 cambered aerofoil profiles. Turbine models having symmetric NACA0018 and cambered NACA2412 profiles have been studied. By comparing the symmetric model with cambered blade models, differences in coefficient of torque have been presented. OpenFOAM is used for performing the 2D simulation with dynamicOverset-FvMesh for motion solver with overset mesh method. Meshed geometry was constructed with GMSH codes and the simulation uses overPimpleDyMFoam algorithm as a solver.

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1 INTRODUCTION

The wind energy sector is one of the leading sectors of growth for sustainable development across the globe. According to the latest global wind report 2021, the industry showed a 53% increase in installation globally in 2020 (Global Wind Energy Council, 2021). Wind energy turbines are categorized as Horizontal Axis Wind Turbines (HAWT) and Vertical Axis Wind Turbines (VAWT). HAWTs are the traditional three-bladed lift-based turbines whose rotational axis is parallel to the ground and has higher acceptability. Vertical axis turbines are less used and have both drag-based like Savonius and lift-based like Darrieus. The axis of rotation is perpendicular to the ground for vertical axis wind turbines. However, Vertical Axis Wind Turbine suffers from low performance, and the need for improvement is a challenge. The VAWTs are considered to have lesser efficiency as compared to HAWTs; however, they have a wide range of operations. Many works have been published to improve the efficiency of these turbines with new design considerations (Ahmad et al., 2016; Mishra et al., 2018; Seeni et al., 2018). Hand et al. (Hand et al., 2021) have presented aerodynamic design parameters that influence the lift type VAWT. Elsakka et al. (Elsakka et al., 2019) pointed out how the Angle of Attack (AoA) variation can enhance performance for Darrieus turbines with a variable pitch by comparing it with the fixed pitch model. Bio-inspiration is one of the techniques of mimicking nature to improve the aerodynamics of the present models. Fish (Fish, 2020) introduced tubercles to the blade's leading edge as a bio-inspired design inspired by gigantic humpback whale flippers. Yadav (Yadav et al., 2021) implemented a bio-inspired nose inspired by cetacean marine mammals for flow separation on NACA airfoil for the 4 and 6 series. Work states for a lower angle of attack, larger perturbation of the nose leads towards multiple accelerations on the extended surface, creating a forward-facing step and thus improving the aerodynamic efficiency. But, at a high angle of attack, it is ineffective due to early flow separation. Lositano & Danao (Lositano & Danao, 2019) studied cambered tubercle leading-edge blades for VAWT and stated a detrimental effect compared to cambered NACA0025 airfoil. Rezaeiha et al. (Rezaeiha et al., 2018) published a work on VAWT CFD study that comprises of tip speed ratio, solidity azimuthal increment and simulation convergence. Bai et al. (Wang et al., 2015) worked on computational analysis of VAWt with tubercle leading edge on NACA0015 and stated the thrust is lower than the straight blade turbine. Howell et al. (Howell et al., 2010) showed 2D results overestimate 3D results and the reason for such drop in result in 3D case is due to end tip vortices. Kjellin at el. (Kjellin et al., 2011) conducted experimental study for 12 KW VAWT and got coefficient of performance 0.29 at tip speed ratio of 3.3 using NACA0025 airfoil. Mohamed (Mohamed et al., 2015) stated the zero pitch angle gives best performance while comparing 25 airfoil profile, LS(1)-0413 airofoil gives 10% extra power compared to NACA0018 and NACA 63-415 gives a wider operating range than all other airfoil models. Jones(Jones et al., 2018) published a computational work for low Reynolds no flow for morphing airfoil the effect of dynamic surface around airfoil was explored computationally. Razaeiha et al. (Rezaeiha et al., 2017) performed experimental analysis and for increasing the pitch angel to -2° the C_p increases for 6.6% in comparison to zero degree pitch angle they stated the change in configuration changes the strength of shed vortices and can decrease the wake generation for VAWTs. Rostamzadeh et al. (Rostamzadeh et al., 2013) has published an experimental and computational for a new design for tubercle was introduced the result for computational and experiment are in good agreements with each other. Khaleghinia et al. (Khaleghinia et al., 2021) published a study for NACA0018 with cavity layouts and claimed the performance increased by the addition of these cavities, a computational study was performed for shape position size and no. of cavities. The greatest value of torque was achieved with a single cavity and a dual cavity result was