AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

INVESTIGATION OF THE EFFECT OF SOME DESIGN PARAMETERS ON THE PERFORMANCE OF WIND TURBINES

BY

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UNDER THE SUPERVISION OF

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بسم الله الرحمن الرحيم

TO

MY PARENTS

MY SISTERS

FOR THEIR LOVE

AND HELP

PREFACE

This thesis is submitted to Ain shams university for the degree of master in mechanical engineering. The work included in this thesis was carried out by the author at the laboratory of fluid mechanics, Energy and automotive depart ment Faculty of engineering, Ain shams university.

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Hoping that this research will be useful for the developing countries and our beloved country, EGYPT.

ABSTRACT

Experimental and theoretical investigations were performed on a specially designed horizontal axis wind turbine. The experimental work was carried out near the exit of a wind tunnel. This tunnel was designed for testing wind turbines.

Tests were run to study the effect of the following design parameters on the performance of the wind turbine. These parameters are: the blade chord length, the blade length, blade setting angle and blade profile. Moreover, the effect of the number of turbine blades was also studied.

As for the effect of the blade chord length, three values were tested which are 50mm, 100mm and 150mm. The blade having a chord length of 150mm was found to be the best one. Concerning the effect of blade length, six ratios of rotor diameter to hub diameter ranging from 4 to 7 were investigated. The best ratios were found to be in the range from 5.5 to 6.5 .

The study of the effect of the blade setting angle covered a range from zero to thirty degrees. The best performance was obtained when the setting angle ranged from five to twenty degrees.

In regard to the effect of blade profile, three types were tested. These are: NACA 0012, NACA 4418 and FX 60-126. The worst performance was obtained with NACA 0012; while the other two profiles showed a better performance.

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As a conclusion of the experimental work, two and four-bladed turbine rotors were tested including all previous parameters. It was found that the four-bladed wind turbine is the most efficient one.

For the theoretical work, the blade element theory was applied using a power coefficient formula which was obtained from the application of both angular momentum equation and blade aerodynamics. The obtained analysis showed that the maximum power coefficient was in the neighbourhood of 0.43. However, the corresponding obtained experimental value was about 0.35.

Finally, it may be concluded that within the tested range the four-bladed rotor having blade profile of NACA 4418 or FX 60-126, chord length of 150mm gives the best performance when the blade setting angle ranges from five to twenty degrees and the rotor to hub diameter ratios are in the range between 5.5 and 6.5 .

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NOMENCLATURES

A	Cross-section area.	m^2
C	Aerodynamic coefficent.	
Cl	Lift coefficient.	
Cd	Drag coefficient.	
Cp	Power coefficient.	
Cpm	Maximum power coefficient.	
D	Diameter of the rotor.	m
dp	Diameter of the brake pulley.	m
D	Drag force.	N
ds	Elemental area.	m^2
F	Force.	N
g	Acceleration.	m/S^2
l	Blade length.	m
i	Incidence angle.	Degree
I	Angle of inclination.	Degree
K	Velocity coefficent.	
L	Lift force.	N
N	Rotational speed.	RPM
P	Power developed.	W
T	Tension in the wire.	Kgf
U	Tangential velocity.	m/s
V	Wind velocity.	m/s
V1	Upstream wind velocity.	m/s
V2	Downstream wind velocity.	m/s

V_i: The air velocity at element i.	m/s
W : Relative velocity.	m/s
ω : Angular velocity.	rad/s
ρ : Air density.	Kg/m^3
α : Blade setting angle.	degree
τ : Torque.	N.m
λ : Tip speed ratio.	
λ_m: Maximum tip speed ratio.	
δ : The blade solidity.	

INTRODUCTION

Nowadays, new sources of energy are searched for, because of the deficiency in the traditional energy sources as petroleum, natural gas and coke.

Renewable energy is the term used to cover those continuous energy flows that occur naturally and repeatedly in the environment. Energy from the sun, wind and tidal waves are some sources of such energy. The heat from within the earth itself (geothermal energy) is also usually regarded as a renewable energy source since in total it is a source on a vast scale; although locally it cannot always sustain continous extraction.

As for wind energy, power can extracted by using wind turbines or aerogenerators. As air flows over the turbine blades, it creates a turning force on the rotor assembly which can then be used either to drive water pumps or more conveniently to generate electricity.

The fundamental questions to be answered concerning windmill location are:-

1- Optimum geographical placement.

2- Variation of wind speed with height.

3- Wind speed variation with time; and knowledge of maximum winds to avoid excessive stresses.

For geographical placement, long-term data are requried over large regions to determine which areas of a country are most appropriate for wind power generation.

The height of a windmill must be decided on essentially economic terms since the simplest noneconomic arguments indicate that the heigher tower is the better. Theoretically the wind blows from high-pressure zones to low-pressure ones. However, at medium & high altitudes, its direction is modified by the earth's rotation.

Variations of the mean wind speed with time must be considered for daily, monthly, yearly, and long term periods. The annual duration of calm spells is important because it indicates the period which must be covered by storage when small or medium-sized wind-driven plants are used.

As for the wind turbine itself, there two main types depending on the axis of rotation. The first type is the horizontal axis in which the rotor shaft is in a horizontal position. The rotor may be single, double or multibladed. The second type is the vertical axis wind turbines in wich the rotating shaft is in an axial vertical position. This type contains many turbine configurations and kinds, as Darrieus, Savonious, and Lafond wind turbines.

In the present work a horizontal axis wind turbine was designed and tested to investigate the effect of some design parameters on the turbine performance. The parameters investigated are the untwisted blade chord length, the ratio between rotor and hub diameters, the blade setting angle and the blade profile. Moreover, the effect of the number of turbine blades was also studied. The tests were carried out using a specially designed wind tunnel.

The theoretical turbine performance was also studied by applying the blade element theory and using a power coefficient formula which was obtained from the application of both angular momentum equation and blade aerodynamics. A comparison was made between experimental and theoretical results indicating the same trend.