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Z. STANIK*,#, G. PERUŃ*, T. MATYJA*

EFFECTIVE METHODS FOR THE DIAGNOSIS OF VEHICLES ROLLING BEARINGS WEAR AND DAMAGES

METODY DIAGNOZOWANIA ZUŻYCIA I USZKODZEŃ ŁOŻYSK TOCZNYCH POJAZDÓW SAMOCHODOWYCH

The article presents methods of diagnosis of rolling bearings; especially those are used in diagnostics of bearings in wheels vehicles. Active experiments were performed on three bearings built in driving wheels of different vehicles. In diagnosis were used selected methods, including the method of metallographic examination.

Keywords: diagnostics, bearings, wheels of vehicles, vibroacoustics

W ramach pracy zaprezentowano metody diagnozowania łożysk tocznych, szczególnie te, które mają zastosowanie w odniesieniu do węzłów łożyskowych kół jezdnych pojazdów samochodowych. Wykonano czynne eksperymenty na trzech łożyskach zabudowanych w kołach jezdnych różnych pojazdów. Wykorzystano wybrane metody diagnozowania, w tym metodę oględzin oraz badań metalograficznych.

1. Introduction

The rolling bearings have found application in many vehicle units. They are very important elements from the traffic safety viewpoint and therefore it is essential to work out effective methods in order to diagnose and early detect the structural damages of rolling bearings.

Diagnosis of rolling bearings may be carried out in many ways. The paper presents recent developments in this field, especially those methods that are applicable to hub wheel bearings of vehicles. It is vitally important that monitoring the technical condition of vehicle (including bearings in motor) in stationary machines is different from monitoring in non-stationary machines [6, 7].

The paper presents results of three bearings examination. The bearings were mounted in wheels of three different vehicles. In practice were applied especial, selected test methods. At first, vibration measurements of nodes bearing were taken and then the bearings were disassembled. Next, the bearings were metallographically examined in order to eliminate a possible impact of material defects on damage of examined bearings.

2. The currents methods of diagnosis of rolling bearings in vehicles

Regardless of the type of vehicle service station (a service authorized by the specific vehicle manufacturer or an independent),to pre-determine the state of bearing wheels of vehicle is used the method of listening while driving. After that is taken the right decision about the next step of diagnostic process. In this way is possible to estimate organoleptically not only the state of bearings but the state of the individual vehicle components, too.

The organoleptic methods are more effective in the case to passenger vehicles because, the distance from the diagnosis items to the person who makes diagnosis and a small number of additional obstacles makes it possible for this person to hear easily any irregular sound generated by the damaged bearing. Diagnosis for heavy vehicles or buses where the driver is far away from drive unit, drive system and wheels is much more difficult.

For this kind of researches are used stethoscopes both traditional and electronic. Stethoscopes because of economical solutions are being applied in practice in vehicle service stations. They are used to diagnose nodes bearings in the motor gear, drive systems and wheels.

Although, this diagnosis method that based only on bearings sounds has a major disadvantage. The sense of hearing and its ability to perceive tends to get used to the processes that change gradually. It without doubt takes place in typical vehicle during its operation. As a result of this phenomenon, the regular users of vehicle are not be able to determine whether the noises generated by the individual elements of the various components of the vehicle are correct or not. Additionally, the users of vehicle may have

* THE SILESIAN UNIVERSITY OF TECHNOLOGY, FACULTY OF TRANSPORT, 8 KRASIŃSKIEGO STR., 40-019 KATOWICE, POLAND

Corresponding author: zbigniew.stanik@polsl.pl

problem to determine the source of disturbing noises.

Independently of used equipment, organoleptic methods are the most effective if such a diagnosis is only done by specialized person. But it also does not fully guarantee the accuracy of diagnosis. In spite of many advantages this method is not fully objective because it uses a subjective sense of hearing. Additionally, it depends on many factors like for example the weather conditions or state of health of person who does such a diagnosis.

