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Sound power level investigation of mini VAWT turbines in an anechoic chamber.

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Summary

The present work shows the noise research results of vertical axis mini wind turbines, measured in the anechoic chamber. Location of all measurement points was determined in accordance with the guidelines of the ISO 61400-11.
The study was performed at a measuring distance of Ro, (which was 1.7 meters from the axis of the turbine to the ground and 0.3 meters in diameter turbine), while the distance R1 was 2.62 meters. The testing of acoustic mini-turbines VAWT was performed on the PULSE platform from B & K, using four measurement channels.
Sound power level and 1/3 octave spectrum was performed in the measuring range from 1 Hz - 10 kHz, for 12 classes of wind. Physical parameters recorded during the study included the current reading speed turbine voltage produced by the turbine generator working and a reading of the fan speed produced at stream of air.
The study included measurement of linear sound level, which was determined on the basis of sound levels A, C and G, and the sound power levels for the frequency A, C and G. The main conclusion of the study was an opportunity to show the impact of the effects of the wind on the sound levels. The difference in sound levels for microphones located in the stream of wind and microphones that were not exposed to this aerodynamic noise were as high as 30 dB.

Keywords: vertical axis wind turbine, frequency analysis, the real test, anechonic chamber.

1. Research methodology

The study of acoustic properties of small turbines VAWT work took place on the PULSE system platform from B & K, using the four channels. Metrics used for the analysis of the sound spectrum was 1/12 octave in the measurement range from 1 Hz - 10 kHz. In addition, for each class of wind speed measured with the FFT in the range
1 Hz - 1 kHz, with a fixed bandwidth, resulting resolution 6400 line measurements. During the study examined identification turbine noise for 12 classes of wind speed by adjusting the air stream by means of a centrifugal fan inverter. Physical parameters recorded during the study included the current reading speed turbines, voltage produced by the turbine generator working and reading speed centrifugal fan generating airflow.
Preparation of test bench generation assumed the air stream in a very limited area.

The tunnel itself had dimensions for indoor square with sides of 0.4 mx 0.4 m, which meant that the location of measuring microphones on the floor was "free" from the influence of wind.

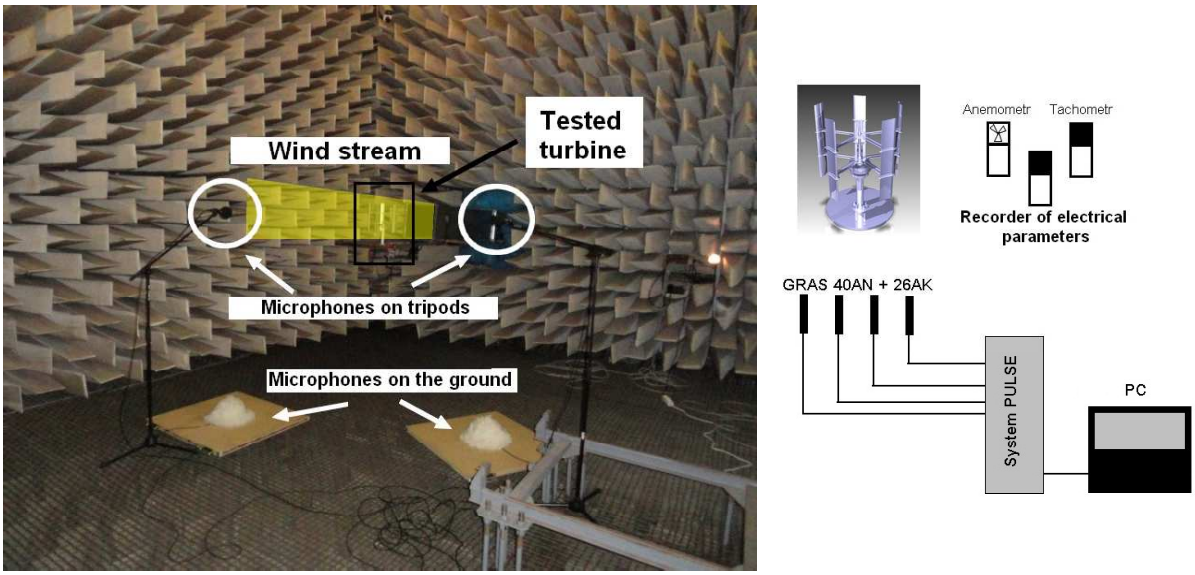

Figure 1. Location of measurement points in an anechoic chamber and a diagram of the measuring circuit.

