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New developments in small scale wind turbines

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Abstract
Considering the global socio-economic context, the pressure on natural resources and of course the effects that exploitation has on natural ecosystems and fauna is more and more evident. The use of renewable energy sources, together with improvements in energy efficiency, can help reduce energy consumption, reduce greenhouse gas emissions and, consequently, prevent dangerous climate change. The integration of renewable energy sources in urban areas and in everyday life is a viable solution. The present paper focuses on the presentation of small-scale wind systems integrated in urban areas and not only to capitalize any energy as efficiently as possible.

Keywords: micro systems, wind power, renewable power supplies.

1. INTRODUCTION

Due to climate change, the research for renewable energies technology has increased in order to produce electricity and to turn cities into sustainable ones. Small scale wind power offers new opportunities in this area, the main advantages being a decentralized electricity production and a decrease in the dependence on grid connections that comes with transmission loss. Viable locations for mounting small scale wind turbines include high rise buildings and many open space constructions with less turbulent wind conditions [1].

The small wind turbine technology (with power smaller than 200 kW) is improving quickly. It should be noted that wind turbines classifications (small, medium and large size) are different from a country to another and vary over time with the technology evolution [2].

Small scale wind turbines can be classified in two main categories, vertical axis wind turbines (VAWT) and the horizontal axis wind turbine (HAWT). VAWT has lower noise and vibration compared to the HAWT for application in urban areas [3, 4].

Wind energy conversion technology is now a well-developed discipline and industry, and experts are available who have specialized in all aspects of this field [3].

2. ADVANCEMENTS IN WIND CONVERSION ENERGY SYSTEMS FOR URBAN AREAS

According to [5] the incorporation of wind turbines in the integral design of buildings has become a promising approach to promote on-site renewable energy conversion in urban areas.

In the following subchapters a classification of these wind turbines is presented from a construction point of view.

A. Radial wind turbines

This concept can be adopted readily into the buildings due to its significantly lower rotational speed compared to the propeller type counterparts [5].

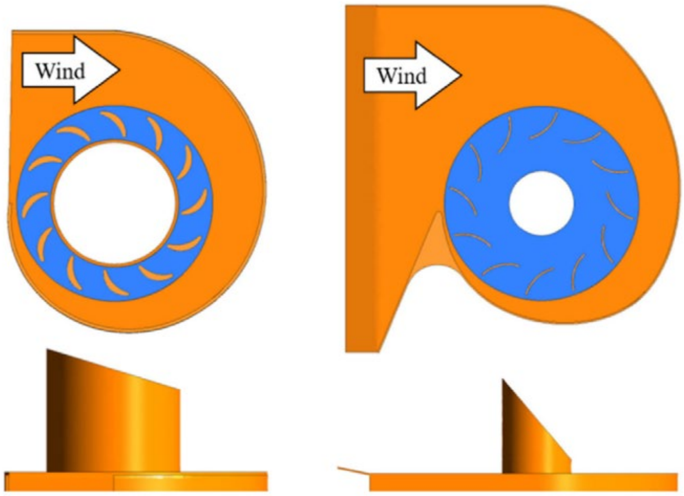


Fig. 1.Design of the RWT (Radial Wind Turbine) [5], [6]

The advantage of this setup lies in the low tip speed that enables the potential usage of recyclable materials which may fail in the deployment in horizontal-axis wind turbine (HAWT) [6].

B. Contra-rotating wind turbines

The two main types of vertical-axis wind turbine (VAWT) can be further classified into Savonius based rotors and Darrieus based rotors [5,7].

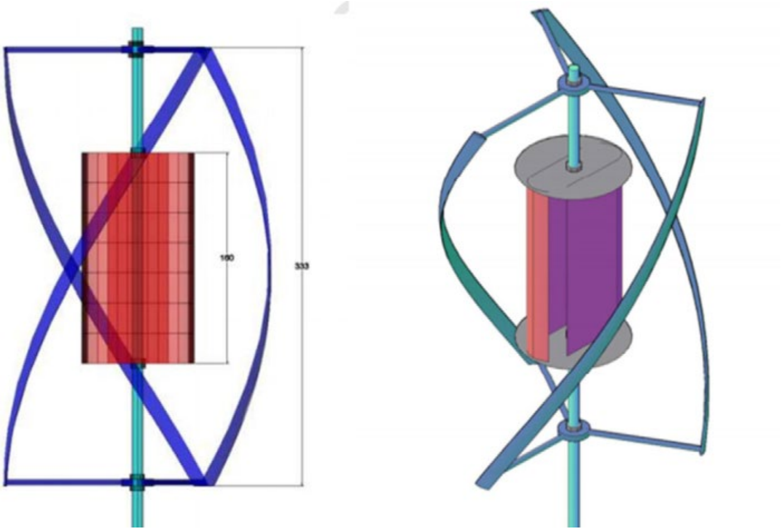
(a) (b) (c)

