

**DESIGN AND OPTIMIZATION OF AFFORDABLE WIND TURBINE BLADE
GEOMETRY FOR A HORIZONTAL AXIS WIND TURBINE UNDER LOW
SPEED WIND CONDITIONS**

By

Jane Christina Irawan
11112082

BACHELOR'S DEGREE
in

MECHANICAL ENGINEERING – MECHATRONICS CONCENTRATION
FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY



SWISS GERMAN UNIVERSITY
EduTown BSD City
Tangerang 15339
Indonesia

August 2016

STATEMENT BY THE AUTHOR

I hereby declare that this submission is my own work and to the best of my knowledge, it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at any educational institution, except where due acknowledgement is made in the thesis.

Jane Christina Irawan

Student

Date

Approved by:

Dena Hendriana, B.Sc., SM, Sc. D, Advisor

Thesis Advisor

Date

SWISS GERMAN UNIVERSITY

Ir. Arko, M. Sc, Ph. D, Co-Advisor

Thesis Co-Advisor

Date

Dr. Ir. Gembong Baskoro, M.Sc.

Dean

Date

ABSTRACT

DESIGN AND OPTIMIZATION OF AFFORDABLE WIND TURBINE BLADE GEOMETRY FOR A HORIZONTAL AXIS WIND TURBINE UNDER LOW SPEED WIND CONDITIONS

By

Jane Christina Irawan

Dena Hendriana, B.Sc., SM, Sc. D, Advisor
Ir. Arko, M. Sc, Ph. D

SWISS GERMAN UNIVERSITY

The main objective of the project is to design a small wind turbine generator of 500W. This paper presents a design and optimization of a three bladed horizontal axis wind turbine with a radius of 3.5 m for low wind speed conditions of 4 m/s. The blade configuration is made to be as simple as possible in order to make it affordable. The simulation is done using open source Computational Fluid Dynamics (CFD) software OpenFOAM. The simulation uses a solver called simpleFoam based on the Reynolds Averaged Navier-Stokes (RANS) with $k-\omega$ turbulence model. The optimization study was conducted by changing parameters of the width of the blade chord, inner tip angle and using a chambered airfoil. The optimization of the power produced a maximum efficiency of 40% of the kinetic energy in the wind. A prototype was then made to be combined with a buoyant device to make an airborne wind turbine.

Keywords: Small scale wind turbine, optimization blades, CFD analysis, airborne wind turbine



SWISS GERMAN UNIVERSITY

DEDICATION

I would like dedicate this thesis work for my parents, Chandra Irawan and Florence Atmadi, my sister, Grace Monica and Lexy.



ACKNOWLEDGEMENTS

In this opportunity, I wish to thank my family for their moral support and patience.

I would also like to thank my thesis advisor, Dena Hendriana, B.Sc., SM, Sc. D and my thesis co-advisor, Ir. Arko, M. Sc, Ph. D for their advice and direction during the completion of this thesis work. Yohannes Fredhi Sangadi Pratomo, A. Md. for the endless support, patience and helpful insight that guide me towards the resolution of the project.

A special acknowledgement is given for my friends, Albertus Nagaputra Rumawas, Vincentius Andi Kurniawan and Surojo Soetan for helping me through all the problems encountered. To all my friends in Swiss German University, especially Emely Adamlu and Galuh Chandra Kirana, thank you for all the great time we had together through the thick and thin.



TABLE OF CONTENTS

STATEMENT BY THE AUTHOR	2
ABSTRACT.....	3
DEDICATION	5
ACKNOWLEDGEMENTS	6
TABLE OF CONTENTS	7
LIST OF FIGURES	10
LIST OF TABLES	13
Chapter 1 - INTRODUCTION	14
1.1 Background	14
1.2 Thesis Research Problems.....	15
1.3 Thesis Objectives.....	15
1.4 Scope of Thesis.....	16
1.5 Thesis Limitation	16
1.6 Chapters Overview	16
Chapter 2 - LITERATURE REVIEW	18
2.1 Wind Power.....	18
2.1.1 Types of Wind Turbine	18
2.1.2 Potential of Wind Energy in Indonesia	20
2.1.3 Small-scale Wind Turbine.....	22
2.2 Theoretical Perspectives	22
2.2.1 Overview of the Aerodynamic Principals	22
2.2.2 Betz Limit.....	24
2.2.3 Lift and Drag Forces.....	26
2.2.4 Tip speed ratio	29
2.2.5 Power Curve	31
2.2.6 Components of a wind turbine.....	32
2.2.7 Orientation system.....	33
2.2.8 Flap-wise Bending	35
2.2.9 Pillow Block Bearing	36
2.2.10 Belt and Pulley system	36
2.2.11 Generator	37
2.3 Software Design	37
2.3.1 Solidworks	38
2.3.2 OpenFOAM.....	38

2.3.3 ParaView	38
Chapter 3 - DESIGN ANALYSIS.....	40
3.1 Wind Speed Data.....	40
3.2 Design Justification	41
3.2.1 Determining the size of the wind turbine.....	42
3.2.2 Number of blades.....	43
3.2.3 Geometrical parameter of the rotor blades	44
3.3 Mathematical Modeling	46
3.3.1 Validation	46
3.3.2 First Design – 3Sy60	50
3.3.3 Second Design – 3Sy45.....	53
3.3.4 Third Design – 3Sy30	55
3.3.5 Fourth Design – 3Ch30	56
3.3.6 Fifth Design – 3Ch35.....	59
3.3.7 Sixth Design – 4Ch35	65
3.3.8 Evaluation	66
3.3.9 Angle of attack from wind analysis.....	68
3.3.10 Equal width	71
3.4 Scaled Prototype	72
3.4.1 Combining Prototype with Airborne Device.....	75
Chapter 4 - prototype construction AND DISCUSSIONS	78
4.1 Structural Design.....	78
4.1.1 Material Selection for Blades	78
4.1.2 Blade Structure.....	80
4.1.3 Power transmission.....	83
4.1.4 Shaft.....	84
4.2 Electronics and Electrical Connection	86
4.2.1 Generator	86
4.2.2 Data Logging.....	88
4.2.3 Anemometer and tachometer.....	88
4.3 Making Small Scale Wind Turbine	89
4.3.1 Rotor blades	90
4.3.2 Pulley system	92
4.3.3 Testing the rotational speed and voltage reader	94
4.4 Test result	95
4.4.1 First Test.....	95

4.4.2 Second Test	98
4.4.3 Airborne Buoyant Device	101
Chapter 5 - CONCLUSIONS AND RECOMMENDATIONS	103
5.1 Conclusions	103
5.2 Recommendations	104
GLOSSARY	105
References.....	106
Appendix 1 - electrical.....	108
DC Motor Permanent Magnet DAITO	108
Appendix 2 - programs	114
Appendix 3 – drawings	116
Appendix 4 – bill of materials	119
Curriculum vitae	120

