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The Assessment of the Effects of the Wear and Tear of Rolling Bearings on the Dynamic Properities in the Non-Stationary Conditions

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Abstract

The article, contains important informations about diagnosis of roll bearings, which are used in car road wheels. Current methods of diagnosis, which are used in workshop practice, are very unsatisfactory, and these methods are subjective in nature. The author of this article, shows the advantages of vibroacoustics methods, which can be used in the diagnosis of vehicle's roll bearings.

Keywords: roller bearings, diagnostics, vibroaucoustics, diagnosis of motor vehicles

1. Introduction

The rotation, which is performed by machines and vehicles, is possible through the use of bearings. In means of transport, the dominant group in the area of practical applications are bearings, which in most cases consist of:

- the inner ring with the treadmill,
- rolling elements,
- the basket,
- the outer ring along with the treadmill,

Rings maintain the correct alignment of the bearing on the bearing trunnion and in the socket as well. The track is supposed to move the load in the direction of the main bearing movement. The basket is responsible for the separation of rolling elements from each other and their even distribution along the treadmill. Contact cooperation between rolling elements and the tracks (external, internal) during the movement causes vibrations, which is heavily dependent on the condition of the associated components [Randall R. B., Antoni J., 2011, Stanik Z.,et al, 2012].
Standard ISO 15243: 2004 contains the generally accepted classification for rolling bearing damage, according to which there are six main groups of defects and sixteen subgroups:

1. electric erosion,
   1.1. excessive voltage
   1.2. the current flux
2. corrosion,
   2.1. corrosion from moisture,
   2.2. corrosion as a result of friction,
   2.3. fretting corrosion,
   2.4. fake Brinell imprints,
3. plastic deformation,
   3.1. overload,
   3.2. dent of contamination particles,
   3.3. dent as a result of improper handling,
4. fracture,
   4.1. forced fracture,
   4.2. fatigue fracture,
   4.3. thermal fracture,
5. fatigue,
   5.1. fatigue originated beneath the surface,
   5.2. fatigue originated on the surface.

Types of damage can be also divided due to the moment of damage: before the operation and during one. In the process of monitoring the condition of the bearing, for obvious reasons, particular emphasis is placed on the damage arising during operation [SKF Polska, 2011].

During the operation of the bearings, their elements cover the tens of thousands of kilometers on the surface of the track while turning at the same time hundreds of thousands of times. Depending on where they work, these elements are exposed to:

- pollution
- overcharge
- forces operating laterally and longitudinally
- inadequate lubrication
- high temperature or its violent fluctuations
- vibrations from the associated components

If you add to this the constant striving to reduce the weight and cost of production of components while maintaining or improving existing structural parameters, this can lead to the downgrading of reliability function of the bearing. What's more, these items are very sensitive to the correctness of the assembly. Figure 1. 1. shows the chosen example of the damage to the bearing arrangement of a vehicle.

Presented example shows the consumption of the journal which is part of the wheel arrangement. This consumption was caused by too low bearing preload, as a result of which there has been movement of the inner track of journal. Exploitation in such adverse conditions caused the loss of materials of the associated components, which was the result of top layer wear. So the big losses of the material qualify the elements to be replaced.

The most promising opportunities for the diagnosis of rolling bearings are based on the dissipative observation methods in the bearing. In the first place there are always methods of vibroacoustic diagnostics [Randall R. B., Antoni J., 2011, Cempel C., 1982].

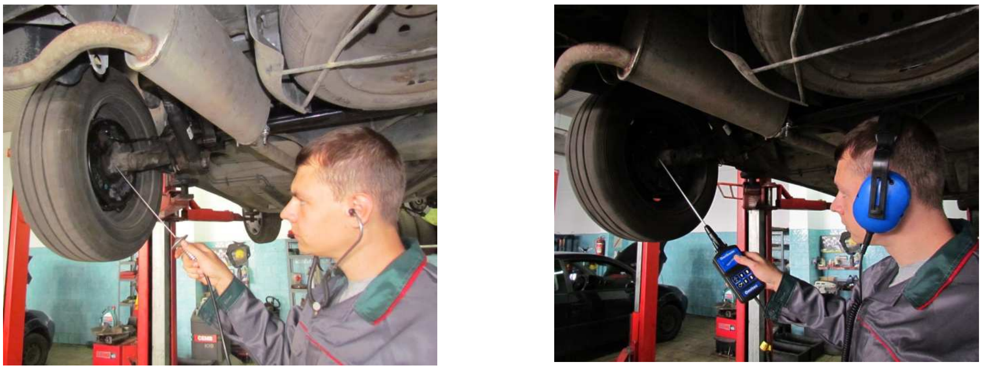
Fig. 1. Worn elements of the wheel bearing.