Diagram of the measuring platform production PULSE B&K included the use of four channels of low-frequency microphones production GRAS 40AN and 26AK preamplifier, enabling linear audio recording levels on the frequency of 0.5 Hz with an accuracy of +/- 2 dB.

The measurement procedure was based on an analysis of the research work of the acoustic small wind turbine mounted on a shaft for ventilation supplied to an anechoic chamber. Variable speed drive centrifugal fan inlet air stream into the chamber followed by the inverter. This allowed to obtain stable wind speed on the forehead channel, which was measured manually using a digital anemometer anemometer's Testo 410-2. Measured the rotational speed of the turbine digital tachometer NDN-838 with a resolution of 0.1 rev/min and a sampling time of 1 second. Range of wind speeds ranged from 6 m/s to about 14 m/s.

2. The scope and frequency analysis of sound power levels of the turbines for different wind speeds

As previously mentioned acoustic tests were performed for the frequency range from 1 Hz to 10 kHz in the analysis of 1/12 octave and 1 kHz using FFT analysis with a fixed bandwidth. All signals presented a linear measurement of sound levels, which were made on the basis of further analysis and acoustic correction. One such analysis was to provide sound levels obtained for different wind speeds to determine the levels and further equivalent sound power level for the frequency A, C and G.

Selection of measurement points was to place them on a special plate on the substrate located at a distance from the turbine, related to its dimensions. The microphone was on the plate was measured and sheltered from the wind with additional transmitters for the purpose of eliminating the acoustic impact of wind on the outcome of the study. The following is a graphic guidelines for the location of the microphone relative to the turbine and the scheme of arrangement of the measuring board. For the tests concerned the distance Ro was 2 meters (1.7 meters from the axis of the turbine to the ground and 0.3 meters in diameter turbine), while distance R1 was 2.62 meters. ISO 61400-11 specifies the method of acoustic analysis, which is further used to determine the sound power level, the designation of source directivity and its tonality.

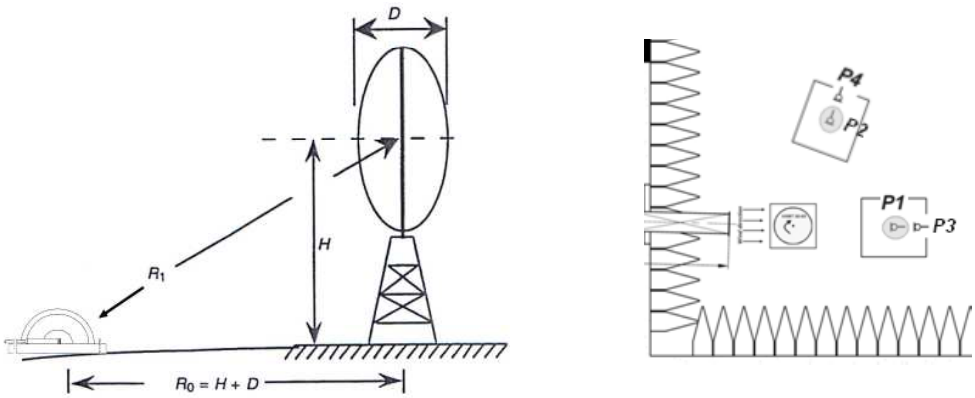

Figure 2. The distance measuring points and their location relative to the test turbine

To determine the sound power level used for sound levels obtained from the measurement point 1 (channel 1), considered as a reference point according to the guidelines standard 61400-11. The sound power level, L_W, are based on sound pressure levels obtained from the measurement point P1 (position of reference - the turbine), for the studied range of wind speed, using the following formula:

$$L_W = L_{i,eq} - 6 + 10 \log ((4 \pi R_1^2) / (S_o)) \quad (1)$$

Where:

$L_{i,eq}$ is a linear sound pressure level

R_1 is measured in an oblique direction and distance in meters from the microphone inside the rotor

S_o is the reference surface $S_o = 1$ m^2.

Constant 6 dB, in equation (1), with around two-fold increase in pressure when the sound level measurements on the ground.

3. Conclusions from the study

Using equation (1) enabled the determination of sound power levels for the studied range of turbines VAWT wind stream velocity of 6 m / s to 14 m / s Determination of sound power levels for each frequency characteristics allowed the fuller reasoning associated with different wind speeds and studied stream turbines.

