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THE MEASUREMENTS OF THE WIND TURBINE VIBROACOUSTIC VIBRATIONS

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Abstract

The subject matter of this paper refers to the issues connected with the study on vibroacoustic vibrations emitted during a wind turbine operation. The paper presents the results of vibration measurements and analyses at a full load of a wind generator MK ii 150 kW by BONUS. Their assessment was carried out based on the analysis of the following parameters: rms values of the vibration acceleration and amplitude density spectra, spectrograms and scaling graphs determined for the vibrations registered in the frequency range from 0 to 10 kHz. The registration of the occurring vibrations was carried out in 12 points located on the turbine tower and four points directly on its foundation. Also the assessment of the influence of height in the range from 0.25 m to 13.5 m, at which the measurements were taken, on the analysis results was carried out.

1. Characteristics of the measuring set-up applied

The work of a high power transformer is connected with the occurrence of noise, the source of which are: cooler fans, magnetostriction vibrations of the core, work of the pumps etc. Depending on the installation place, transformers should meet environmental standards connected with admissible noise levels that can be emitted to the environment. Meeting environmental standards referring to the admissible level of the acoustic pressure occurring around a transformer causes much trouble to technical service people in charge of operation of a given unit and to people responsible for observing environmental standards in power plants. It is advisable to measure the level of acoustic pressure occurring around the transformer unit diagnosed during a periodical check-up of the technical condition of power transformers.

Such check-ups are required not only for environmental reasons but also for the evaluation of damage to the cooling system elements (fans, pumps) [1].
The paper presents research results of the acoustic pressure level occurring around a unit transformer 160 MVA. The research was carried out using an integrating meter of the sound intensity SVAN – 945A.

2. Methodology of measurement taking

The object under study was an air turbine MK ii by the firm BONUS of the power of 150 kW, which worked in nominal conditions and which has been characterized, among others, in work [1].

The assessment of vibroacoustic vibrations generated by the work of the air turbine under study was carried out based on the analysis of the following parameters:

- RMS value of vibration acceleration ask (in cm/s2);
- amplitude density spectra, spectrograms and scaling graphs determined for the vibrations registered in the frequency range from zero to 10 kHz.

Measurement points were located at the height of 1.8 m (counting from the foundation level) and distributed equally every 450 on the circumference of the turbine supporting structure (points P1-P8). Additionally, the vibrations of the foundations were investigated in four extreme points marked P9-P12, respectively, which are shown in Fig. 1.
Also comparative measurements of the occurring vibrations of the turbine under study were taken by placing an accelerometer on the entrance door to its tower at three different heights: 0.5 m, 1,5 m and 2 m. The measurement points adopted were marked as as: P13-P15. In the further part of the vibroacoustic investigations carried out, the influence of the height of the measurement registration on the values of the rms acceleration of the vibrations generated was determined. Therefore comparative measurements of vibrations were taken and registration took place inside the air turbine tower at the height from 0.25 to 13.5 m in straight line determined by point P8.

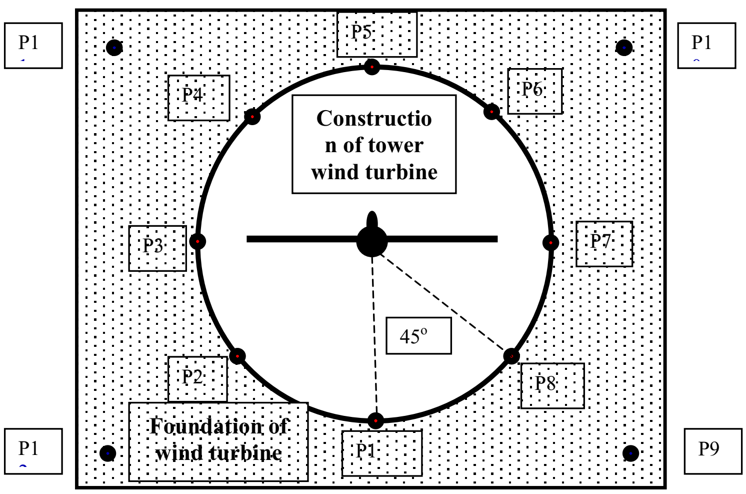

Fig. 1 Distribution of measurement points placed on the tower construction

of the turbine MK ii 150 kW by the firm BONUS at the height of 1.8 m (P1-P8) and on the foundation surface (P9-P12)

3. The analysis of the vibroacoustic vibrations emitted by the air turbine under study

Table 1 lists rms values of vibration acceleration ask, which were determined for the whole frequency band analyzed in the range (0 10) kHz for the measurement points: P1-P15 distributed on the circumference of the turbine tower and directly on its foundation.

