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Aero-acoustics noise assessment for Wind-Lens turbine

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ABSTRACT

This paper introduces an aero-acoustic computational study that investigates the noise caused by one of the most promising wind energy conversion concepts, namely the "Wind-Lens" technology. The hybrid method - where the flow field and acoustic field are solved separately, was deemed to be an appropriate tool to compute this study. The need to investigate this phenomenon increased gradually, since the feasibility of utilizing Wind-Lens turbine within densely populated cities and urban areas depends largely on their noise generation. Ffowcs Williams-Hawkings (FW-H) equation and its integral solution are used to predict the noise radiating to the farfield. CFD Simulations of transient three-dimensional flow field using (URANS) unsteady Reynolds-averaged Navier-Stokes equations are computed to acquire the acoustic sources location and sound intensity. Then, the noise propagates from the before-mentioned sources to pre-defined virtual microphones positioned in different locations. ANSYS-FLUENT is used to calculate the flow field on and around such turbines which is required for the FW-H code. Some effective parameters are investigated such as Wind-Lens shape, brim height and tip speed ratio. Comparison of the noise emitted from the bare wind turbine and different types of Wind-Lens turbine reveals that, the Wind-Lens generates higher noise intensity.

1. Introduction

Noise and visual impact caused by wind turbines give rise to environmental problems concerning public acceptance of wind energy. Wind turbine noise research has gained importance as wind turbines have scaled up the ladder of energy production. The problem with wind turbine noise is one of the most studied environmental impact subjects. It is controversial as, although noise levels can be measured, its impact on the environment and the public's perception of the noise is partly subjective. There are, however, many studies on the impact of wind turbine noise on human health and wildlife. Frequency of wind turbines ranges from low values that occasionally inaudible to higher values within the normal audible range [1]. The human ear perceives loudness as a discrete response to the amplitude of sound waves. For a given sound pressure level, the ear does not detect all frequencies to be of equal loudness. The human ear comprehends loudness in the normal hearing range which is 20 Hz-20 kHz [2].

Current human life standards require noiseless and quiet machines. Aeroacoustics are applied in various industries. Amongst them is the aerospace industry, where airframe noise emanating from high-lift devices, landing gears and jet engines has a great importance. Also reducing the noise generated by wind turbines is a hot topic nowadays. However, the focus in the present paper is on noise generated by a new type of wind energy converter called “Wind-Lens”. A new small-type wind energy system consists of a diffuser shroud with a broad-ring brim at the exit periphery and a wind turbine inside it. Wind-Lens turbine has demonstrated power augmentation by a factor of about 2–3 times as compared to a bare wind turbine, for a given turbine diameter and wind speed [3]. The existence of a low-pressure region is generated by a strong vortex formed behind the broad brim, which draws more mass flow to the wind turbine inside the diffuser shroud.

In general, there are various sources of noise for wind turbine. Those can be divided into two main groups. The first source of noise is the mechanical noise, which is produced by the gearbox, generator, yaw drives, cooling fans and auxiliary equipment. The second source of noise is the aerodynamic noise. Aerodynamic noise can be of tonal or broadband nature. Both depend strongly on the rotor geometry, airfoil sectional shapes and their surrounding flow conditions. The aerodynamic noise is typically generated when the airflow passes over the blades. It can be classified into three categories: Turbulent inflow noise, Airfoil self-noise and low frequency

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noise. Turbulent inflow noise generated due to the interaction between the blades and the atmospheric turbulence existed in the form of local pressure fluctuations. This mechanism contributes mainly to a broadband type of noise. The interaction between the airfoil and the turbulence induced within its boundary layer and near wake region is responsible for generating the airfoil self-noise. Different airfoil self-noise mechanisms, including their tonal and broadband characteristics, are described as following:

- Turbulent-boundary-layer – trailing edge noise
- Laminar-boundary-layer – vortex shedding noise
- Separation stall noise
- Trailing-edge-bluntness – vortex shedding noise
- Tip vortex formation noise

A detailed description of different airfoil self-noise mechanism

Table 1
Parameters of Wind-Lens turbines [3].

Diffuser	Aii	Bii	Cii	Sii
L_t/D	0.225	0.221	0.221	0.225
AR	1.173	1.288	1.294	1.119

Table 2
Parameters of C-type Wind-Lens turbines [3].