The x-axis contains the *Frequency [Hz],* in the range from 1 Hz to 10 kHz, and the y-axis, the left graph shows the *Sound pressure level in [dB]* on the right side of the chart-weighted *Sound power level [dB]* for different frequency characteristics.

For the turbine H-rotor 3-arm images and spectral sound power levels are as follows:

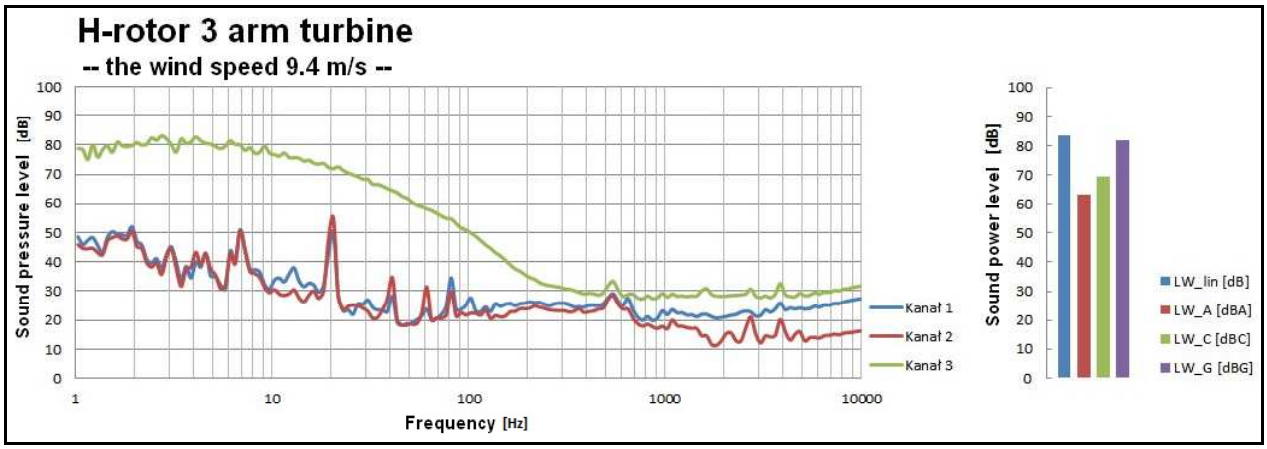

Figure 3. The spectrum of sound and sound power level of the turbine 3 arm of the wind speed 9.4 m/s

Analyzing these results it should be noted both on the same spectral shape and sound levels for different frequencies. Next on the difference in sound pressure level for the different channels of sound power levels, the corrected line-level frequency characteristics.

For the turbine H-rotor 3-arm images and spectral sound power levels are as follows:

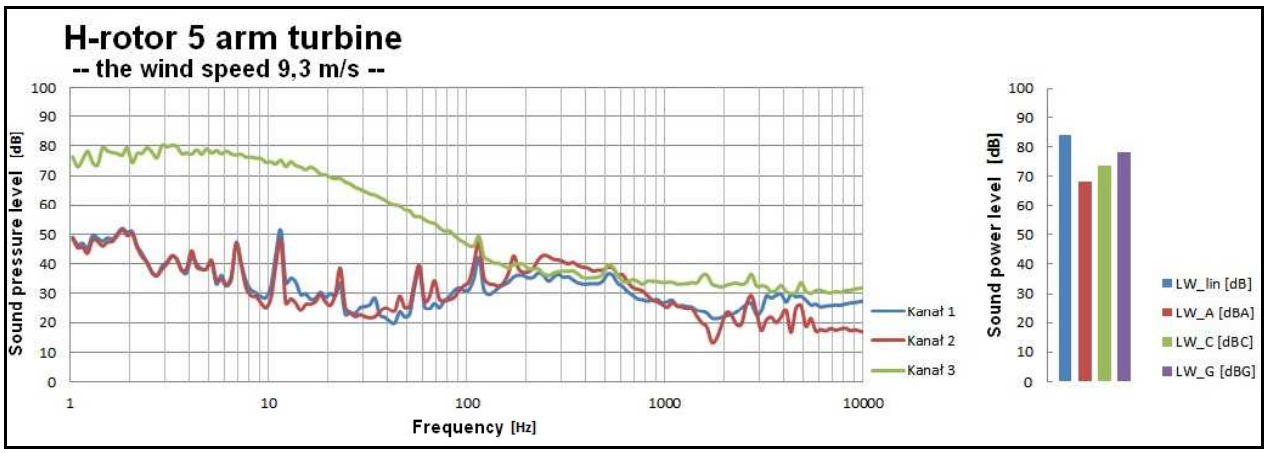

Figure 4. The spectrum of sound and sound power level of the turbine 3 arm of the wind speed 9.3 m/s

The obtained results the following conclusions:

1. The spectrum of the amplitude - frequency can be clearly seen "moving" peak sound levels associated with the rotational frequency of the turbine. The relationship particularly evident for the higher speed wind stream.