Table 1 RMS values of vibration acceleration ask

Measurement Point	Rms value of vibration acceleration a_{RMS} [cm/s^2]
P1	19.0721
P2	23.3629
P3	15.8775
P4	12.2613
P5	12.1356
P6	13.2154
P7	18.0511
P8	15.3634
P9	5.3770
P10	10.8152
P11	5.5096
P12	6.4445
P13	17.4930
P14	23.6191
P15	30.7607

Fig. 2 shows determined vibration acceleration ask values in the function of the tower height of the air turbine under study. On the curve determined, there can be observed an increase of the acceleration values of the vibrations registered in the range from 0.25 cm to 2.25 m, after which their decrease occurs and only from the height of 3.5 m a repeated exponential increase of their values from 22.08 cm/s2 to 70.63 cm/s2 takes place. The values of vibration acceleration ask registered on the foundation surface of the turbine under study were in the range from 5.377 cm/s2 (point P9) to 10.8152 cm/s2 (point P10) and were significantly lower than those registered directly on the metal construction of the tower of the turbine under study.

In the second part of the registered vibrations analysis carried out, their time-frequency analysis was performed based on the amplitude density spectra determined as: a module of the discrete Fourier transform – FFT, two-dimensional spectrograms of the power spectral density treated as a square of the short-time module of Fourier transform – STFT, and scaling graphs calculated by using a continuous wavelet transform CWT. The dependences used in calculations, connected with time-frequency transformations, were characterized in detail in monograph [2].

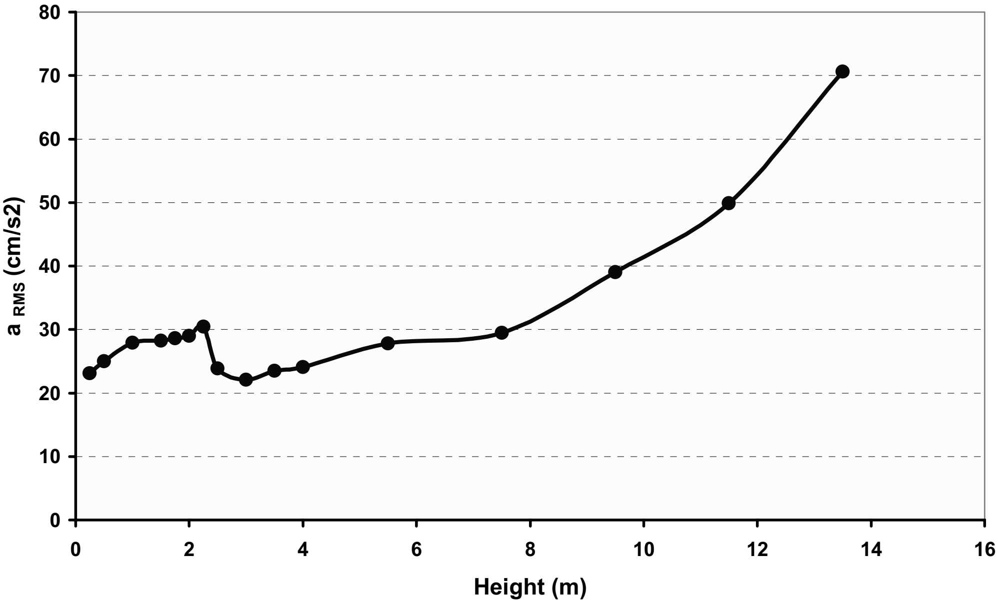

Fig. 2 RMS value of vibration acceleration ask in dependence from the height of the air turbine tower

The obtained results of the time-frequency analysis of vibroacoustic vibrations registered are shown as an instance for one measurement point chosen from the characteristics shown in Fig. 2., located at the height of 0.25 m. Figs 3-5 show the results obtained for to the turbine vibrations registered at the height of 0.25 m above its foundation level. Based on the frequency characteristics runs (Fig. 3) it can be observed that components in the range from 200 HZ to 800 Hz have the biggest participation in the frequency spectrum, and in the range from (0-5) kHz a big number of resonance peaks of relatively varied amplitudes occurs. Above the frequency of 1 kHz, the spectrum analyzed is of a practically flat run without significant extrema.

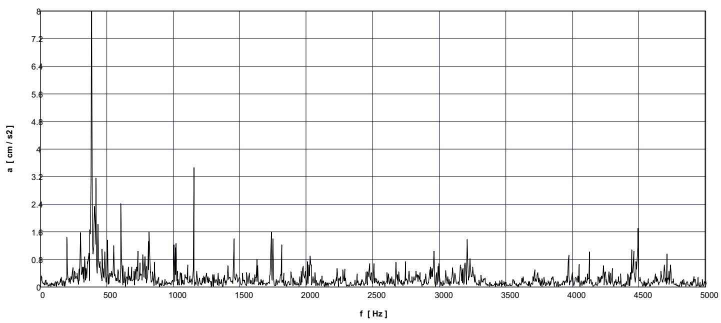

Fig. 3 Amplitude spectrum of vibroacoustic vibrations generated by the work of the air turbine registered at the height of 0.25 m in a restricted frequency range (0-5) kHz

On the spectrogram of the spectral density of vibrations registered at the height of 0.25 m (Fig. 4), time-frequency structures of the biggest amplitude, in the frequency range from 200 to 500 Hz, occur in the whole time interval analyzed of the length of 40 ms. There can be also observed single structures of duration times (10-15) ms in the following frequency ranges: (1-1.2) kHz; (3-3.2) kHz and (4.5-4.7) kHz, but of significantly smaller amplitudes and connected with them power participation.

