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POWER OUTPUT OF A WIND TURBINE IN TUBULAR HOUSING EQUIPPED WITH A DIFFUSER

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K e y w o r d s: wind turbine, tubular housing, diffuser, power output of a wind turbine.

A b s t r a c t

This paper presents the results of a study conducted on a model wind turbine in tubular housing equipped with a diffuser. The impact of the diffuser's diameter and length on the wind turbine's power output was tested. The highest output was reported when the ratio of the diffuser's inlet and outlet diameter was 1.7 and relative diffuser length reached approximately 0.6.

MOC SIŁOWNI WIATROWEJ PRACUJĄCEJ W OBUDOWIE RUROWEJ WYPOSAŻONEJ W DYFUZOR

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S ł o w a k l u c z o w e: siłownia wiatrowa, obudowa rurowa, dyfuzor, moc siłowni wiatrowej.

A b s t r a k t

W artykule przedstawiono wyniki badań modelu siłowni wiatrowej pracującej w obudowie rurowej z zainstalowanym dyfuzorem. Testowano wpływ średnicy i długości dyfuzora na generowaną przez tę siłownię moc. Najwyższe wartości mocy uzyskano wówczas, gdy stosunek średnicy wlotowej do wylotowej dyfuzora wynosił 1,7, a względna długość dyfuzora około 0,6.

Introduction

There is a growing demand for the supply of electric power with low wattage of 0.5 – 2 kW to sites which remain outside the reach of power transmission lines. Such sites include stations for monitoring forests and freeways, power supply units of hydrological and meteorological stations, agricultural driers, fish pond aeration units, etc. The construction of transmission lines connecting remote and isolated power receivers is not financially justified. The same applies to photovoltaic fuel cells due to their low efficiency and high production costs (FILIPOWICZ 2002, AKHAMOV 2006). The construction of mini wind farms in the vicinity of such sites seems to offer a reasonable solution to the problem (LEE 2000). Mini wind farms have already been introduced in highly industrialised countries, in particular in Germany. Standard rotor diameter does not exceed 2 m. A wind turbine's low output of 0.2 – 1 kW does not always meet user needs. With constant wind force, a turbine's output can be maximised by increasing the rotor diameter as in theory, it raises the device's output to a second power.

A new solution was proposed to ensure that the increase in power output does not require resizing of the wind turbine. The blade and turbine set were placed in tubular housing connected to a diffuser. Owing to this solution, the resulting power output will be several dozen percent higher than that of conventional wind turbines.

Objective

The objective of this study was to determine the impact of the diffuser's geometric parameters on the power output of a wind turbine in tubular housing.

Methodology and investigated site

The investigated site was a three-blade model wind turbine in tubular housing with a diffuser (Fig. 1). Rotor diameter was 338 m and the diameter of the tubular housing was 340 mm. Diffusers with the diameter of 340, 374, 408, 440 and 510 mm were built to investigate the impact of the diffuser's outlet diameter on the wind turbine's power output. Three diffuser lengths were applied in this study: 70, 140 and 210 mm, respectively (Fig. 2).

Since a universal mathematical model describing the operation of a wind turbine will be developed at subsequent stages of the study, relative dimen-

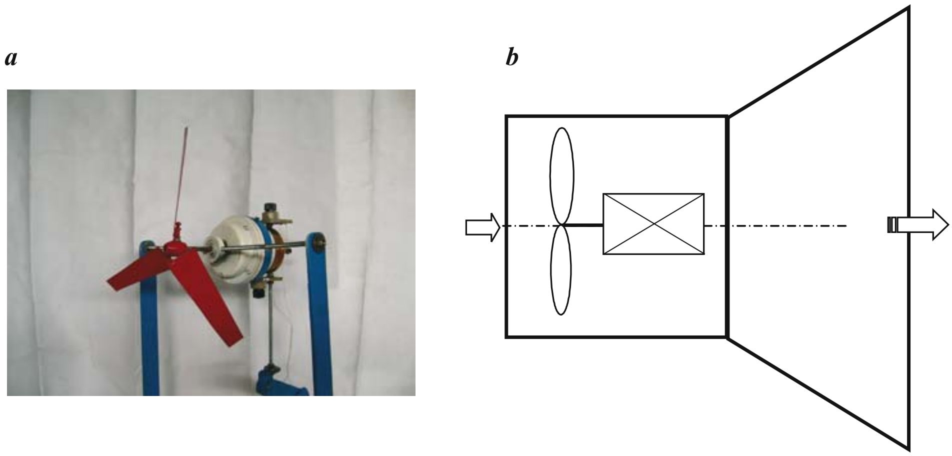

Fig. 1. Wind turbine model (*a*) and a diagram of tubular housing with a diffuser (*b*)