Fig. 2. Design of Savonius–Darrieus CRWT(Contra-rotating wind turbines)
(a) – Savonius-Darrieus wind turbine;(b) - Savonius wind turbine;(c) - Darrieus wind turbine [5]

Savonius rotors possess advantages such as low cut-in speed, capability to cope with turbulence, and high starting torque, making them useful in urban environments. Darrieus rotors, on the other hand, are characterized by their ability to maintain high conversion efficiency at high wind velocities [5].

C. Hybrid Savonius–Darrieus rotor

The Savonius–Darrieus rotor (EUIPO, Community design No 004035269–0001, 2017) which is designed to produce optimized performance in low to medium wind speed regions [5].



(a) – 2D view *(b) – 3D view*

Fig. 3. Savonius turbine enclosed by Darrieus turbine [5], [4]

The shape, size, and relative positions of the Savonius and Darrieus configurations are optimized to realize the hybrid wind turbine without interference from the wake of each rotor design [5].

3. NEW RESEARCH IN WIND TURBINES DESIGN

The following subchapters present some of the latest experimental base for new possible designs in small scale wind turbines.

A. Biometric blade design

According to [8] a design inspired by bird wings enable robust aerodynamics and thus the wind turbine is capable a high efficiency.

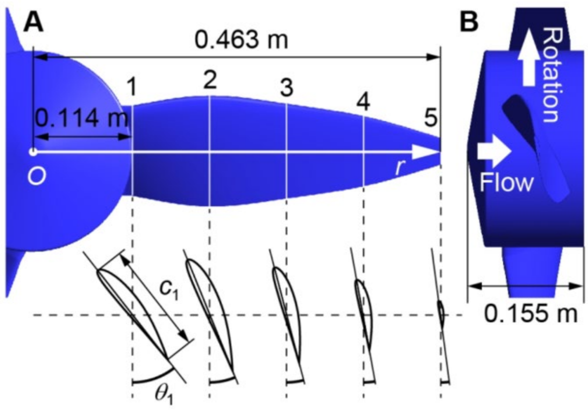


Fig. 2. A basic blade model of small wind turbines [8]