The specificity of the tasks carried out by transport vehicles causes a significant setback to the applicability of the known methods of bearing arrangement diagnosis. One of the largest challenges posed in front of the technical assessment systems of the motor vehicles bearings include constant changes of their load and speed [Madej H., 2010] For these reasons, the following work focuses on the issue of assessment of the impact of the bearing wear on the observed vibration characteristics.

2. Object and test method

The primary method of monitoring the state of bearing arrangements of the vehicle wheels used in the workshop practice is listening while driving. This method constitutes the first stage of the diagnosis. In this way, one can organoleptically assess the status of individual components of the vehicle. It is quite effective in the case of passenger vehicles, because the noise generated by the worn bearing moves into the cabin which enables the diagnosis of bearing malfunction. However, the sense of hearing, and the ability of its perception tend to get accustomed to the phenomena, which are gradually growing, which undoubtedly takes place at a typical operational wear of the bearings. This may result in the situation when the noise emitted by excessively worn bearing will be considered by the user as the correct one. Furthermore, inexperienced in the practice user is not able to determine the origin of the disturbing sounds. This is due to the fact that they can be generated through the different elements of the various components of the vehicle, including, for example, bearing arrangements. in the boxes, bridges, machinery, engine, etc. Therefore, this type of diagnostic methods should be very subjective, and the quality of diagnosis strongly depends on the experience of the person conducting the diagnostic test.

a) **b)**



Fiig. 2. Testing bearing arrangement of the wheels using stethoscopes, a) classical , b) with amplifer

Another variation of organoleptic methods supported by technical solutions is listening to bearing sounds using stethoscopes. Using stethoscopes one can actually listen to bearing units in both the machinery of the engine, the driveline as well as to bearing nodes of the wheels. However, regardless of the design of a stethoscope (classical or acoustic signal built-in amplifier) there are cases of misdiagnosis (Fig.

2). In the diagnosis of the nodes of the wheels, measurements are mostly conducted on the unloaded car wheels lifted on the jack.

Described problems of diagnosing bearings of the wheels were the premise to take trials to develop objective methods for assessing the technical condition of the bearings of the car wheels. Performed analysis allowed to accept certain assumptions. Forced rotation of the bearing arrangement will be carried out using an external drive system. In the conducted research ,the outer wheels was used. The proposed scheme of test bench shows the Fig. 3.

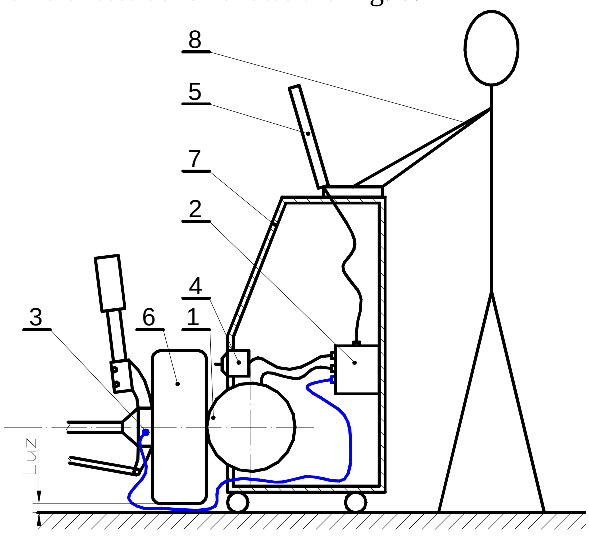


Fig. 3. The outline of methods testing the condition of the wheel bearing. 1-the outer drum of the drive system, 2-controlmeasure layout, 3-the tested bearing, 4-wheel speed sensor, 5-user interface 6-driven (raised) vehicle wheel, 7-external drive system casing , 8-the experimenter

The advantage of the device presented is the possibility of broadcasting of the assumed spin speed of the wheels regardless of the vehicle's engine. This helps eliminate the adverse interference vibrational signals caused by the work of the individual elements in the driveline. Thanks to this solution, you can examine the bearing nodes of the propelled wheels and not propelled ones by elimination of vibration and noise coming from the drive unit. However, it is noted that this type of device is not in a position to set a preliminary axle load, and thus the wheel-bearing nodes are not loaded, as in the case of normal operation.

