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COMPARISON OF THE SOUND PRESSURE MEASUREMENT AND THE SPEED MEASUREMENT OF THE GEARBOX VIBRATING SURFACE

Summary. The paper attempts to assess the utility of sound pressure level registered in the near field of about 0,01 m away from the vibrating surface in the studies of the housing vibroacoustic activity. Based on the studies performed for the four pairs of wheels, with different loads and different speeds of gearbox, have been indicated the usefulness of the noise recorded in near field in vibroacoustic analysis.

PORÓWNANIE POMIARÓW CIŚNIENIA AKUSTYCZNEGO I PRĘDKOŚCI DRGAŃ KORPUSU PRZEKŁADNI ZĘBATEJ

Streszczenie. W artykule podjęto próbę oceny przydatności poziomu ciśnienia akustycznego, zarejestrowanego w polu bliskim przekładni zębatej, wynoszącym około 0,01 m od powierzchni korpusu, w badaniach jego wibroaktywności. Na podstawie badań przeprowadzonych na czterech parach kół, przy różnych obciążeniach i różnych prędkościach obrotowych, wykazano użyteczność sygnału hałasu zarejestrowanego w ten sposób w analizach wibroakustycznych przekładni.

1. INTRODUCTION

Registered acoustic signal can be successfully used to locate noise sources in the construction of complex machines. There can be used, in such cases, the inversion method and the correlation method. Practical examples of their use are provided, inter alia, in [1-6] papers. A new approach in the application of the acoustic signal present intensity methods, especially in the movement of the acoustic wave in response to obstacles, which was presented in [1, 7] papers. In vibroacoustic activity assessment and diagnosis of gears, there was predominantly used the vibration signal. In the studies of vibroacoustic sensitivity presented, among others, in [8-16] papers, the measurements were made using piezoelectric transducers and a laser vibrometer. The application of this method in the study enabled the authors to measure vibration assessment, for example the housing on the basis of the normal velocity of selected data points. This assumption is consistent with relation (1) given in [9, 11, 13] which allows to determinate a sound power radiated by a vibrating surface.

$$N_a = \rho_o \cdot c \cdot v_{sr}^2 \cdot S \cdot \eta_r \tag{1}$$

Where:
ρ_o – the density of the surrounding medium, c – the speed of sound in air, $v^2_{śr}$ – average value of normal vibration velocity, S – the radiation surface, η_r – the coefficient of sound radiation

The measurement is affected by an error associated with the choice of measurement points and depends, for example, on the ribbing of the measured object.

Among more complex objects, it seems to be useful the sound pressure level measurements, which contain the resultant acoustic signal across the vibrating surface. The results of these studies are presented, for example in [9, 13]. Pressure signal is recorded at a distance of about 0,5 or 1 m from the source. The impact of qualitative and quantitative components of the acoustic signal comes from many other sources (causing distortion), difficult to isolate causes that often such a signal can considered only as a reference signal.

The paper attempts to assess the utility of sound pressure level registered in the near field of about 0,01 m away from the vibrating surface in the studies of the housing vibroacoustic activity.

2. THE OBJECT AND METHOD OF THE STUDY

The tests were performed at the FZG circulating power stand in the laboratory of transmissions systems at the Faculty of Transport at the Silesian University of Technology. The study used a measuring system consisting of a co-directional microphone, a Norsonic signal analyzer, which measured the sound pressure level at a distance of approximately 0,01 m above the central point (K7) of a ribless housing and, additionally, approximately 0,5 m above this point. At the same time, for comparative purposes, the vibration signal of this point (K7) was recorded by the laser vibrometer. According to the study presented in [13] the value of the body point of K7 vibration level may be useful to assess its vibration activity. The recording of signals was performed by using a National Instrument NI 4472 data acquisition card and a computer with the software LabView 8.6. The location of the measurement microphone together with the selected measuring point is given in Figure 1. The comparative studies recorded sound pressure level near the gearbox housing (0,01 m above the surface), in which, there were assembled 4 pairs of gears with helical teeth. The gear wheels characterized with an increasing total contact ratio ε_C, equal respectively: 2,24; 2,65; 3,0; 4,0 (the detailed parameters of the wheels are given in the paper [13]). The measurements were performed at a constant wheel speed of respectively n_1 = 900 rpm or n_2 = 1800 rpm and accelerating the gearbox speed from 300 - 3000 rpm. During the tests the applied unit load to the gearbox equaled Q_1 = 1 MPa and Q_2 = 2.15 MPa.