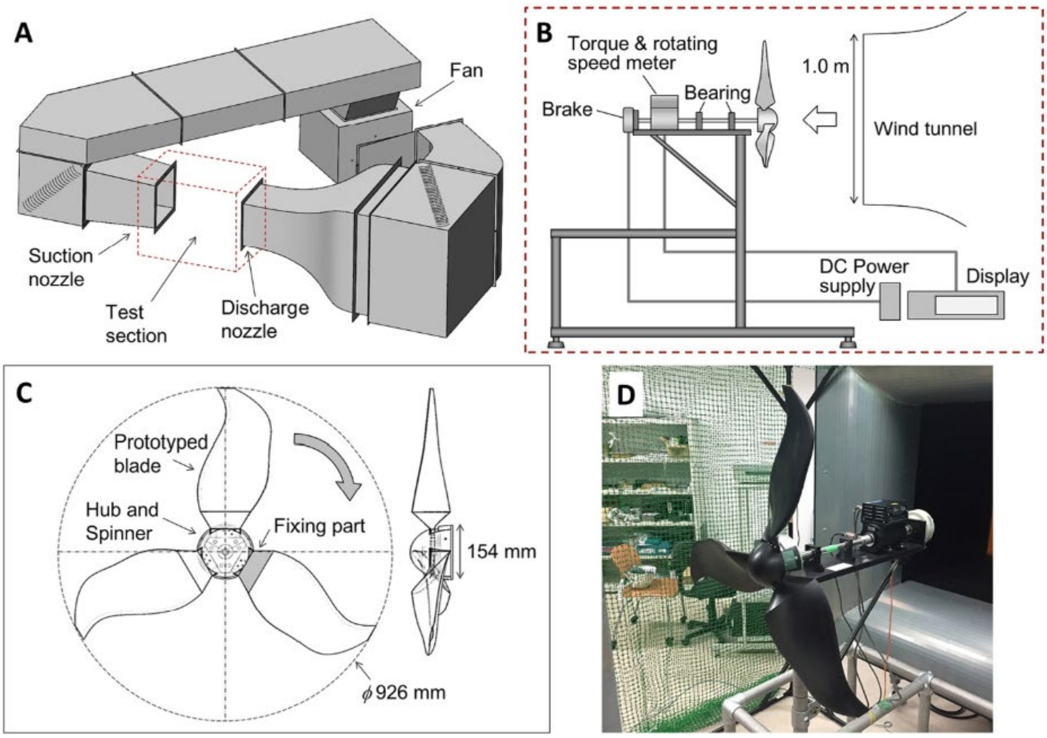


Fig. 3. Experimental setup for torque and rotating speed measurements. (A) Perspective view of low-speed wind tunnel. (B) Side view of torque-measurement setup. (C) Front-and side-view of a prototype rotor with bioinspired-flexion blades. (D) A snapshot of experimental setup. The distance between outlet and rotor is approximately 57 cm [8]

After the aerodynamic test, biomimetic blade design demonstrated great potential for wind turbines and that robustness-oriented blade design can provide a practical and effective methodology for innovation in wind turbine design for complex natural turbulent environments. This is presented bellow in figures 4 and 5.

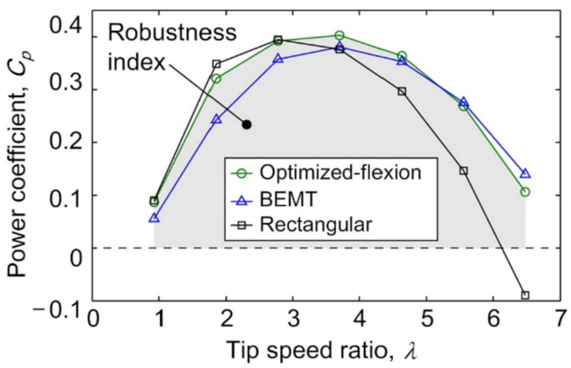


Fig. 4 Comparison of power coefficients Cp vs tip-speed ratio l of three blades: optimized-flexion blade, BEMT blade, and rectangular blade [8]

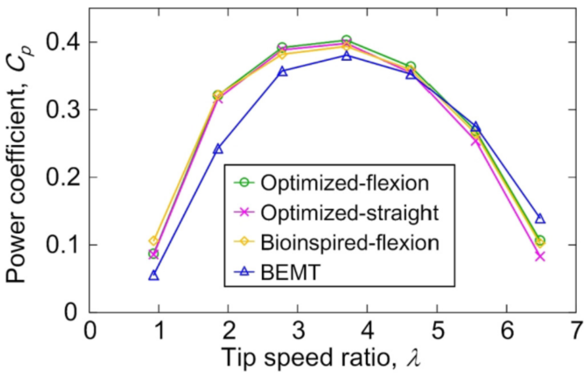


Fig. 5 Comparison of power coefficients vs tip-speed ratios of four blades: optimizedflexion blade, optimized-straight blade, bioinspired-flexion blade, and BEMT blade [8]

The advantages of the small-scale wind turbine include low cost and large application areas. For adapting to wind variations, a mechanism to vary the pitch of the blades is necessary, this can increase the price since this mechanism are complex. With this new robust design presented in [8] the wind turbine can withstand unstable wind conditions.

B. Simple multi-blade drag based micro vertical axis wind turbine

In order to develop a simple multi-blade, drag based micro vertical axis wind turbine with reasonable power output for the application in built-up areas, six micro vertical axis wind turbine of 300 mm diameter with various blade configurations has been designed [9].

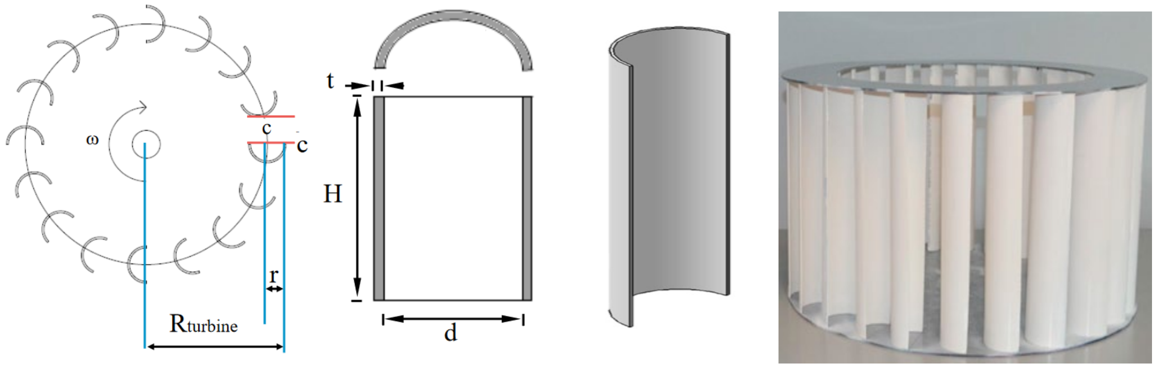


Fig. 6. Design of the 16-blade turbine and blade geometry [9]

