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SOIL VIBRATION ANALYSIS GENERATED BY WIND TURBINE – CASE STUDY

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Abstract: *The paper presents the most important sources of vibration for wind power plants. It has been shown that vibrations are transferred to the ground through the foundation. As part of the experiment, vibrations were measured on the foundation and 500 m from the mast. It has been shown that for a longer distance the vibrations are imperceptible to humans.*

Keywords: Wind power plant, Foundation, Vibration.

1. Introduction

Human civilization is based on energy conversion. However, traditional methods based on burning fossil fuels cause environmental pollution. Wind power plants, despite their impact on the human environment, are considered an ecological source of energy. The wind turbine does not emit greenhouse gases when producing energy. However, there may be an impact due to noise, vibration and waste arising from use (Karwowska et al., 2014 and Karwowska et al., 2015).

Industrial electricity production is made by wind turbines with a horizontal rotor axis (Horizontal Axis Wind Turbines, HAWT). The source of mechanical energy is a wind turbine connected to a power generator. Transmission can be done by mechanical gears or without their use.

Due to the large diameters, the wind turbine rotors must rotate at low operating speeds. Usually it is 15 - 20 rpm. This limitation results from the speed of critical blade tips. Their actual linear speed is close to the speed of sound. The work of the rotor blades is the first source of vibrations.

A typical synchronous generator produces electricity at a speed exceeding 1500 rpm. For this reason, gears increasing the rotational speed are placed between the turbine and the power generator. Gears and a high generator speed are also responsible for the higher noise and vibration emissions caused by the turbine. This type of turbine is called a gear turbine.

To reduce vibrations generated by turbines, direct drive (DD) constructions are used. They generate electricity in low-speed, multi-pole, synchronous ring generators. The rotor in this type of construction is connected directly to the generator. In this way, the source of vibration is reduced.

The dominant wind turbine structure is the three-blade system. The blades are made of glass fiber or carbon fiber reinforced polyester. The use of carbon fibers allows designers to increase the size of the blades and, consequently, the turbine to increase the power output. The gondola can rotate 360 degrees so that it is always in the optimal position during operation. The information necessary for control is obtained from measuring instruments mounted on the nacelle cover. The control system also uses this information to determine the blade pitch and generator load.

In addition, vibrations can be generated by the operation of bearings, and their level increases with their wear.

The wind power plant is founded on a previously prepared foundation. Foundations for wind power towers are usually built as reinforced slab foundations. For soils with lower load capacity, more complex foundation systems are also used. These are prestressed foundation wells and prestressed plate and pile foundations. The main task of foundations is to transfer loads to the ground (Cempel, 1998).

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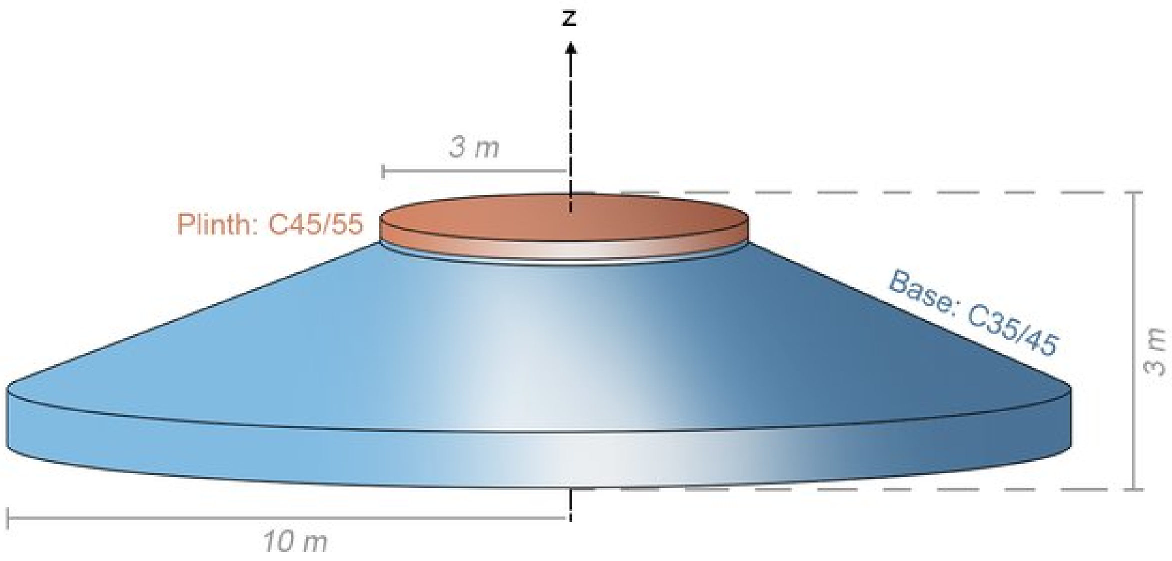


Fig. 1: Concrete wind turbine foundation.