2. Sound power levels, the designated sound level of a linear channel 1 (reference point) behave under different values of the frequency characteristics, and only vary in their levels for the next stream velocity of the wind. These changes are linear with respect to the increasing wind.

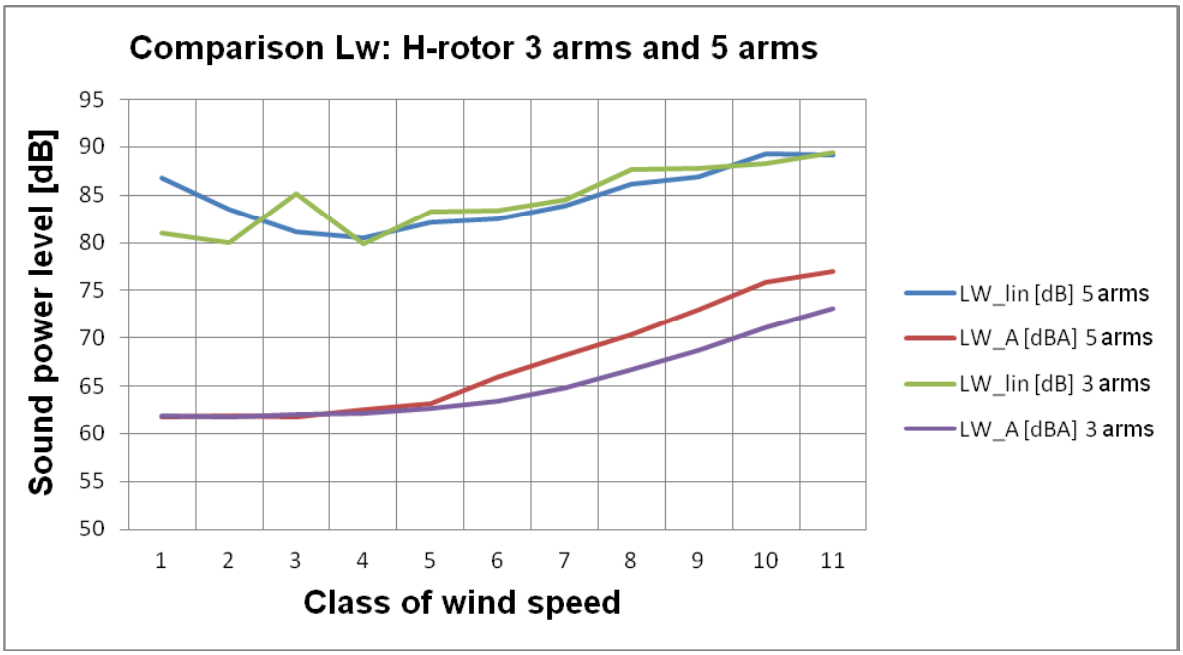

Figure 5. Comparison of linear sound power levels and A levels of H-rotor turbine 5 and 3 arm.

3. The sound power level A corrected for wind classes from 1 to 5 is a very similar, only the 5 class wind speed turbine with five arms is characterized by higher levels of approximately 7 - 9 dB, the highest class of wind. Higher sound power level for the frequency A, 5 class wind speed is caused by the fact more likely to five arms turbine compared with the three arms turbine. Acoustic Interaction turbine with five arms for wind speeds above 5 stream class, seems to be the most dominant right for the audible range. It can be concluded after analyzing the sound power levels without adjustment of frequency, where the power levels are in those classes of wind look very similar.

4. Comparing the characteristics of the sound level for a test turbines, the analysis performed at the measuring point No. 1 show that the initial speed wind stream sound level is 40 dB and forth for a turbine with three arms is about 50 dB, and for the turbine of the five arms of about 55 dB . The result is that for higher wind speed turbine with five arms is louder. This is due to the shape of the sound spectrum and larger amplitudes in the audible range, for analyzing the audio level for the tested rope turbine does not differ substantially among themselves.

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