Based on the study presented [9], one turbine with diameter and height of 322 m and 153 m and blade diameter of 41 m will provide the 1.6 kW power required to supplement 10% of the power requirement. However, it is impractical to design such a large turbine. A practical turbine in terms of size and cost is a turbine of diameter and height of 2.4 m and 1.2 m with a blade radius of 0.32 m which can produce 10 W of power.

C. Lotus-shaped micro-wind turbine

A lotus-shaped micro-wind turbine has been developed as a decoration for urban and rural areas. This wind rotor consists of guide and semi-circular blades [10].

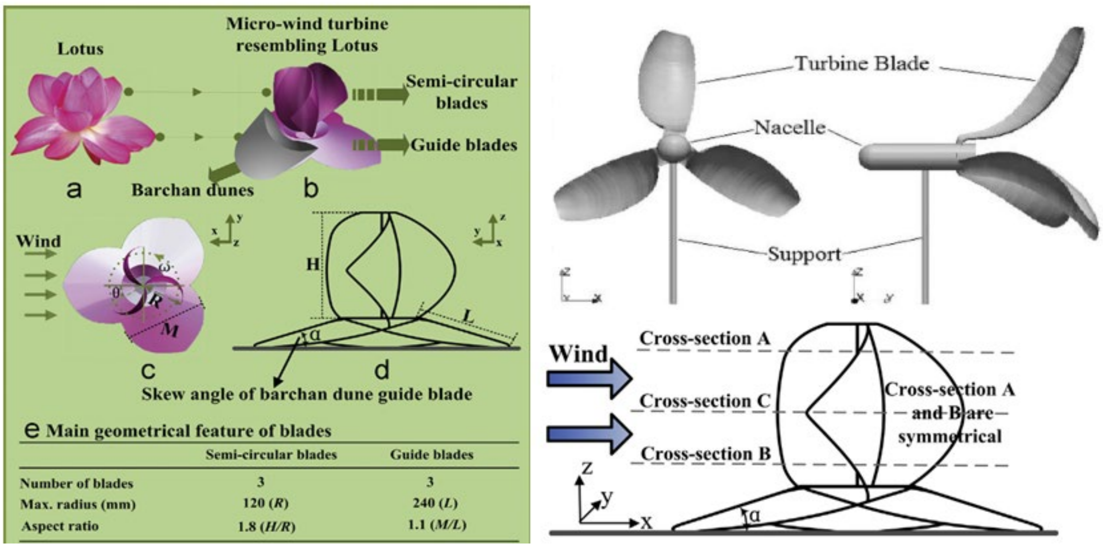


Fig. 7. Design process of a lotus-shaped micro-wind turbine [10], [11]

A lotus-shaped micro-wind turbine was designed as a decoration for populated urban areas. This turbine consists of guide and semi-circular blades. The guide blades can sculpt the oncoming wind to improve the performance of the wind turbine. The semicircular blades can be used to drive a generator through its shaft [10].

Examples of different areas within cities where wind turbines were mounted and used are presented in figure 8.

Fig. 8. Different examples of small-scale wind turbines in urban areas [12], [13], [14], [15], [16], [17]

These examples are technical approaches that rely on previously unexploited areas in the urban environment that provide decentralized power supplies. Given the current energy crisis and the green approach for producing it, these solutions provide a much-needed option for supplying our daily needs.

4. CONCLUSIONS

The diversification of energy sources provides independence from multiple green technologies without the pollution factor and wind power is the most impactful source after hydro energy.

Scale down wind turbines have an important flaw; at the same wind speed, they generate far less power compared to large wind turbines. In large wind turbines, there are active yaw systems and electronics pitch control, while small scale wind turbines have no pitch control or a mechanical one and a passive yaw system, however they still have moving parts which is a challenge regarding both installation and design.

Wind technology is continuously developing with a strong dynamics. The main advantages include the low price and the use of the wind power within the city, an energy that would otherwise be wasted.

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