Effect of through holes on the performance of hydrofoils used for Darrieus type hydrokinetic turbine

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Long Abstract

Introduction

Darrieus type hydrokinetic turbines, capable of working in environment offering bi-directional freestream flow, can be used for marine current energy harvesting. Successful extraction of energy from these flowing sources will go a long way in mitigating the energy crisis in a sustainable fashion. However, these Darrieus turbines suffer from some significant disadvantages. The major drawbacks of a Darrieus turbine include low starting torque resulting in its inability to self-start and also exhibits a high torque ripple. Various ideas have been suggested to overcome these drawbacks, like implementing external mechanical or electrical self-starting mechanisms, active and passive pitch control, helical bladed turbines, etc [1,2,3].

In the past, cavities have also been created on the aerofoil surface to improve stall angle [4]. The current work focuses on increasing the stall margin of the symmetrical aerofoil blade used in the Darrieus turbine, by creating a through hole on the aerofoil section. This will help in improving the performance of the Darrieus turbine. This forms the background of the present work.

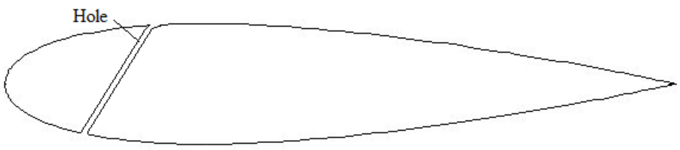

Figure 1. Schematic of the modified aerofoil geometry

Methods

NACA 0018 is chosen as the aerofoil for the current analysis. Through hole is created between the low pressure and high pressure surfaces of the aerofoil. This pressure difference would generate a jet flow to the upper surface and hence impart momentum to the boundary layer. A computational fluid dynamics approach is used to conduct the analysis. The work is carried out in two steps. As a part of the first step, simulations were carried out with single isolated aerofoil with and without holes. These simulations were carried out at a Reynolds number, based on chord length and a freestream velocity, of 100k. In the second step, suitable aerofoil geometry, including those with holes, were used as blades of Darrieus turbine and the performance of the turbine is predicted.

Initially, the flow analysis is done for the NACA 0018 aerofoil without any through holes, to obtain the critical stall angle and the point of flow separation. The geometry and the mesh is generated in ICEM CFD. Hexahedral meshing is used for the geometry and mesh refinement is done near the aerofoil wall since k-ω SST model requires fine resolution near the wall to capture flow separation.

For analysis of the aerofoil with the hole, the mesh region around the outlet of the hole is refined to obtain accurate values and capture the effect of momentum impartment precisely. Fig. 1 shows the mesh details close to the aerofoil.

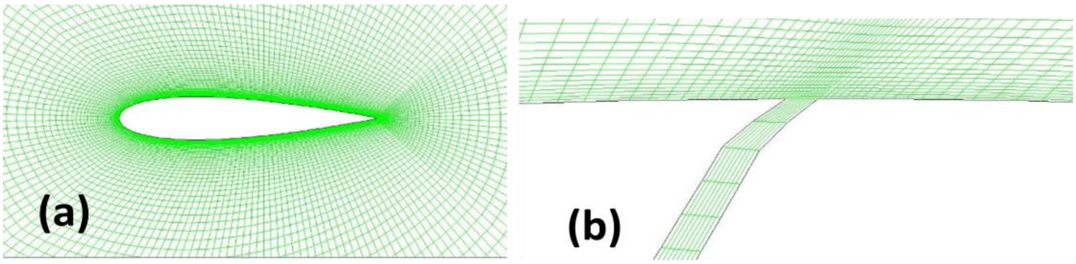

Fig. 1. (a) Mesh around the aerofoil. (b) Zoomed view near the opening of the hole.

Numerical analysis was carried out using ANSYS Fluent. The turbulence model used is k-ω SST. Semi-implicit method for pressure-linked equations (SIMPLE) scheme was used for pressure velocity coupling. The second order upwind was applied to discretize the convective terms of the governing equations. The absolute convergence criterion was set to 10^{-5}. Different parameters which might affect the delay in stall angle are blowing ratio, angle of jet and distance of jet outlet from the point of separation. A through hole was placed at different locations, at different angular orientations and was simulated for a range of blowing ratios. Lift and drag coefficients were calculated at different angles of attack. Table 1 shows the different geometries attempted and the variation in stall angle. An increase of 3 degrees in critical stall angle is observed in the current work.

Table 1: Different locations, angular orientation and blowing ratio used to determine their effects on stall angle.

Case	Blowing Ratio	Angular orientation of the jet (°)	Outlet position from the point of separation (mm)	Stall angle(°)
1	1.25	20	1	14
2	1.25	30	1	14
3	1.25	40	1	15
4	1.20	40	5	15
5	1.33	40	1	13
6	Without Hole			12

Further studies have been carried out to examine the effects of these holes on the performance of the Darrieus turbine. These resulted will be discussed and presented.

References

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