Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 128 (2017) 302–308

Energy Procedia

www.elsevier.com/locate/procedia

International Scientific Conference "Environmental and Climate Technologies", CONECT 2017, 10–12 May 2017, Riga, Latvia

The control of blades orientation to air flow in wind energetic device

Janis Viba, Vitaly Beresnevich*, Martins Irbe, Janis Dobelis

Institute of Mechanics, Riga Technical University, Kalku iela 1, Riga, LV–1658, Latvia

Abstract

New wind energetic devices with controlled orientation of flat blades to air flow are developed. The proposed device consists of main central wheel and several flat blades hinged to the wheel with the ability to change the orientation of their working surfaces relative to the direction of incoming wind flow. Experimental analysis of blade's interaction with air flow is performed. Aerodynamic coefficients for blade's drag and lifting forces are determined experimentally in wind tunnel ARMFIELD. Optimization of system parameters is made using programs *Excel* and *MathCad*. To increase the efficiency of energy transformation, it is proposed to change by special law an angular position of flat blade during rotation of the central wheel. For this purpose axles of blades are kinematically connected with the central wheel. It is shown that optimal angular rotation frequency ratio between central wheel and blade is equal to 2. Serviceability and main advantages of the proposed method are confirmed by experiments with physical model of airflow device.

Peer review statement - Peer-review under responsibility of the scientific committee of the International Scientific Conference "Environmental and Climate Technologies".

Keywords: air flow; blade; energy extraction; experiment; mathematical simulation; central wheel

1. Introduction

Wind installations are widely used in engineering during long time (wind mills, wind motors, wind devices for water pumping etc.) [1–3]. Operation principle of these devices is based on air flow action on blades mounted on special wheel and further transformation of air flow kinetic energy into the mechanical energy of wheel rotation.

* Corresponding author. Tel.: +371-67089469; fax: +371-67089746.
E-mail address: vitalijs.beresnevics@rtu.lv

1876-6102 © 2017 The Authors. Published by Elsevier Ltd.
Peer review statement - Peer-review under responsibility of the scientific committee of the International Scientific Conference "Environmental and Climate Technologies".
10.1016/j.egypro.2017.08.317

Efficiency of energy transformation at great extent is dependent on blade's orientation relative to air flow. In majority of existing air flow devices there is no possibility for special change of blade's orientation relative to air flow during rotation of main wheel, and therefore position of blade can be optimal only in specific time instants [4].

Special variation of flat blade's turning angle during rotation of main wheel is realized in the device described in [5]. But interrelation between turning angles of blade and main wheel are not optimal in this device. Due to this potential possibilities to increase efficiency of energy extraction are not fully realized.

Theoretical analysis of air flow interaction with rotating flat blade in different aerodynamic conditions is considered in [6, 7]. It is shown that position of blade is optimal, if resulting aerodynamic force gives maximal torsion moment about longitudinal axis of main wheel. Performances of modern wind turbines in different aerodynamic conditions are analyzed in [8, 9].

This paper deals with experimental analysis of flat blade's interaction with air flow in order to find optimal control law for variation of blade's turning angle during rotation of central wheel.

2. Analysis of air flaw interaction with flat blade

Model considered in this paper is shown in Fig. 1. Flat blades 2 are hinged to the central wheel 1, besides longitudinal axes O_1 and O_2 of wheel and blades are mutually parallel. Position of blade 2 relative to air flow is given by angle α, but rotation of wheel 1 is evaluated by angle φ. In order to increase the efficiency of wind energy transformation, it is necessary to find optimal relations between angles φ and α during operation of the system.

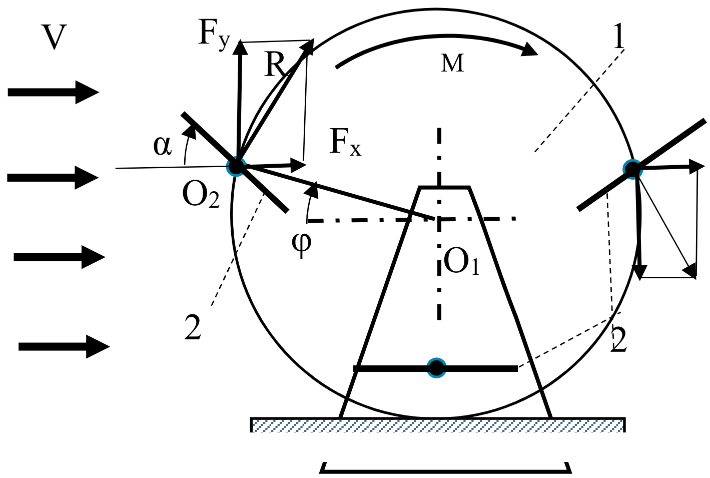

Fig. 1. Principle model of wind device: 1 – central wheel; 2 – flat blade.

In accordance with aerodynamics theory [10], flat blade 2 placed in air flow is subjected to action of aerodynamic force R (Fig. 1). Force R can be resolved into two components: drag force F_x (acts along flow direction) and lift force Fy (acts in direction perpendicular to air flow). The following formulae are used to calculate these forces [4]:

$$F_x = \frac{1}{2} C_x S \rho V^2 ; \qquad F_y = \frac{1}{2} C_y S \rho V^2 \tag{1}$$

where

C_x and C_y	dimensionless drag and lift aerodynamic coefficients;
S	area of blade's working surface;
P	density of air medium;
V	velocity of air flow.