Diffuser	C0	Ci	Cii	Ciii
L_t/D	0.1	0.137	0.221	0.371
AR	1.138	1.193	1.294	1.555

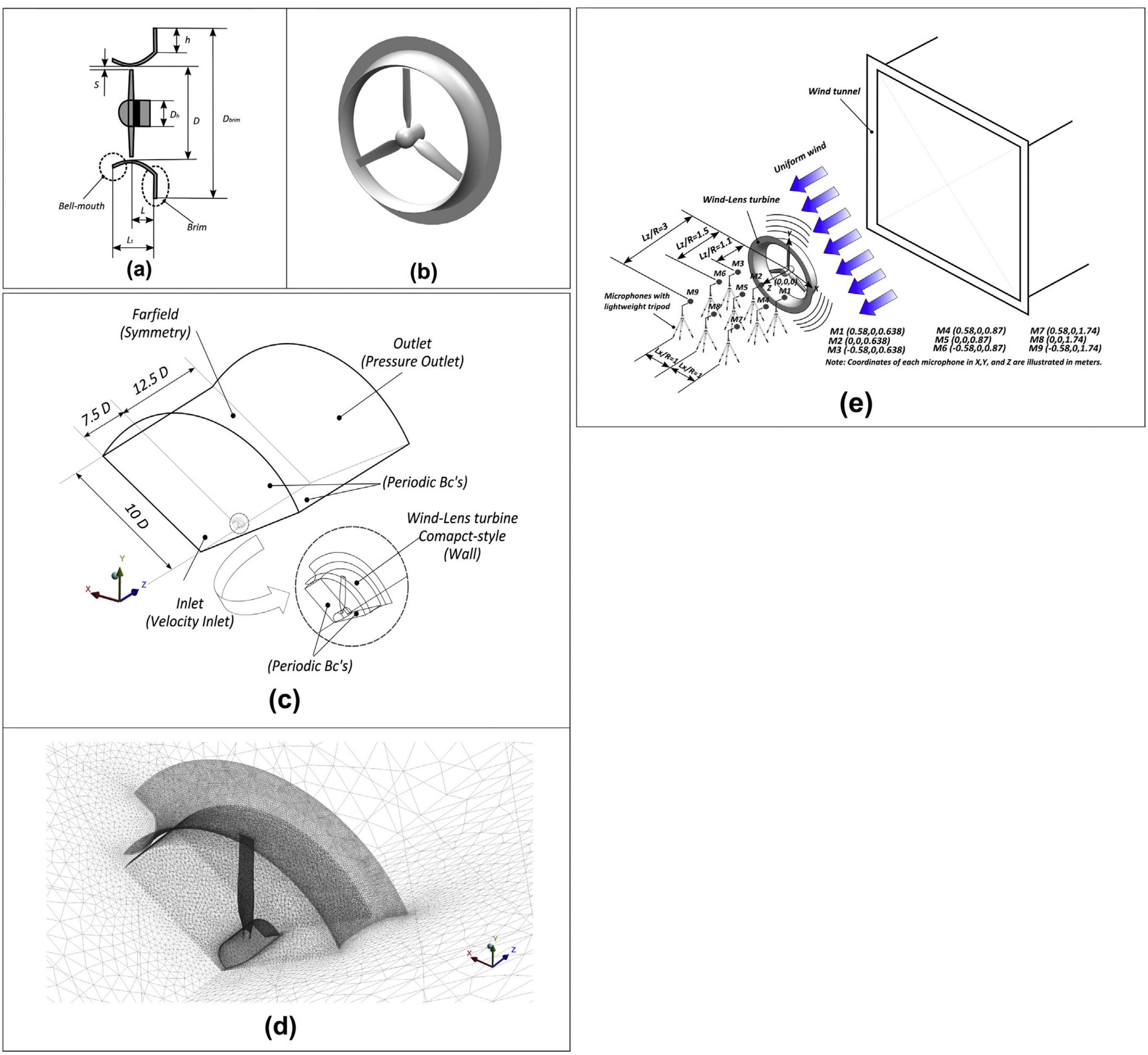

Fig. 1. a) Schematic of Wind-Lens turbine; b) geometry; c) computational domain; d) Unstructured computational mesh; e) Location of the 9 microphones.