In accordance with the accepted assumptions, the research program has been developed of examining bearing units of wheels, which were subject to normal operation. A view of the research car along with the balancing machine used to drive the wheels of the vehicle lifted Fig. 4.

Fig. 4. View of the vehicle together with the dynamic balancing machine used in the research.

Fig. 5. Placement of mounting of vibration acceleration sensor

At the time of research, vibration accelerations were registered, located on the outer casing of the bearing arrangement of the wheels, which is a component of a vehicle. Vibration acceleration transducer anchorage is shown in Fig. 5. The selection of vibration transducer mounting location was dictated by the geometric structure of the bearing arrangement.

3. The results and analysis

The aim of study was to assess the impact of the condition of the bearings on the character of the frequency components contained in the vibration signal generated at the time of its work in non-stationary conditions. The reference signal associated with the rotation of the wheels of a vehicle, which was recorded synchronously for vibration acceleration bearing housing, was a course change of ABS voltage sensor. The tested signal was the one that was retrieved directly from the sensor (not-standardized by the steering wheel anti-lock system). Research was carried out during the rundown tests of the wheel speeded up initially to the speed of 1240 [RPM]. Examples of results recorded during the rundown tests is shown in Fig. 6.

a) b)

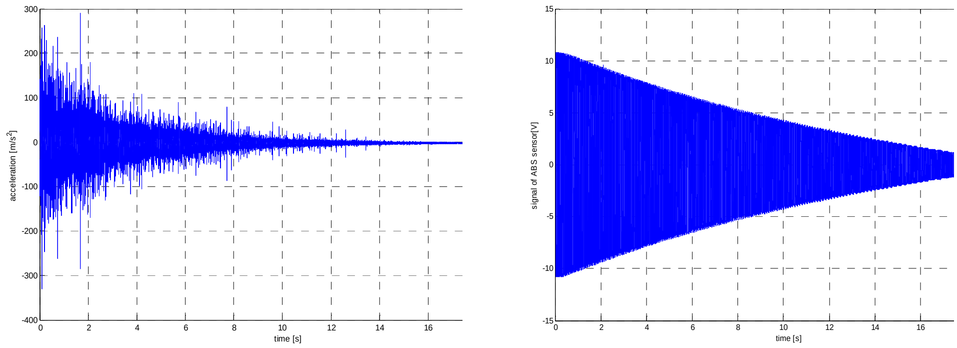


Fig. 6. Sample test results: a) vibration acceleration signa, b) signal from the ABS sensor speed reference

Variable at the time nature of the force applied has allowed to obtain a complex frequency response of the system. An analysis of the frequency of vibration acceleration signal components was carried out in the field to 8 [kHz]. The adoption of such scope was due to the applied type of vibration acceleration transducer mounting. Examples of the results of the frequency analysis are presented in Fig.7 and 8 in the form of short-duration power spectral density distributions.

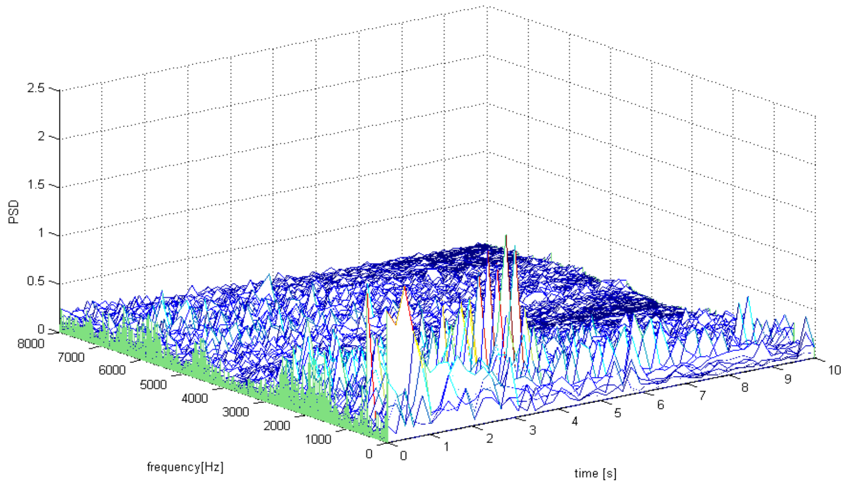


Fig. 7. Short-duration power spectral density of vibration accelerations obtained for operating mileage of 92358 [km] (the beginning of the growth of energy emissions to vibroacoustic external environment)

