

THE VIBROACOUSTIC METHODS AND THEIR APPLICATION IN THE DIAGNOSTICS OF THE COMBUSTION ENGINE'S ROLLER-BEARING FITTINGS

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Abstract

The roller-bearings are the most widely used appliances of the engine's fittings. The regular use of the roller-bearings leads to their degradation and subsequently to their damage. In extreme situations, the damaged roller-bearing can come to a standstill leading to the engine's failure. As for the maintenance of the engine, it would be crucial to work out the methods of supporting the diagnosis of the engine's fittings and its elements. The methods would enable to determine the condition of measure without the need of the disassembly. The vibroacoustic methods present the greatest possibilities in that field. The authors attempted to realize that task for a chosen element of the combustion engine's fittings in a car. The article presents the results of the conducted research and the study concerning the diagnosis of the bearing's timing belt tensioner pulley. The investigation was conducted for new roller-bearings as well as damaged. Different values of tension in investigations were applied by timing belt, which were placed for help of instrument PR-20. The accelerations of radial vibrations of screw fixing the tensioner pulley were measured during experiments. The recording of accelerations of vibrations was done for different constant engine speeds. The results of the research were analyzed by using software MatLab. The study indicated the measure sensitive to the changes of the technical condition of the tested element. The findings obtained confirm the usefulness of the presented method which in the form of a suitable algorithm may use as the basis for creating a diagnostic device.

Keywords: vibroacustics methods, diagnostics of roller bearing, combustion engine fittings

1. Introduction

In the technical devices that involve elements performing rotary motion we have to use the bearings. In the case of combustion engines the main kinematic pairs, taking part in the conversion of chemical energy of the petrol into the mechanical one, are often made on the basis of the slide bearings. However, in every engine we can distinguish many devices whose proper functioning determines the technical condition of the whole drive unit. In the engine's accessories group, we get to have whirling elements whose bearing is realized by means of the roller bearings. The examples are: cooling liquid pumps, automotive generators, tension rolls, V-belts and camshaft belts. In the process of operating we face a gradual degradation of bearing that leads to damages that seem to be unnoticeable to a certain point. Taking that into account, the diagnosis of the bearings in the engine's accessories is vital during the exploitation time. To make it less time consuming and to minimize the costs of diagnosis, the best possibilities are created by vibroacoustic methods. The article presents the research results and their analysis in the view of diagnosis of the toothed belt's tension roll bearing in the timing gear drive.

2. Object and research methods

The research required conducting a number of measurements of vibrations accelerations for various technical conditions of tension roll's bearing in the timing gear belt. The object of research was an automotive vehicle 1.2 dm^3 with the mutli-injection of 55 kW.



Fig. 1. The view of the timing gear's drive after dismantling the shield and the place of fastening of the vibrations speed detector

To evaluate the acceleration of vibrations, the piezoelectric transducer was used fastened by means of a magnet in the place shown in the Fig. 1. During the research it was observed that the vibrations of the tension roll's bolt were in two perpendicular directions on the surface towards the crankshaft axis. The registration was applied for the following conditions of the research:

- engine heated up to(about 90°C),
- measurements conducted in the stationary conditions,
- recording time – 2 s,
- rotational speed of engine-900- idle running, 1500, 3000 pm,
- PCB320C15 piezoelectric accelerometer was used,
- measurements performed for the new and the damaged roll.

The measurements of vibrations were carried out for various loadings of the tension roll's bearing. The change of the radial loading of the bearing was obtained thanks to the regulation of the preliminary toothed belt. Settling the chosen value of the belt's tension was performed by means of a device controlling timing gear tension type PR-20. Measurements were conducted on the active side of the belt between the rack of wheel of the camshaft and the toothed belt of the cooling liquid pump.

3. Results and analysis

The conducted research enabled to gather a base of measures composed of the signals of vibrations obtained for tension rolls working under various loadings and rotational speeds. Examples of results are shown in the Fig. 2. Considering the fact that the tension roll is fastened to engine's frame in normal conditions, the obtained vibration signals contain a high-energy components coming from an assembly of a crankshaft, pistons and connecting rods and other devices in the drive unit.