Another method of diagnosis technical condition of wheel bearings in service workshop consists in measurement of clearances. Test is made by using jerk machine which is able to generate forces in chassis of vehicle similar to those that occur during normal car operation. But when the vehicle manufacturer uses the combined hubs of second and third generation, the clearances may not be detected what finally makes this method less effective. In this case a proper diagnosis can only be made basing on the vibration and noises bearing during their operation.

In order to estimate the bearings state, the new diagnosis methods apply the diagnostic instruments that are able to record the size of the residual processes resulting from the movement of machinery. These include the already mentioned vibrations, noise and heat.

Such diagnostic instruments are the temperature meters which are relatively simple diagnostic devices. These devices allow taking a temperature measurement of the element bearing or the bearing itself. Thanks to this method is possible to detect the increased coefficient of friction caused e.g. by insufficient lubrication of bearings. A quite new generation of diagnostic tools are the thermal imaging cameras but because of cost their application is limited.

This method allows only detect the end stage of bearing wear because the bearing shows the higher temperature during its operation just in thermal phase. This thermal phase is the last phase of destruction after noise and vibration phases. Under the circumstances the method described above is not very effective.

The next diagnostic method of bearings is the vibroacoustic method. On the basis of literature sources and the practical experience of Authors [9-12, 14], follows that vibration methods give better effect. They are often more effective in detecting any damages than the methods which base on acoustic measurements. The vibroacoustic method also allows monitoring the condition of the bearings and additionally thanks to created database of symptoms is possible to determine the bearings degree of destruction [5].

In service workshops, in order to make a noise measurement are used acoustic pressure meters. These devices are used very often during vibroacoustic researches. In service workshops, acoustic pressure meter is applied in order to make a noise measurement. They enable to analyze of the volume level, the results obtained are mainly displayed in the decibel scale filtration A or C. The main disadvantage of this method is that the acoustic signals generated by bearing can not be separated from the other sources of noise and disturbances. Hence, the method is not suitable for direct application. A study of effective methods of analyze signals and separation technique and estimation residual processes creates technical capabilities to obtain useful information about tested elements.

The main problem of vibroacoustic researches is superposition of signals generated by the individual bearing nodes. In vehicles are lots of bearings, e.g. engine with fittings. Such a large number of bearings installed on rather small area of vehicle may lead to problems with a proper interpretation of results. As result of it, a wrong diagnosis may be given. The methods of bearings diagnosis, which base on results obtained by measuring the residual processes, may be conducted during a usual vehicle operation. A significant development of measurements techniques during the last decade allows doing such measurements. Thanks to it the diagnosis of bearing while driving seems to be more effective.

The last, diagnostic method involves disassembly of bearings and their analysis. However this method has a significant drawback, namely requires a lot of time, is expensive, and additionally it is not always possible to do. Disassembly of the bearing in bearing node of wheel because of constructional solutions may cause its destruction. A careful examination of bearings does not always allow for the early detection of their destruction or signs of wear. Some structural damages may occur at the level of the material structure [8, 13, 15-18]. It means that in order to detect them, should be done destructive testing.

For these reasons, the method discussed is not used in practice but may be quite helpful to search for the cause of failures or to determine the reasons for destruction of machine elements as a result of failure.

3. The research subjects

At present, the bearings that are fixed in vehicles may be divided into those from catalog or specially designed which take into account all structural solutions specific to each vehicle. The nodes of bearing wheels are constructed in form of integrated double row ball bearing which transfers both the longitudinal and transverse load. There are also such design solutions where the elements of bearing are e.g. integrated with the hub of wheel.

The results listed below relate to wheel bearings from catalog for three different vehicles. The study was conducted for nodes bearing with double row ball bearings.

Firstly, was tested the bearing of wheel of Fiat Panda, marked as (SKF) VKBA 1401. The bearing is shown on figure 1.