sions were applied to process the results obtained in the investigated site, i.e. the diffuser's relative diameter and relative length. This solution will support the application of the geometric probability law during the construction of larger structures in the future.

The diffuser's relative diameter i_d was defined as the ratio of its outlet diameter to the diameter of the wind turbine's tubular housing. The relative diameter was 1, 1.1, 1.3, 1.5 and 1.7, respectively. The diffuser's relative length j_d was the ratio of diffuser length to housing diameter. The relative length was 0.2, 0.4 and 0.6, respectively. Higher values were not applied in line with DZIERŻANOWSKI'S (1983) claim that they do not contribute to a further increase in the turbine's output.

In addition to the previously applied lengths, diffuser length of 0.8 was also introduced to determine the impact of the diffuser's relative length on the wind turbine's power output.

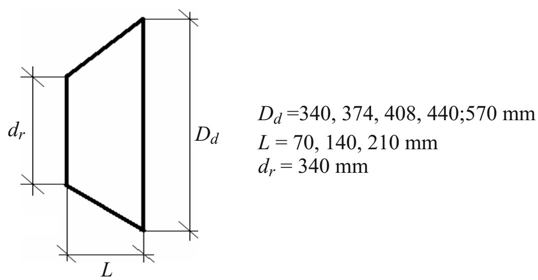

Fig. 2. Diffuser geometry

A single phase, self-excited AC turbine applied in Jarecki centrifuges was used.

The study was conducted in an aerodynamic tunnel with the diameter of 0.7 m and length of 4 m (Fig. 3). The velocity of the air stream flowing through the tunnel was in the range of 0-4.5 m s^{-1} (WIERCIŃSKI 2005). The measurement methodology and the method of determining the wind turbine's power output are described in a paper by CHARKIEWICZ and ROMAŃSKI (2007).

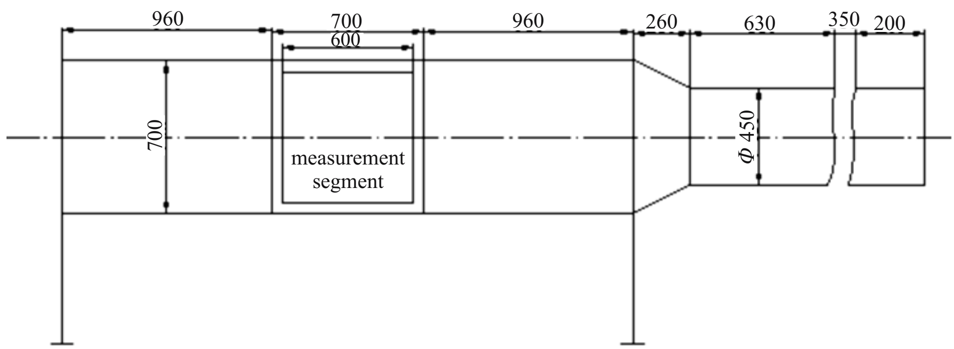

Fig. 3. Diagram of the aerodynamic tunnel

Results and analysis

The impact of the diffuser's geometry parameters on the power output of the model wind turbine in tubular housing is presented in Figure 4 and in Figure 5. Tests were performed at air stream velocity of 4.5 m s^{-1}. The analysis of the above relationship indicates that the power output of the model wind turbine in tubular housing is largely determined by the diffuser's diameter. The dependencies for three diffuser lengths were described with second degree polynomials with very high coefficients of determination of more than 0.95.

A steep increase in power output was observed from small values of the diffuser's relative diameter up to 1.5. A power output decrease was reported in respect of diameters larger than 1.65, which is why the relative output diameter of a diffuser should be kept under 1.65.