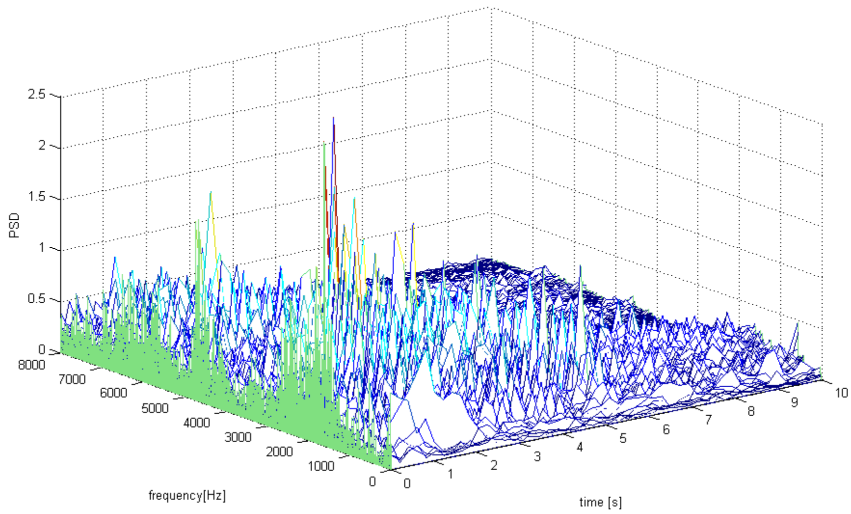


Fig. 8. Short-duration power spectral density of vibration accelerations obtained for operating mileage of 97403 [km] (clearly audible sound effects and increased heat emission in the bearing tested).

Frequency of vibration acceleration time-schedules contain multiple frequency components. This is because the complexity of the design structure of the bearing arrangement. The use of force raking individual partial frequency allowed to show complex character of vibrations resulting from the multi-resonance structure of the mechanical filter, which is the assessed mechanical layout. The assessment of the impact of changes on the condition of the bearings with preload was made by using averaged power spectral density distributions time windows. The selection of analysis window position on the timeline, took into account the speed of the wheels. Comparison of selected frequency sections of the frequency-power spectral density of vibration accelerations of the wheel bearing arrangement is shown in Fig. 9 and 10.