A person exposed to mechanical vibrations is exposed to damage to tissues and blood vessels. Long-term exposure to vibrations can cause lesions in the vascular, osteoarticular and nervous systems. Changes in the osteoarticular system of the hand arise due to local vibrations with frequencies less than 30 Hz. Observed include deformation of joint gaps, calcification of joint capsules, periosteal changes, changes in bone tissue. The mechanism of formation of disorders in the functioning of internal organs consists in stimulating individual organs to resonance vibrations (the natural frequencies of most organs are in the range of 2 ÷ 18 Hz) (Karwowska et al., 2014, Karwowska et al., 2015 and Ligaj et al., 2018).

2. Methods

The aim of the study was to assess the propagation state of vibrations transmitted in the ground generated by a wind power plant at a distance of up to 940 meters from the wind power plant mast. The research was carried out in order to estimate the level of vibrations emitted by the studied wind power plant. The tests were carried out using the characteristics of the vibration signal, which is a good carrier of information about the technical condition of the object.

The wind power plant in Rypin - Rypałki was the object of research. The wind turbine is located at 53.109670 north latitude, 19.434430 east longitude. The tested wind turbine was produced by Vestas. The installed V90 2 MW model has the following parameters:

Rotor		Mast	
Diameter:	90 m	Hub height:	95 m
Sweep area:	6362 m^2	Weight	
Nominal turnover:	14.9 rpm	Gondola:	68 t
Rotation range:	9.0 - 14.9 rpm	Rotor:	38 t
Number of blades:	3	Tower:	200 t

The measurements of the characteristics of the vibration signal on the test stand were made using a single-axis piezoelectric sensor. This sensor was connected using shielded cables to the four-channel VIBDAQ+ data activation module. The machine was directly picked up by a piezoelectric PCB Piezotronics sensor ICP model 352C68.

At first, vibration measurements were made on the wind power plant mast. Then measurements were taken in one direction from the wind power plant, every 50 m. Due to the large number of results obtained, selected vibration signal reception points will be discussed.

3. Results and Conclusions

During the tests, vibration characteristics were measured at points located on the basis of the foundation tower of a wind power plant, the remaining points were located on the plot and their distance was determined relative to the point of the wind power plant. Due to the large number of results obtained, selected vibration signal reception points will be discussed.

The presentation of the test results includes the presentation of a graphic interpretation of the obtained vibration time series and a cascade graph for the vibration spectrum. The effective value of the vibration process signal was analyzed. The selected measure is one of the most commonly used to describe and quickly assess the level of vibration propagation in vibration diagnostics. It is used in asymmetrical vibrations and takes into account the average value in time domain.

The measurements were made for a wind speed of 3.5 $m \cdot s^{-1}$ at a height of 2 m above ground level.