The measurements to determine the dependence between the power output of a wind turbine with a diffuser and diffuser length were performed for relative diffuser diameters of 1.1, 1.3, 1.5 and 1.7. The investigated relationships show a characteristic pattern as the wind turbine's power output increased proportionally to an increase in the diffuser's relative length in the

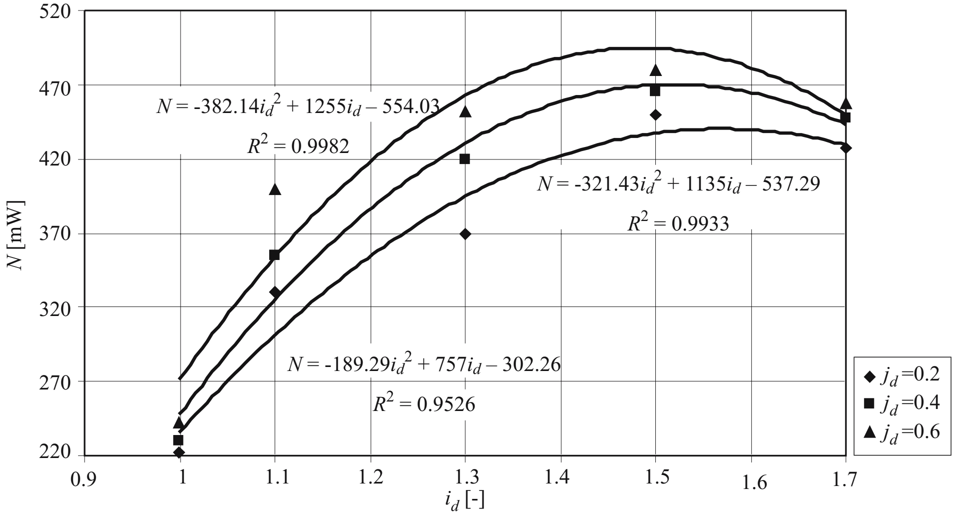

Fig. 4. Relationship between the power output of a wind turbine with a diffuser and the diffuser's relative output diameter

range of 0.2 – 0.6. A minor drop in output was reported when the diffuser's relative length exceeded 0.6. These results confirm the findings of other authors who observed that the ratio between the diffuser's length and its diameter should not exceed 0.6 (DZIERŻANOWSKI 1983).

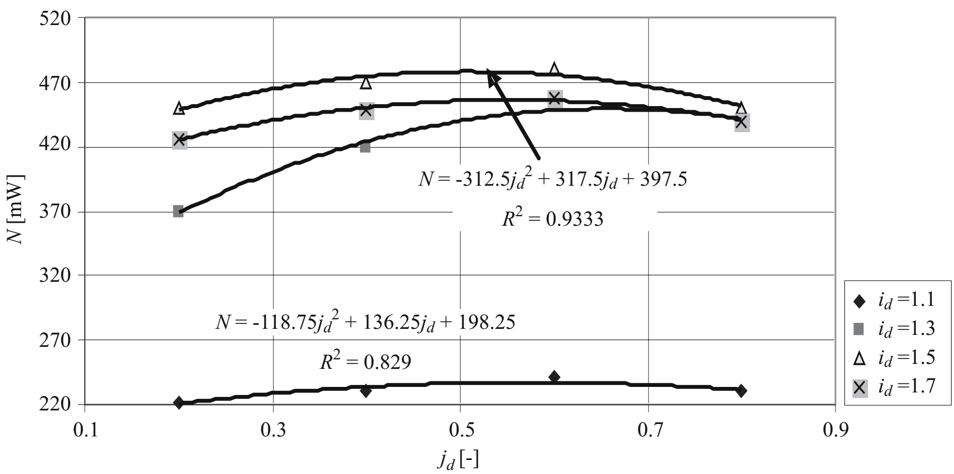

Fig. 5. Relationship between a wind turbine's power output and the relative length of the diffuser

Conclusions

1. A wind turbine's power output increases rapidly with an increase in the diffuser's relative diameter. The highest output is reported at a relative diameter of 1.5.

2. An increase in diffuser length leads to an increase in a wind turbine's power output. The highest output is reported at a relative diffuser length of around 0.6.

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