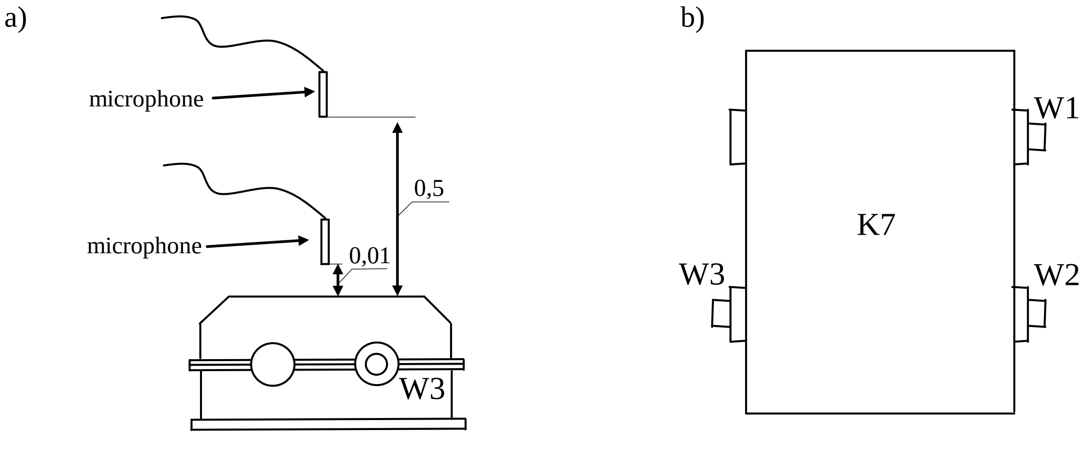


Fig. 1. The location of the microphone (a) and the selected measuring point (b)
Rys. 1. Miejsce usytuowania mikrofonu pojemnościowego (a) oraz wybrany punkt pomiarowy (b)

3. EXEMPLARY ANALYSIS RESULTS AND CONCLUSIONS

On the basis of the recorded vibration signals of the K7 point was determined vibration measurement depending on:

$$v_{śr}^2 = \frac{1}{n} \sum_{i=1}^{n} (v_i\ (t))^2 \qquad (2)$$

Where: v_i (t) - velocity of vibration at the time t, n - number of analysis time samples.

In the case of the sound pressure level signals, there was determined the effective value. The level of vibration and sound pressure in dB was compared, assuming that the reference values $v_{ref.}$ were respectively $v_{ref.}=5\cdot10^{-8}$ m/s and $p_{ref.}=2\cdot10^{-5}$ Pa. The results of the measurements made for gear acceleration with the load per unit of Q_2 = 2,15 MPa, respectively for a pair of wheels (ε_C = 2,24) and a pair of wheels 3 (ε_C = 3) are given in Figure 2. They were presented the change in the value of vibroacoustic activity measurement, where:

- $v^2_{śr}$ K7 - the square of the average normal velocity of point K7,
- p_{RMS} $K7_{0,01}$ - RMS sound pressure level at a distance of 0,01 m above the point K7,
- p_{RMS} $K7_{0,5}$ - RMS sound pressure level at a distance of 0,5 m above the point K7.