In that case it was impossible to use the diagnostic measures based on characteristic frequencies for damaged elements of a bearing. In fact, even the analysis of energy signals of vibrations in the whole frequency band didn't bring the desirable effects. The conducted analysis of the frequency allowed for establishing the range of frequencies in which we can observe structural roll vibrations independent of the rotational speed (Fig. 3).

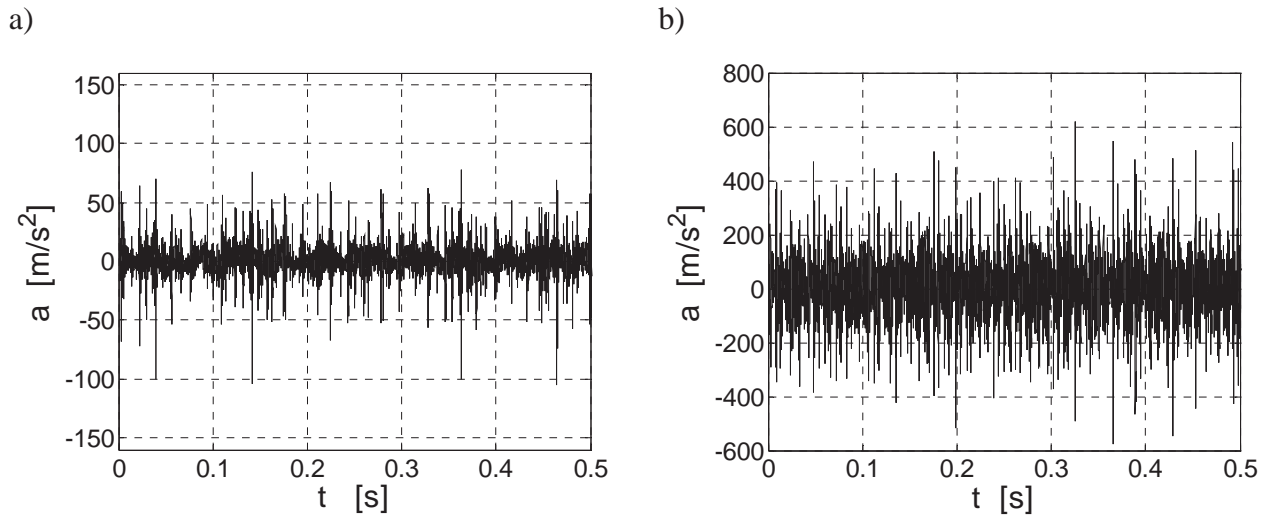


Fig. 2. Exemplary signals recorded for a new roll with a) rotational speed 900 [rpm] and with lowered tension roll, b) rotational speed 3000 [rpm] and over standard tension roll

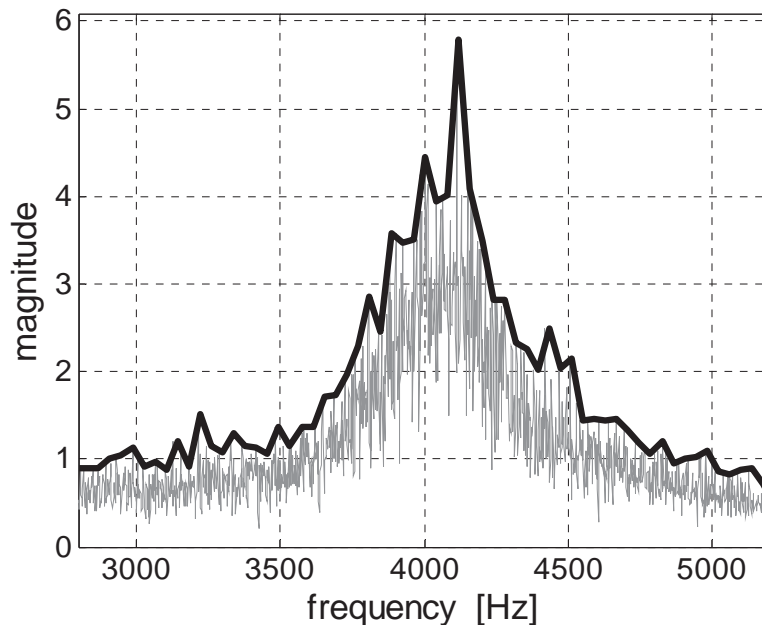


Fig. 3. Spectrum of the speed of vibrations for the damaged roll appropriately for 900 [rpm] and for the lowered value of the tension roll

