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Ice accretion simulations on rotating NACA0018 airfoil

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Ice accretion on wind turbine blades happens in cold climate regions. Vertical axis wind turbines (VAWT) are very sensible to ice accretion due to poor self-starting capability and power generation performance. Numerical simulations of VAWT's icing are very complicated, transient problem. Thus, the unsteady simulation needs a huge amount for computational power. This paper presents a steady-state approach on VAWT rotating blade ice accretion. Unsteady airflow solution obtained through ANSYS Fluent™, then droplet impingement, and ice accretion obtained using FENSAP-ICE. Numerical results were averaged over one period. The ice distributed over whole blade cord length with minimal thickness near the middle. Maximal ice thickness changes periodically depending on azimuthal angle.

Keywords: VAWT, icing, numerical simulations, CFD

INTRODUCTION

Cold climate regions can offer 10% higher wind power due to increased air density at lower temperatures [1]. But wind turbines located there facing low temperatures below operational conditions and icing events. Which are effect on wind turbine performance and safety [2, 3].

While working VAWT blades create cylindrical surface and this corresponds to 3D case. Along with that, relative velocity, AOA depends on rotational speed and azimuthal angle. Position of each blade changes with time [4,5]. Thus, unsteady simulations must be carried on. However, icing events can last from several minutes to hours and transient simulations will require a huge computational time. Consequently, quasi-steady simulations must be used to predict ice accretion on VAWT blades.

The aim of this study is to present a quasi-steady approach to simulate VAWT blade icing. FENSAP-ICE was used to solve airflow solution, droplet impingement and ice accretion [6]. The results showed that maximal thickness of ice accumulated on leading and trailing edges.

NUMERICAL METHODS

FENSAP module was used to solve Spalart-Almaras one-equation turbulence equation. DROP3D helps to calculate water droplet collection efficiency by the Eulerian method. The Eulerian method solves Euler and Navier-Stokes equations at the continuous phase. Ice shapes were obtained using ICE3D which solves mass and energy conservation equations [7, 8]. The overall layout of numerical simulations described in Fig.1.

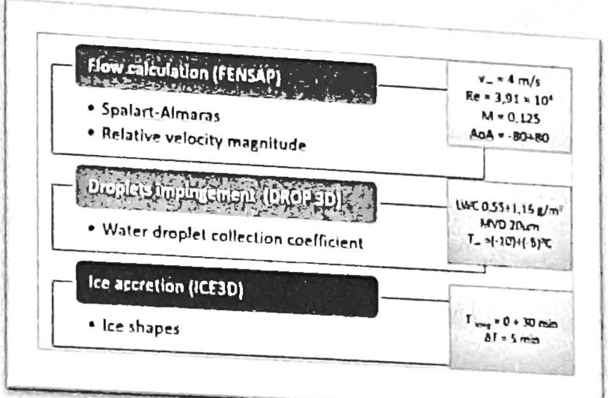

Fig.1. The structure of numerical simulations

In this study, a single NACA0018 airfoil with cord length 0.125m was used. The blade is rotating with constant angular velocity 100 rpm. Rotation center located on 0.25 cord length. Convergence criteria was set to 0.1% of blade lift force deviation. Converged solution achieved after 10 full periods. Angular time-step was set to $\Delta\theta=5^0$ to reduce calculations time. Free stream velocity was set to 4 m/s and air temperature was set to 265K. Droplet impingement and ice thickness were averaged for 5 periods after convergence. Ice rate and location averaged over period.

RESULTS AND DISCUSSION

Ice location and maximal thickness is directly related to the angular position, relative velocity, droplet collection efficiency. Fig.2 presents averaged ice thickness after over last 5 periods after convergence achieved.

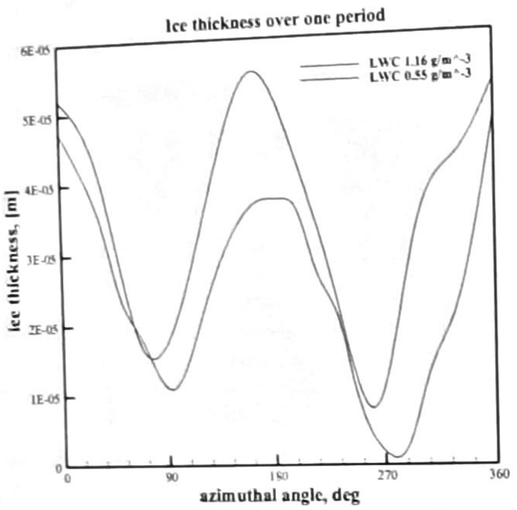

Fig. 2. Dependence of ice thickness on azimuthal angle for LWC 0.55 g/m^3 and 1.16 g/m^3

From the graph above, ice thickness changes with azimuthal angle. Maximal thickness almost the same near the leading edge and trailing edge (180^0). Between 0- and 180-degrees ice accumulates on top surface of the blade. Similarly, bottom surface of the blade experiencing icing between 180- and 360 degrees. Thus, during one rotation the whole blade surface will be covered by ice.

CONCLUSIONS

In this study, the ice thickness on the rotating VAWT blade affected by azimuthal angle was studied. Through the research, some useful conclusions are obtained as follows:

1) as the azimuthal angle changes maximal ice thickness moves from the leading edge towards the trailing edge;

2) ice covers the whole blade surface with minimal thickness near 90^0 and 270^0;

3) LWC affects maximal ice thickness accumulated on rotating blade.

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NOMENCLATURE

AOA – the angle of attack, deg;
CFD – computer fluid dynamics;
LWC – liquid water content, g/m^3;
MVD – median volume diameter, μm;
VAWT – vertical axis wind turbine;
HAWT – horizontal axis wind turbine;

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