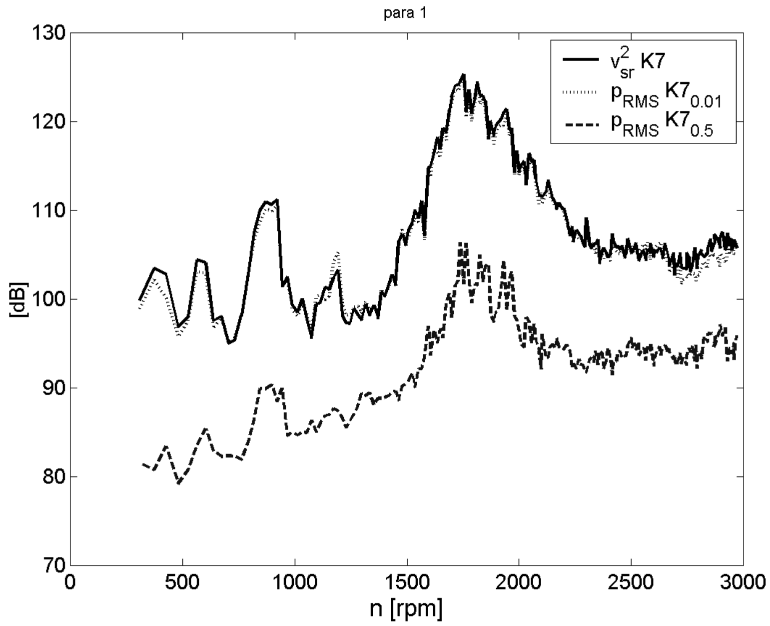
The changes in the value of vibroacoustic activity measurement shows a considerable similarity between the qualitative and quantitative values of sound pressure level registered at the distance of 0,01 m and the normal velocity of the measuring point K7. Much bigger differences are observed when comparing the values of sound pressure level recorded at a distance of 0,5 m from the housing with its vibrations. Quantitative differences are associated with a decrease in the intensity of sound power, which decreases with increasing distance from the radiation of a point. Qualitative differences of these signals are caused by external influences, which source is, among others, the closing gearbox or engine of powertrain.

Generalizing the test results, there were analysed the measurements made at a constant speed of n_2 = 1800 rpm and for two loads of gear unit, respectively Q_2 = 2,15 MPa (Fig. 3a) and Q_1 = 1 MPa (Fig. 3b).

Again, the changes in sound pressure level at a distance of 0,01 m from the housing and the normal vibrations of the body have a similar change, regardless of wheel loads and their total contact ratio.

The acquired analytical results indicate the usefulness of the sound pressure level measured in near-field (about 0,01 m) in assessment of gearbox housing vibration. Comparing the calculations of vibroacoustic activity has shown a similar change of value of energy the noise signal and the surface vibration signal. It was also found that the values of the effective sound pressure level recorded at a distance of 0,01 m and of 0,5 m from the gearbox housing are different. The impact of environmental factors that disturb their characteristic is lower in the place where the measurement was performed in near-field (0,01 m). The presented method requires further research to demonstrate the usefulness of such tests for the study of non-contact machine elements.

a)



b)