In the Fig. 4 a-d we can see a set of spectrum fragments for rolls in different technical conditions according to the changes of radial loading.

From the point of spectral analysis of the registered signals, it is visible that radial loading of the tension roll leads to vibration energy shift towards higher frequencies. It happens independently of the condition of the roll's bearing. For the damaged bearings, we can notice a great increase of the accelerations of vibrations especially in the given frequency band. So as to evaluate the condition of the bearing, the energetic measure was used as a value of effective acceleration of vibrations (RMS). The diagram of the signal path processing shown in Fig. 5.

The measure of the energy included in the signal turned out to be the most sensitive diagnostically. It showed monotonic features for different conditions (loading and technical conditions). The Fig. 6 shows the results of the amplitude analysis of the filtered vibration signals, for the nominal loading of the radial bearing for different engine speeds.

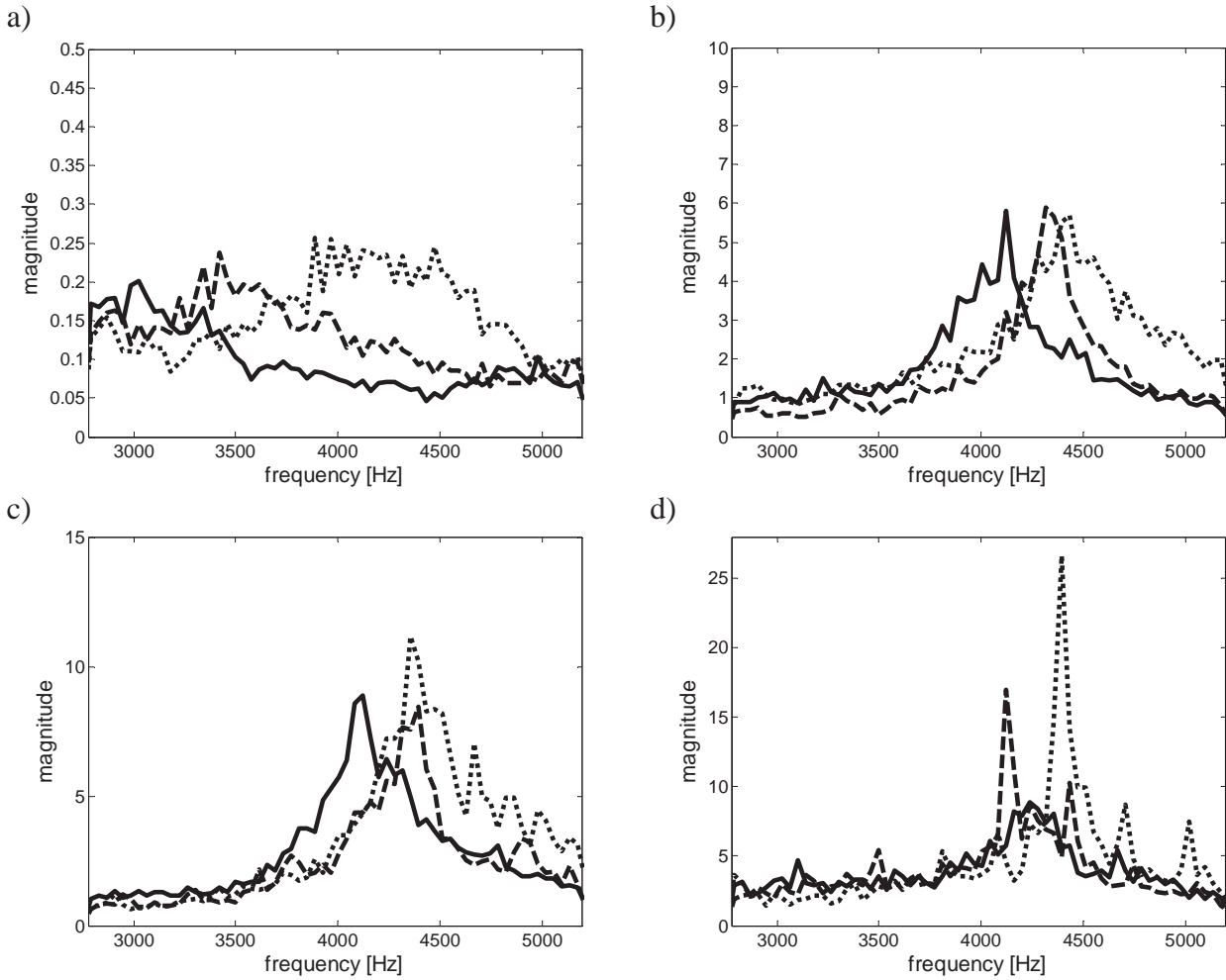


Fig. 4. The influence of the changes of the radial loading of the roll on the structural resonance's position for various rotational speeds: a) new roll 900 [rpm], b) damaged roll 900 [rpm], c) damaged roll 1500 [rpm], d) damaged roll 3000 [rpm], — lowered loading, - - - nominal loading, over standard loading