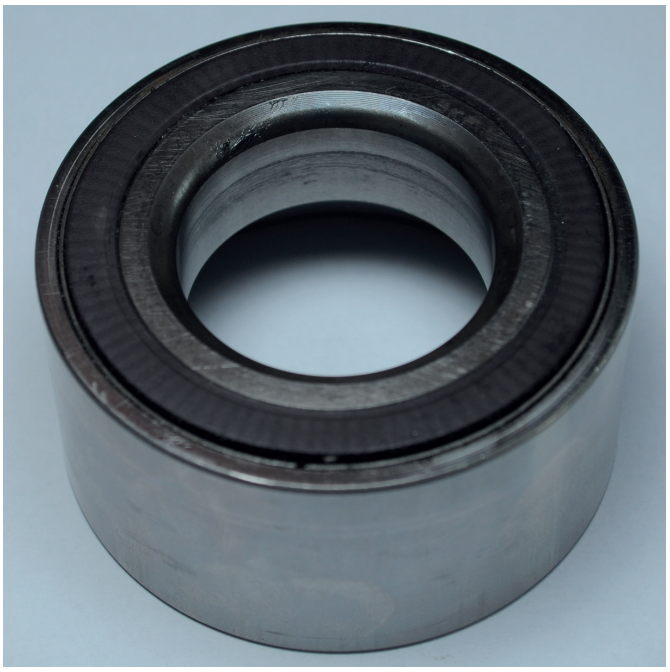

Fig.1. Bearing- VKBA 1401- wheel of Fiat Panda

The second bearing from Renault Kangoo is presented on figure 2. The bearing is marked as VKBA 3692 and was produced by SKF.

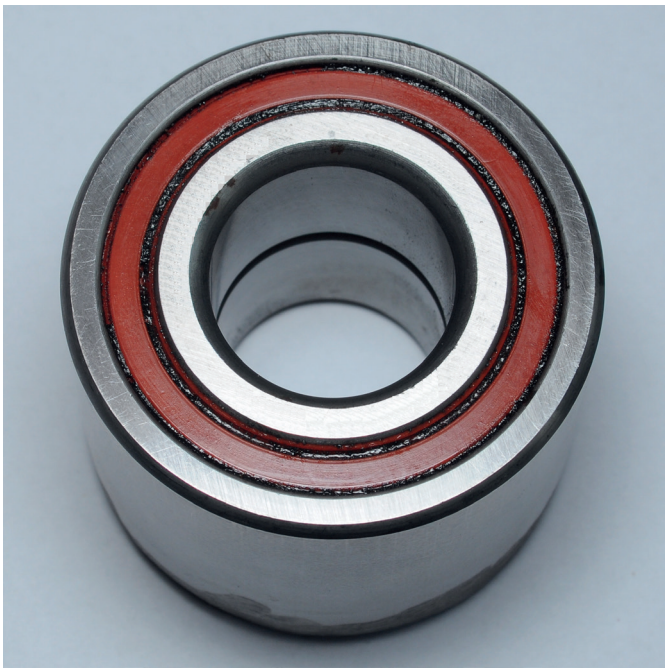

Fig.2. Bearing-VKBA 3692 wheel of Renault Kangoo

As the third, was tested the bearing of Toyota Avensis. It was produced also by companies SKF and is marked as VKBA 6831. It is shown on figure 3.

Fig.3. Bearing VKBA 6831 with inside track

The wheel bearings in nodes bearings were tested during their normal operation. After dismantling the bearings were analyzed and then metallographic examination were made. In order to eliminate the presence of the material defects which could be the reason for detected damages were made the metallographic specimens.

4. Analysis of bearings

In bearing of Fiat Panda was detected micro- destruction of outer raceway. Magnification of this destruction is shown on figure 4.