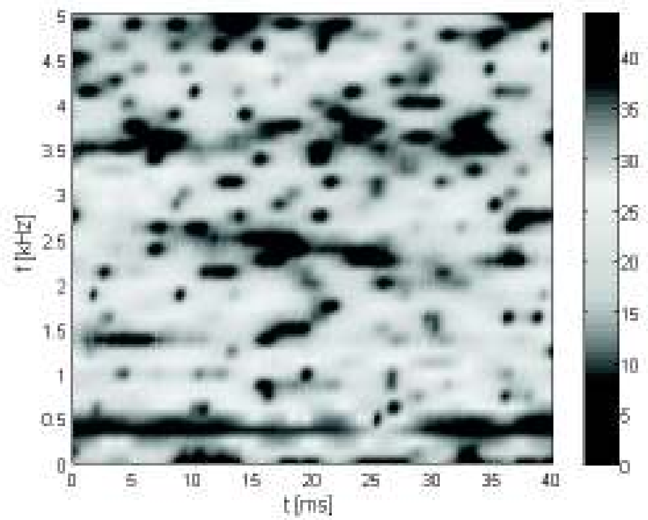

Fig. 4 Two-dimensional spectrogram of power spectral density of vibroacoustic vibrations registered at the height of 0.25 m in a restricted frequency range (0-5) kHz

On CWT scaling graph, shown in Fig. 5, there can be observed wavelet structures in the frequency range (320-550) Hz, which occur with various intensity in the whole analyzed time interval from 0 to 400 ms.

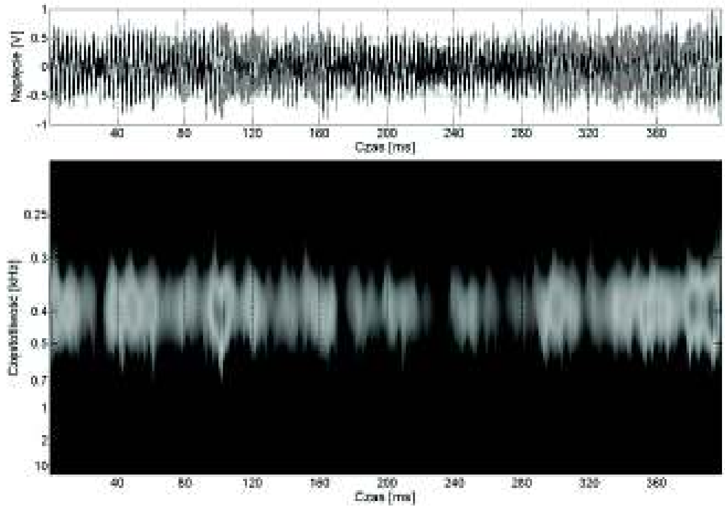

Fig. 5 Scaling graph of vibroacoustic vibrations registered at the height of 0.25 m shown in the whole analyzed frequency range (0-10) kHz

4. Summing-up

To sum up, based on the results obtained of the analysis carried out in the time and time-frequency domains it can be observed that:

- the change of the height, in the range from 0.25 to 13.5 m, at which the registration of the vibroacoustic vibrations generated was carried out, influenced significantly amplitude density spectra and time-frequency structures shown on spectrograms, and wavelet images shown on scaling graphs,
- for the measurement points under study, varied rms values of vibration acceleration a_{RMS} were obtained in a very wide range (from 5.3770 to 30.7607 cm/s^2).

In the case of the assessment of the noise level emitted by air turbines, the results obtained are directly referred to its negative influence on people, which can mean worsening of the comfort of living, worse work efficiency and in extreme cases hazard to health. Vibroacoustic vibrations of turbines are connected mainly with hazard to technical environment, which manifests itself with a decrease of mechanical strength, acceleration of aging processes, worse accuracy, reliability and resistance, and therefore deterioration of basic indexes characterizing constituent elements of the system converting wind strength into electric power. Vibrations also have a significant role in reducing the strength of foundations and constructions of air turbine towers. It should be stressed that so far no standards have been elaborated that would define clearly limit criteria that would make it possible to assess the influence of the vibrations accompanying turbines on their technical properties. Reviewing literature it can be observed that vibroacoustic investigations have been carried out so far to determine the negative influence of turbines on animals living on wind farm areas, especially fauna from the families of moles and weasels.

Due to big geometric dimensions of modern turbines, complexity of using mechanical systems and relatively short time of their being in use there appears a need for determining standards connected with their vibroacoustic properties. Research work connected with vibroacoustic examinations of wind generators should aim at correlating resonance frequencies occurring in time-frequency analysis results with a strictly defined source of vibrations, which in consequence would make it possible to carry out a detailed diagnostics of the condition of the particular systems taking part in the process of converting wind strength into electric power.

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