CFD ANALYSIS OF THE MITIGATION OF AERODYNAMIC UPLIFT LOADS USING ROOF INTEGRATED WIND TURBINES FOR REDUCED WIND DAMAGE AND POWER SUPPLY PRODUCTION

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Low rise building roofs often experience high wind-induced damage in coastal areas in the United States. These coastal areas are prone to hurricanes with wind speeds exceeding 150 mph [1]. Due to the high suction experienced, the roof of a low-rise building is susceptible to wind damage [2]. Mitigation devices have been studied to lessen these negative effects. Lin and Surry performed wind tunnel measurements in Western University, Canada and discovered that minor alterations to roof corners can diminish wind damage [3]. These researchers found that porous parapets placed on a building edge can reduce roof suction. Similarly, Suaris and Irwin applied perforated parapets at roof corners which resulted in a 60% peak pressure coefficient reduction [4]. Experimental studies have also been conducted at Florida International University, USA using the Wall of Wind Experimental Facility (WOW EF) by Blessing et. al [5]. The WOW EF explored the optimal cases in the placement of a roof wind turbine and its wind direction to maximize the reduction in wind uplift. The wind suctions were reduced as the localized pressure coefficients were also reduced by about 70%. The area averaged peak pressure coefficients for the worst wind direction showed a 30%-44% decrease in magnitude.

Wind turbines are commonly placed on buildings in areas of high wind loads to produce wind energy. The turbines generally fixed to a building roof are known as Building Augmented Wind Turbines (BAWT) [6]. There are two types of BAWT's: Horizontal Axis Wind Turbines (HAWT) and Vertical Axis Wind Turbines (VAWT) [7].

This study focuses on the application of an Aerodynamic Mitigation and Power System (AMPS) (US Patent, Gan Chowdhury et al., Patent Number: US 9,951,752 B2, April 2018) by applying a HAWT in three distinct cases to take advantage of the following: reduction in wind damage, wind energy production at low and high wind speeds, ease of integration, low maintenance cost, and pleasing aesthetics. The previous work and its corresponding patent by Chowdhury et. al [8,9] is the basis of this study.

A scaled-down building and turbine were modeled using SolidWorks. Four configurations were assembled. Case 1 consisted of a bare deck model with no applied turbine. Case 2 explores the turbine being installed slightly above the building roof. In Case 3 and 4, the wind turbine was directly in contact with the roof edge although the positioning of each's turbine was distinct. The computational fluid dynamics (CFD) analysis setup has been optimized for Case 1 in regards to the mesh parameters and test setup.

An initial study was conducted to optimize the number of iterations using ANSYS Fluent. A computational domain with offsets from the geometry origin was applied. A Boolean feature was employed to subtract the building from the computational domain for proper fluid flow. Outlet pressure was assigned to 0 Pascals. Various other parameters were inputted.

The test setup was of the model k-epsilon with a near-wall treatment in which gravity was considered. The wind velocity of 75 m/s normal to the boundary was given to the system. Hybrid initialization was assigned as the solution method. This choice produced a complex, accurate predication that used boundary interpolation methodologies to solve the system as a Euler problem.

The residual monitors were all enabled with absolute criteria of 0.001. Convergence check was disabled to reduce computational time. Calculations were run with a range of 30 to 2,000 iterations.

The pressure and velocity difference were plotted for each iteration to view the effects of the various manipulations. Positive results led to steady-state conditions experiencing convergence. Based on graphical representations of pressure and velocity over several examined iterations, the value of 1,000 iterations was determined to be a valid number of iterations for a converging steady-state condition.

Moreover, different meshes were examined to optimize the results produced for this study. Seven meshes were created and compared in different planes – the XZ plane, YZ plane, and YX plane. Copious parameters were manipulated: growth rate, defeature size, curvature normal angle, number of cells across a gap, and element sizing. After several iterations, Mesh 4 delivered the most accurate results with the least number of elements and nodes. This, in turn, required the least amount of processing time.

Overall, a vital aspect of an accurate CFD study is the user-inputted parameters. This study optimized the mesh parameters and test setup, including the number of iterations, to produce the minimal amounts of elements and nodes all while still generating accurate and consistent results throughout the roof surface. Future research will include: (1) CFD analysis of dynamic AMPS system to mirror the results found in Chowdhury et. al. [8,9] and (2) its resultant power production for the electrical maintenance of infrastructures.

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