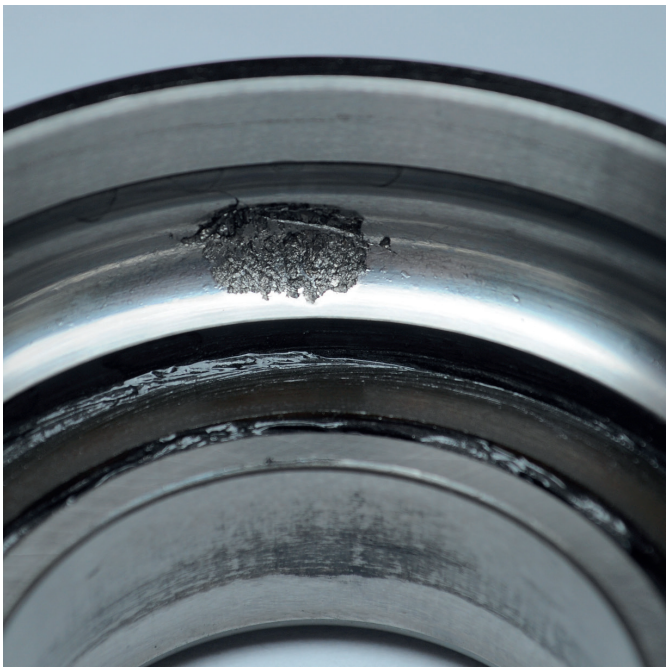

Fig. 4. Micro – destruction of outer raceway (Fiat Panda)

The second wheel bearing was removed from Renault Kangoo vehicle. All elements of bearing were destructed evenly. The vehicle bearing of Toyota Avensis had traces of destruction and additionally it had extensive pitting hole. It is shown on figure 5.

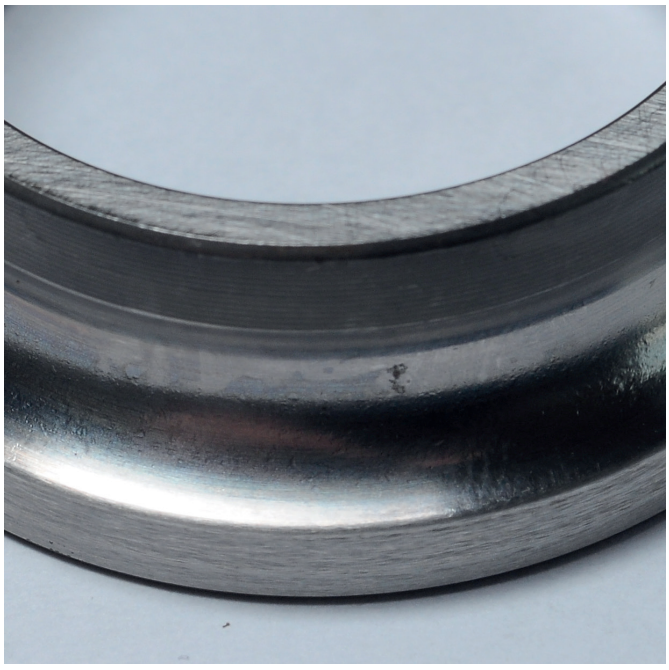

Fig. 5. Traces of destruction and pitting hole of bearing (Toyota Avensis)

5. The results of metallographic tests of bearings

The metallographic specimens were made in order to estimate micro-structure of materials which were used to produce the ball-bearings of the Renault Kangoo and Toyota Avensis vehicles. Macro-structure of outer raceway Toyota Avensic was also estimated.

The specimens for metallographic tests were the rolling elements of outer raceway of mentioned bearings. Some of specimens were from outer raceway which was previously removed from Toyota Avensis. Macro-structure of material near damage is shown on figure 6.