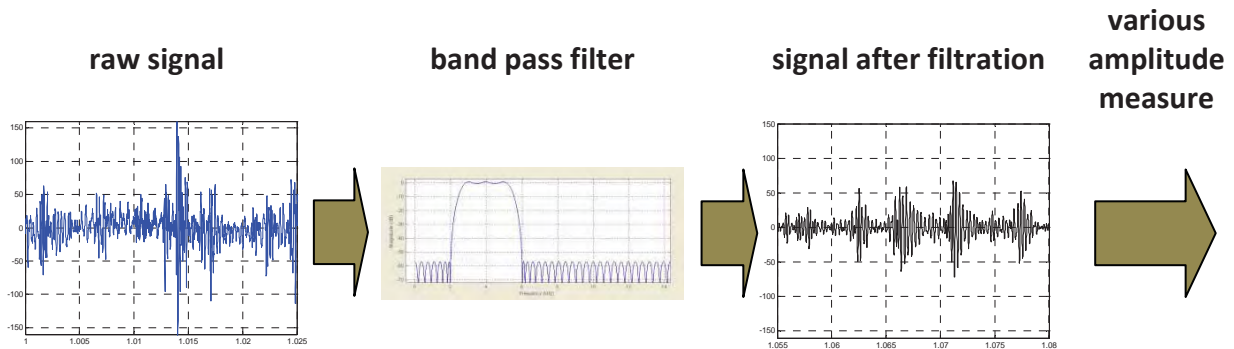


Fig. 5. The signal processing diagram

Effective values for the chosen frequency of vibrations are sensitive to the changes of the technical conditions. Effective values of acceleration of vibrations registered in perpendicular towards direction of the cylinder axis are marked with greater diagnostic resolution.

4. Summary

The values obtained for the new roll in a given rotational speed are always lower than those for the damaged rolls. The greater diagnostic resolution occurs in the perpendicular direction towards

cylinder axis vibrations. The change of the rotational speed of the engine and the tension roll influences the values of the analyzed measures. The rotational speed increase results in the greater effective value of the signal in a given frequency band. The analysis shows the dependence of the radial tension loading and the resonant frequency of the examined system. The establishment of the boundary value of a given measure must be linked with defining the rotational speed of the roll. The measure for the roll has to be assigned and the rotational loading resulting from the roll tension must take place as well.