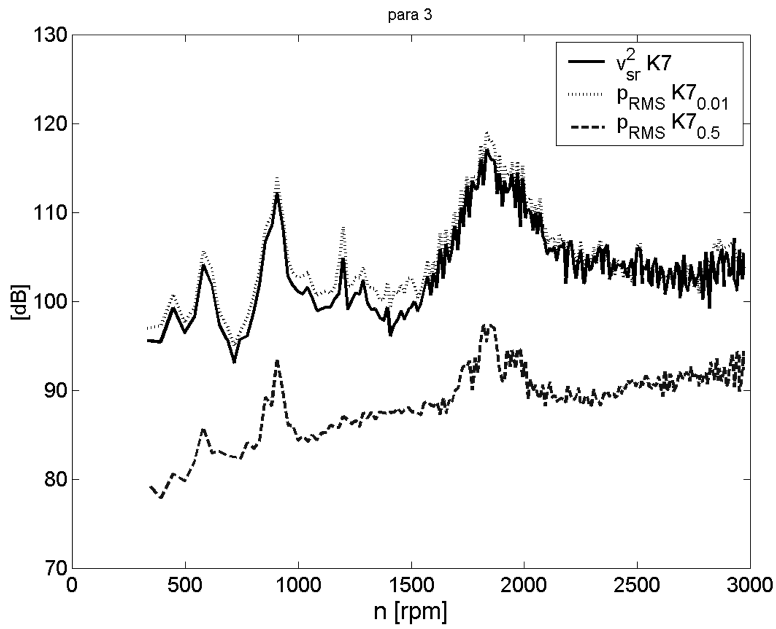
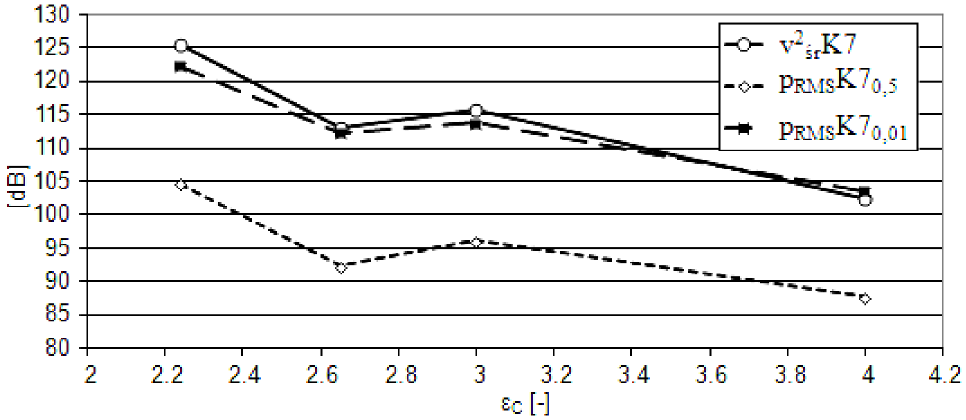


Fig. 2. Comparing the vibration measure $v^2_{śr}$ and p_{RMS} appointed during acceleration:
a) pair 1 (ε_C = 2.24), b) pair 3 (ε_C = 3)

Rys. 2. Porównanie miary wibroaktywności $v^2_{śr}$ oraz p_{RMS} wyznaczonych podczas rozpędzania:
a) para 1 (ε_C=2,24), b) para 3 (ε_C=3)

a)



b)

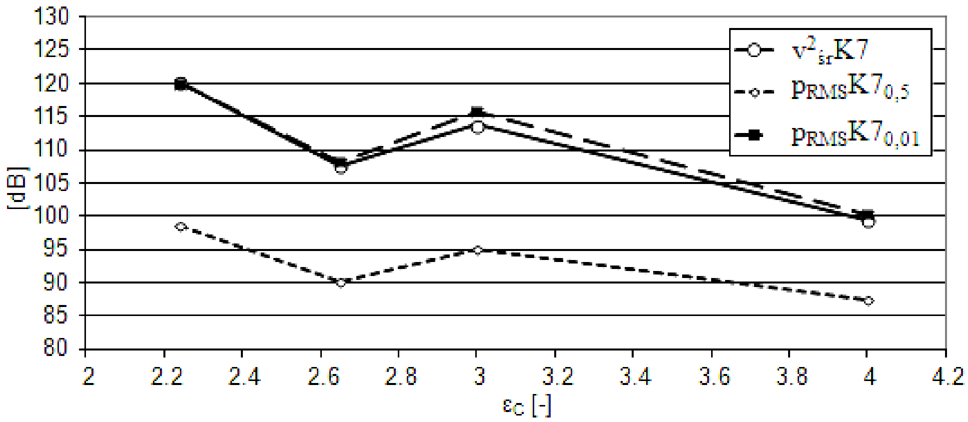


Fig. 3. Comparing vibration measurement $v^2_{śr}$ and p_{RMS} set at a constant speed depending on unit load at work:
a) n_2=1800 rpm, Q_2=2,15 MPa
b) n_2=1800 rpm, Q_1=1 MPa

Rys. 3. Porównanie miary wibroaktywności $v^2_{śr}$ oraz p_{RMS} wyznaczonych przy stałej prędkości obrotowej w zależności od obciążenia jednostkowego zazębienia:
a) n_2=1800 obr/min, Q_2=2,15 MPa
b) n_2=1800 obr/min, Q_1=1 MPa

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