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CFD SIMULATION AND ANALYSIS OF PERFORM
DEGRADATION OF WIND TURBINE BLADE IN D
ENVIRNONMENT
Investigation of the Flow Charac
of a Wind Turbine in a Dusty Environmen

A thesis submitted in partial fulfillment of the requirements for the degr
of Science at the Faculty of Engineering, Ain Shams Universit

By

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STATEMENT

This thesis is submitted in partial fulfilment of the Master of Science in Mechanical E
Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been sul
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ABSTRACT

When a wind turbine operates in a Saharan environment under dusty flow conditions, the surface roughness of the blade will increase due to dust accumulation. This roughness may lead to a severe drop in performance parameters (C_L , C_D), which in turn results in a significant drop in turbine power. This work is done to provide the details of the dust deposition process over the wind turbine blades and to record the subsequent effects on performance parameters. A numerical model is created in addition to a deposition model for particle transport using computational fluid dynamics (CFD) package FLUENT to record the performance for wind turbines which operate in dusty environments. The deposition model is created to simulate the dust build up over the blade surface. This deposition model is implemented in C-language using FLUENT's user defined functions (UDF) capability as a wall boundary condition for the blade surface upon particle impact. First the deposited mass in each cell on the blade surface after a certain operational time was obtained and stored using the deposition model with the FLUENT's user defined memory location (UDML) functions. This mass was then converted into an equivalent roughness height to estimate the new surface profile of the blade. The deterioration in performance parameters is explored for the new profiles after each year of operation over one year.

The performance of a NACA 63-215 airfoil section under different operational conditions over a time period of one year has been studied. For the case study at hand and also for validation, operating conditions similar to those of the experimental study of Khalfallah [1] were used. Khalfallah and Koliub [1] conducted an on-site investigation for dust deposition over the blades of a stall controlled wind turbine (Nordtank 300 kW). According to the specification and site characteristics, an average Reynolds number of 1×10^6 can be achieved over the blade length with an angle of attack of 4° .

The flow field around the two-dimensional clean and fouled airfoil section (NACA 0012) is solved by numerical solution of the two-dimensional incompressible Navier-Stokes equations coupled with a turbulence model which is chosen to be SST $k-\omega$. For validation purposes, the numerical results are compared with the experimental results of Khalfallah and Koliub [1] and the results of Ren [2]. The developed model is used to assess the effect of roughness height on both the lift and drag coefficients.

Key words: wind turbines, dusty flow, performance deterioration.

DEDICATION

To my Dad, Sister, and Dr. Aya for always being there.

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