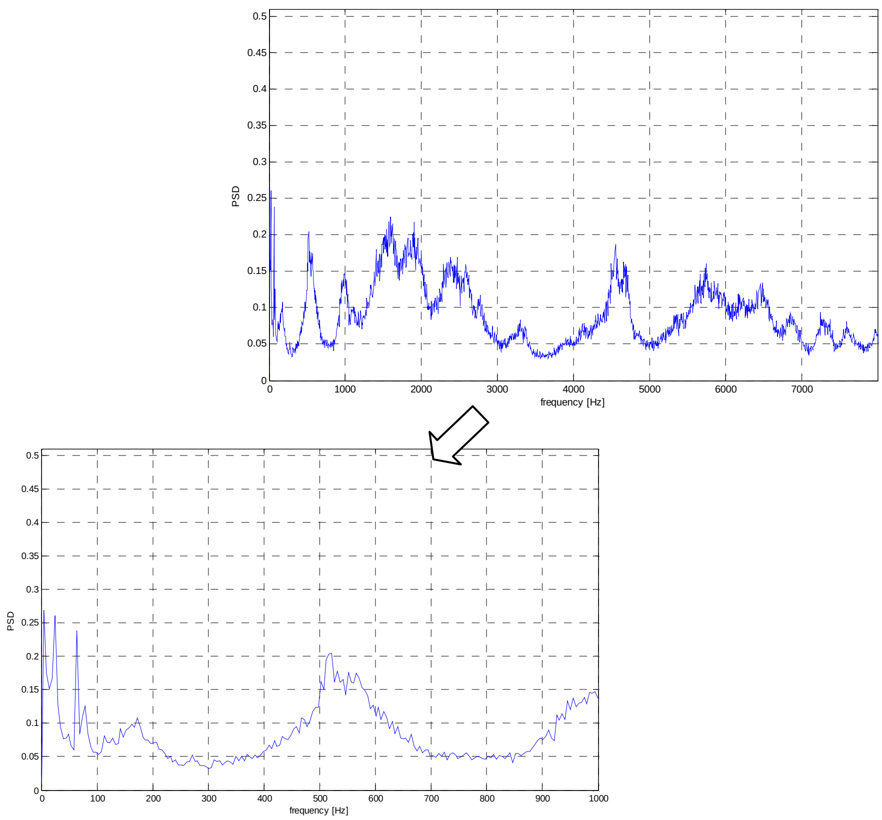


Fig. 9. The power spectral density of vibration accelerations obtained for operating mileage of 92358 [km] (the beginning of the growth of energy emissions to vibroacoustic external environment)

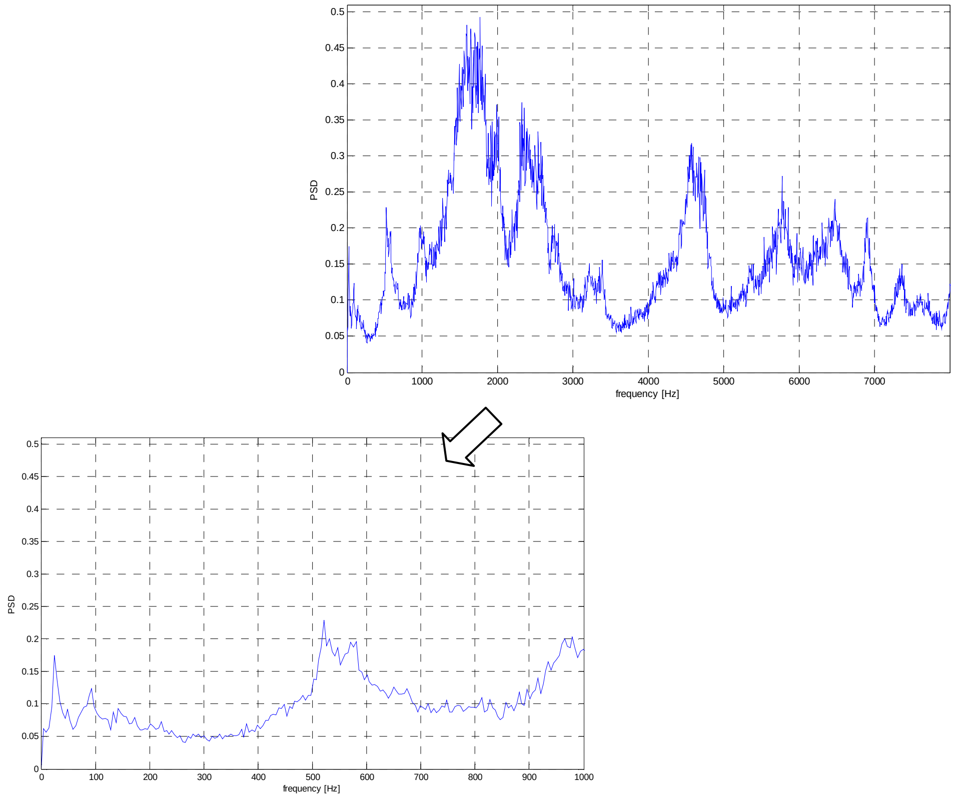


Fig. 10. The power spectral density of vibration accelerations obtained for operating mileage of 97403 [km] (clearly audible sound effects and increased heat emission during the bearing)

Along with the damage to the bearing working items, changes occur in the position of the frequency components in the field. 150 [Hz]. The remaining range, analyzed at the time of the research , cannot justify theses about the impact of the condition of bearings on resonant frequencies, which are manifested in the form of local maxima. The deterioration of the condition of the bearing is the cause of the growth of high-frequency vibration energy at their unchanged frequency structure.

In conclusion, it can be noted that the research on the wheels bearings carried out by unballasted wheels rundown method provide significant information about the form of the multi-resonance mechanical system, that is the wheel bearing .

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