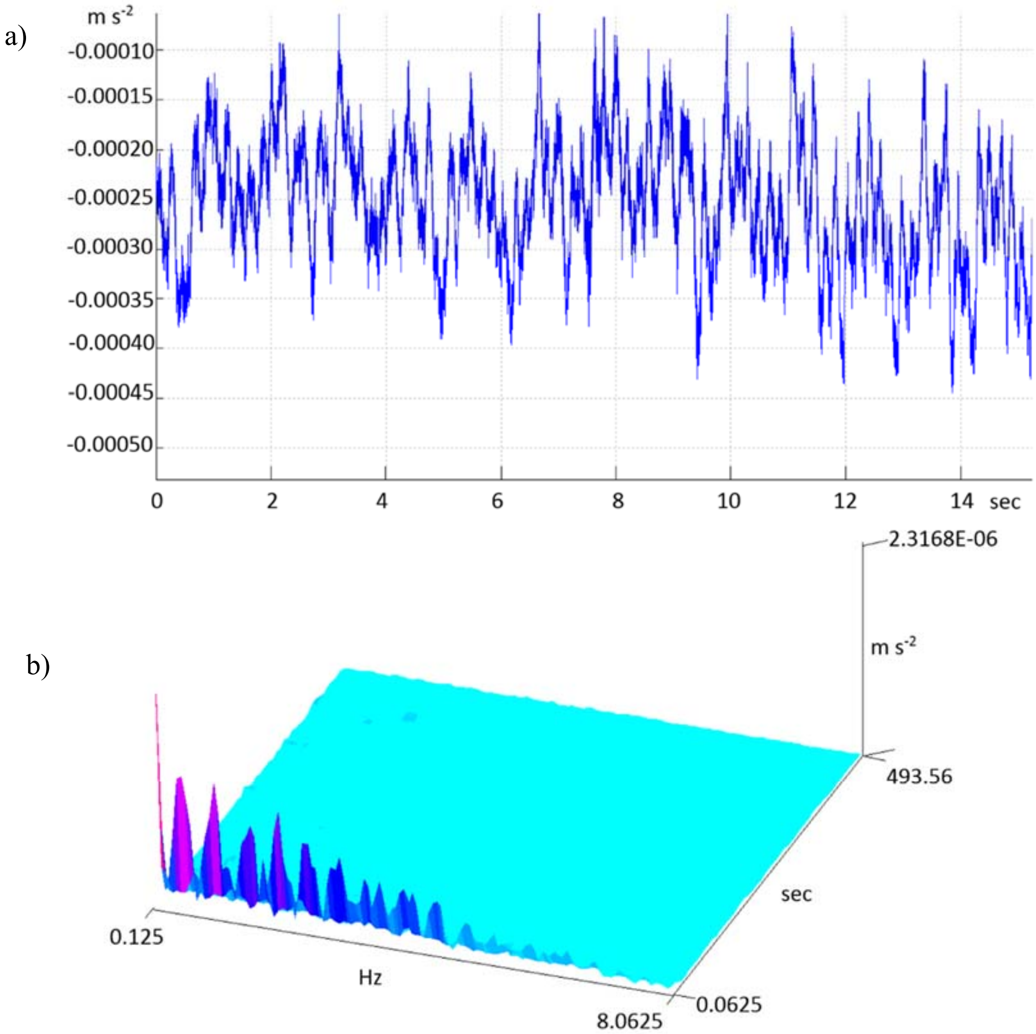
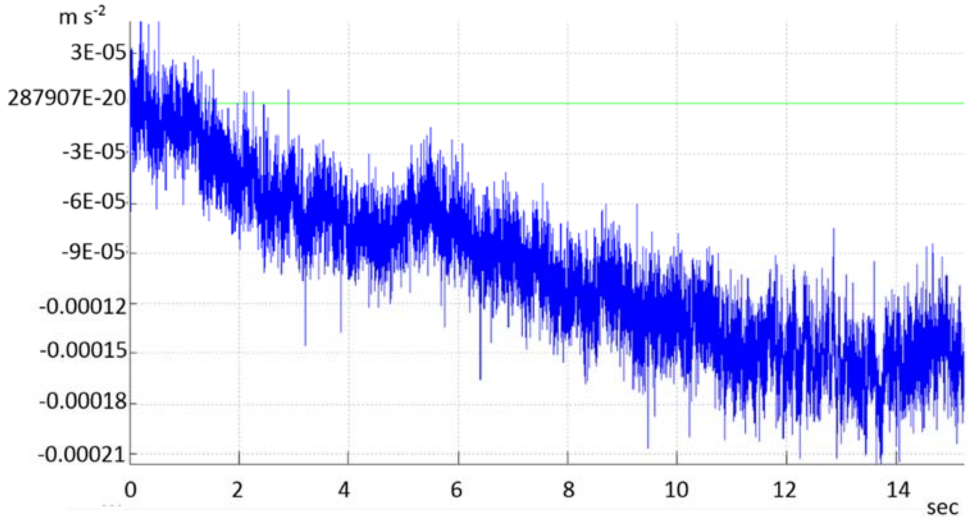


Fig. 2: Graphic interpretation of test results for a point on the mast foundation, a) time history, b) signal spectrum.

The tests are preliminary, in order to increase the accuracy of the diagnosis it would be necessary to make measurements in subsequent time intervals. They indicate the need for further verification of vibration propagation in soil in the process of wind power plant operation.

a)



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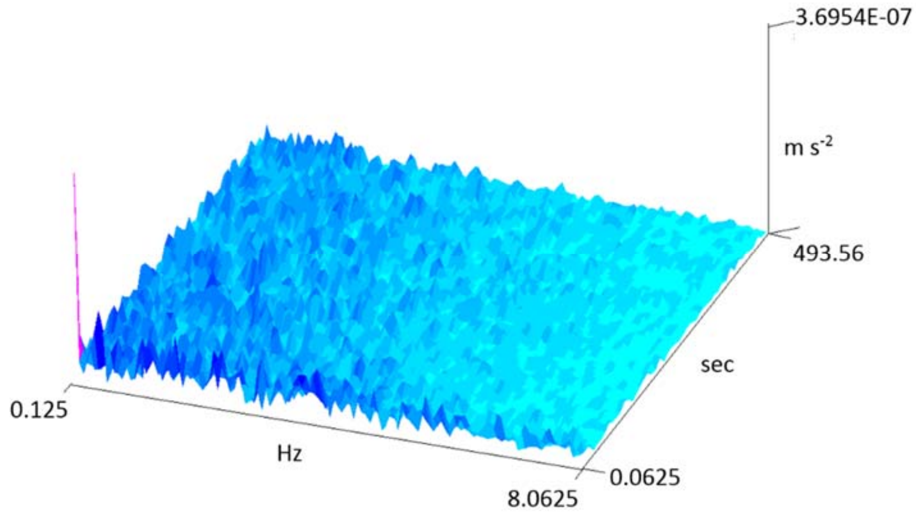

Fig. 3: Graphical interpretation of test results for a point 500 m away from the mast foundation, a) time history, b) signal spectrum.

Analysis of the obtained test results indicates that the wind power plant generates low frequency vibrations up to 1 Hz. In connection with the above fact, that the level of generated vibration signal is lower than 1 Hz, it should be concluded that it is not harmful to the human body and is safe for surrounding.

There is a need to verify the propagation of vibrations in the ground. For points located on the ground with the same properties, the relationship for vibration damping was found. However, we do not know what it will look like when the soil properties change.

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