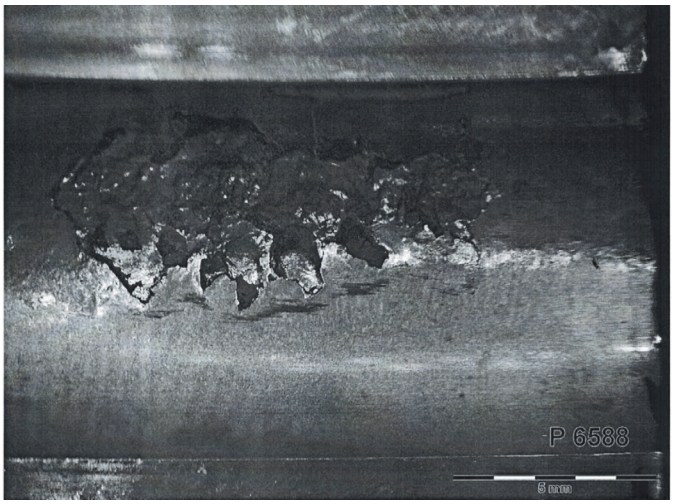

Fig. 6. Macro-structure of material from outer raceway of Toyota Avensis bearing

Results from analysis of both rolling elements of bearings suggest that micro-structure contain perlite. SKF company that produces all analyzed bearings, gives information that for bearings production are most commonly used (depending on application):

- bearing chromium hardened steel,
- induction hardened bearing steel used to produce bearing unit of assembly hub and to produce the car wheel with mounting flange (according to the same sources of information),
- alloy chromium-nickel steel and chromium-manganese steel with amount of carbon on the level 0,15%, surface hardened,
- stainless steel X65Cr14 oraz X105CrMo17,
- steel used for bearings which are operated in elevated temperatures,
- materials - silicon nitride.

Microstructure of bearing rolling element of Toyota Avensis wheel is shown on figure 7, microstructure of the same element but from Renault Kangoo is shown on figure 8.

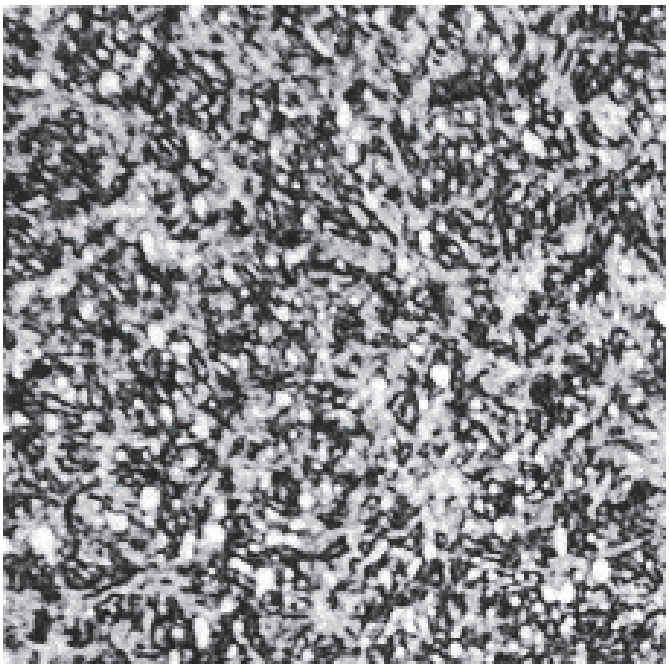

Fig. 7. Microstructure of bearing rolling element of Toyota Avensis wheel, magnification 1000x, etched by nital