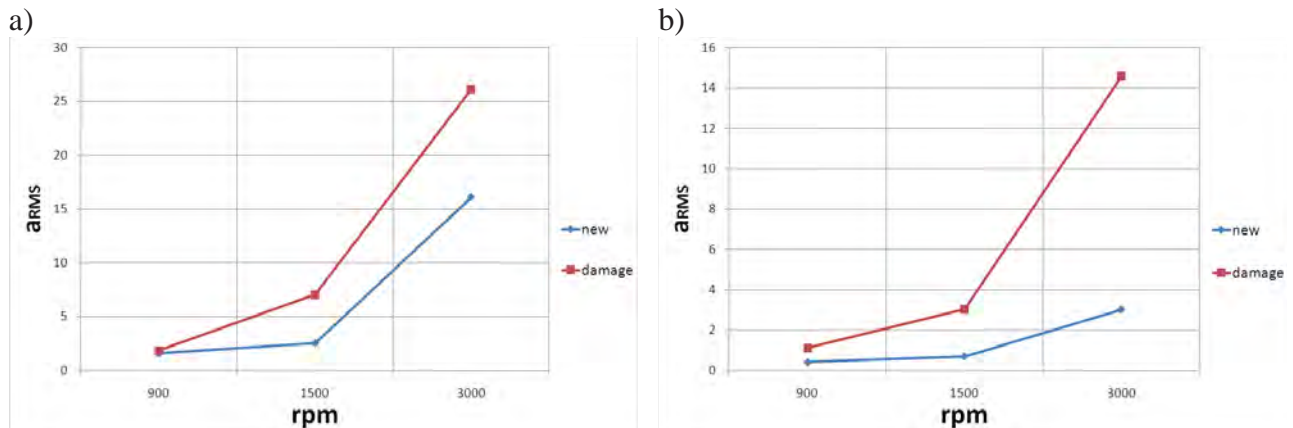


Fig. 6. Effective values of vibrations acceleration for different rotational speeds for the damaged and the new roll: a) direction compatible with the cylinder axis, b) perpendicular direction

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References

- [1] Madej, H., *Diagnozowanie uszkodzeń mechanicznych w silnikach spalinowych maskowanych przez elektroniczne urządzenia sterujące*, Biblioteka Problemów Eksploatacji, Katowice-Radom 2009.
- [2] Dąbrowski, Z., Madej, H., *O użyteczności symptomów wibroakustycznych w nowoczesnej diagnostyce silników spalinowych*, Przegląd Mechaniczny Nr 1, s. 32-35, 2007.
- [3] Cempel, Cz., *Diagnostyka wibroakustyczna maszyn*, PWN, Warszawa 1989.
- [4] Batko, W., Dąbrowski, Z., Engel, Z., Kiciński, J., Weyna, S., *Nowoczesne metody badania procesów wibroakustycznych*, ITE, Radom 2005.
- [5] Barczewski, R., Szymański, G., *Zastosowanie metod selekcji sygnału drganiowego w diagnostyce silników spalinowych*, Pojazdy Szynowe 3-4, s. 108-111, 2004.
- [6] Bendat, J. S., Piersol, A. G., *Engineering Applications of Correlation and Spectral Analysis*, 2nd Edition, 1993.
- [7] Charchalis, A., *Analiza sygnałów drganiowych w aspekcie ich wykorzystania w diagnozowaniu okrętowych turbinowych silników spalinowych*. Zagadnienia Eksploatacji Maszyn, PAN, Nr 3, s. 329-340, 1993.
- [8] Geng, Z., Chen, J., Hull, B., *Analysis of engine vibration and design of an applicable diagnostic approach*, Int. J. Mech. Sci. pp. 1391-1410, 2003.
- [9] Lyon, R. C., *Understanding digital signal processing*, Prentice Hall PTR, 1st Edition, 1997.
- [10] Łazarz, B., Madej, H., Peruń, G., Stanik, Z., *Vibration based diagnosis of internal combustion engine faults*, Diagnostyka Nr 2(49), 2009.
- [11] Zheng, G. T., Leung, A. Y. T., *Internal combustion engine noise analysis with time-frequency distribution*, Journal of Engineering for Gas Turbines and Power, Vol. 124, pp. 645-649, 2002.