Chapter 10
Numerical and Experimental Investigations on a Bio-Inspired Design of Darrieus Vertical Axis Wind Turbine Blades With Leading Edge Tubercles

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ABSTRACT

Various improvements can be made to Darrieus vertical axis wind turbines (VAWT) for maximum performance in an urban environment. One such improvement is the inclusion of bio-inspired leading-edge tubercles to increase the aerodynamic performance. These structures, found on the flippers of humpback whales, are believed to aid the mammal in quick maneuvering. The objective of the chapter is to investigate and compare the performance of a Darrieus type VAWT with the inclusion of leading edge tubercles. The performance of the turbine with leading-edge tubercles on the blades is compared with the turbine with normal blade, computationally (with computational fluid dynamics using transition SST turbulence model) and experimentally. The focus lies on building an experimental setup to compare the performance of leading-edge tubercles with the baseline turbine.

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1 INTRODUCTION

Easily available to us in one of the greatest quantities as a source of power, the wind is also one of the most inexhaustible sources of energy. To harness the potential, of this energy, different kinds of turbines are used. Based upon the orientation of their axis of rotation, these turbines can be placed in two clusters – horizontal axis wind turbines (HAWTs) and vertical axis wind turbines (VAWTs). The fact that VAWTs can perform, irrespective of the direction of the winds, is what primarily segregates them from HAWTs. This is what gives the VAWTs an edge over the HAWTs, as the latter requires orientation in the direction of the wind, resulting in a need for additional mechanism, which means enhanced costs, in addition to more chances of failure. What makes VAWTs the most suited choice for application in urban environments is the fact that these turbines are omnidirectional. The impact of the direction of the wind does not affect them and they can support repeated occurrences of changes in wind direction that are violent or unsteady. The current designs are considered to be highly effective in comparison to the older designs, as has been shown by various proposed designs and testing. (Amano, 2017; Gupta, 2015).

Considering the factors that they can be installed near the ground, do not require a strict operating mechanism, and can take-off without high wind speed, are economical, safe for the environment, unaffected by irregular patterns or the direction of the wind, made us choose in VAWTS for our research.

The categories of Darrieus and Savonius in turbines are the two further classifications of VAWTs. Because of the high negative torque produced by the returning blade (Alom & Saha, 2018), the efficiency of the Savonius type turbine is comparatively less. The research is centered on Darrieus type turbines which work using the lift forces generated due to the aerofoil geometry of the blade. To create a cost-effective model design of a straight blade VAWT for small-scale power generation is the focus of the study. Parasitic drag and induced drag are the significant reasons behind the low performance of Darrieus turbines (Islam et al., 2008). Tip vortices play center stage in induced drag.

To perceive and advance efficient HAWTs, major work has been carried out in the past few years, but not much attention had been laid on VAWTs. Work on many criteria that affect the performance of a VAWT were published by Islam et. al (Islam et al., 2008). In-depth research was done on the consequences of the utilization of many numbers of design parameters, which resulted in more cost-effective and efficient turbines. We learn from the additional study by Persico et. al (Amato et al., 2013) that large-scale vortices have a powerful impact on the tip region of the wake shed by the H-shape turbine. As a consequence of the periodic fluctuation of the blade aerodynamic loading, these vortices pulsate notably during the period. This resulted in a great advantage in the execution of the present work to develop an efficient turbine for carrying out experimental studies. As observed in a recent study done on various wingtip devices, namely endplates and winglets, by Mishra et al, it was found that the endplates improved the performance of a Darrieus type VAWT significantly (Mishra et al., 2018).

The evolution of all living organisms to a well-adapted structure and material over all these years has been through natural selection. New technologies inspired by biological solutions at macro and nanoscales have taken off, courtesy of Bio-mimetics. All through the existence of the human race, the species have bought from nature the answers to problems and challenges. Nature has provided solutions to engineering problems such as self-healing capabilities, tolerance, and resistance to harsh environmental and climatic exposures, hydrophobicity, ability to self-assemble and harness solar energy. Scientists, researchers, and academicians have been ever enthralled to study nature and take inspiration from it. In the field of wind turbines, research has been done on bio-inspired materials for better efficiency. Ryoichi S Amano et al introduced a novel concept by using self-healing polymer composites for turbine blades. (Arun et al.,