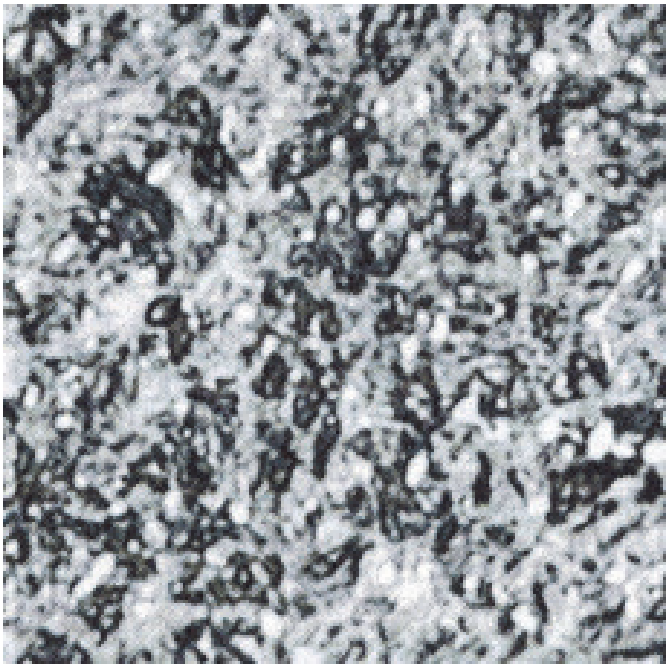

Fig. 8. Microstructure of bearing rolling element of Renault Kangoo wheel, magnification 1000x, etched by nital

The bearings raceway has elevated quantity of perlit. Figure 9 shows magnification 1000x of this structure. Raceway of surface bearing was etched by nital. This same element, but for Renault Kangoo, is shown on figure 10.

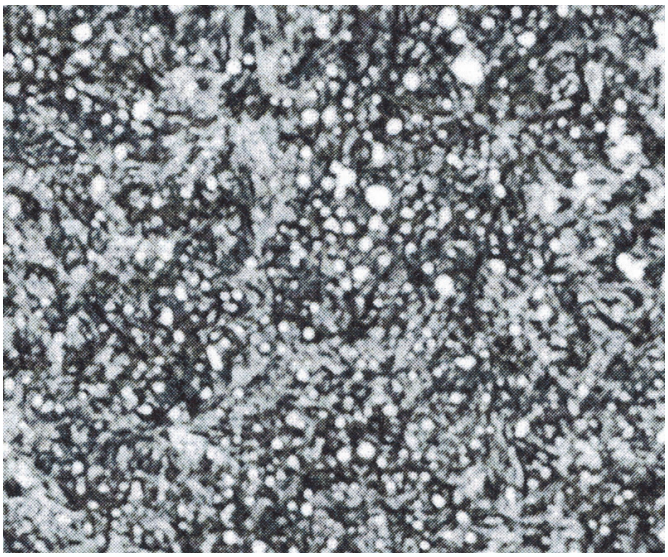

Fig. 9. Micro-structure of bearing raceway of Toyota Avensis wheel, magnification 1000x, surface etched by nital

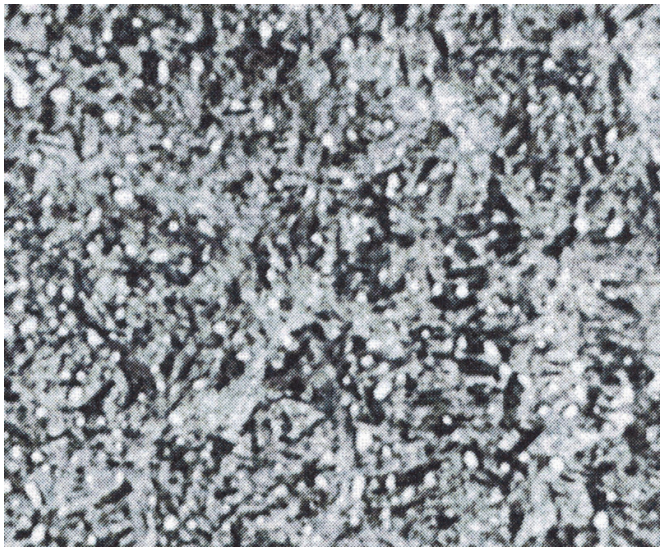

Fig. 10. Micro-structure of bearing race of Renault Kangoo wheel, magnification 100x, surface etched by nital

The research revealed a slight decarbonising of raceway surface for both bearings. The surface structure of raceway etched by nital at 100 x magnification is shown on figure 11 and 12.

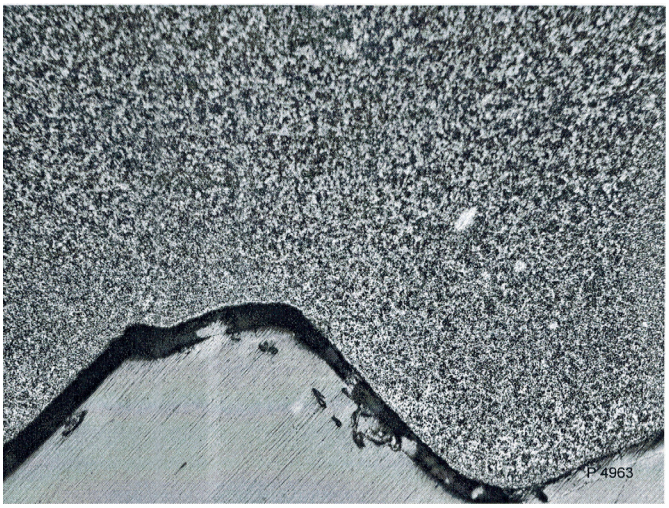

Fig. 11. Micro-structure of bearing race of Toyota Avensis wheel, magnification 100x, surface etched by nital

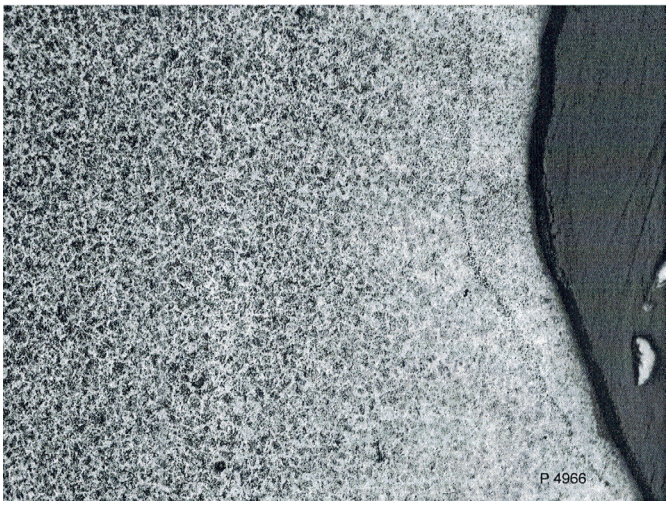

Fig. 12. Macro-structure of bearing race of Renault Kangoo wheel, magnification 100X, surface etched by nital

6. Diagnosis of bearings by vibroacoustic methods

All rolling bearings both the new and the used are generators of vibration. The source of the noise and vibration are the rolling elements which are moving during operation. Moreover, the vibration may be symptom of damage and destruction of bearing or its misuse e.g. pollution, improper lubrication. and operational failures in the form of pollution or improper lubrication.

Vibration measurements are particulary useful when a vibration signal of mechanical from damaged element is disturbed only by movement of kinematics pairs or by signals from another damages in this area. Acoustic signal may be disturbed by acoustic effects e.g. from another malfunctions of machine or from measuring environment. Vibration signal contains more information relevant to the diagnosis and shows a greater sensitivity to changes in the state [1-4].

The vibroacoustic methods require preparing an appropriate algorithm. Due to functioning of the machine, nature of its work and dimensions of parameters it is necessary to use different methods of measurement and different methods of processing the obtained signal. Only such an approach allows obtain the best results.

During all tests, were made the measurements of vibration acceleration of bearings. Frequency of recorded signals was 51.2 kHz.

Firstly, was tested the node of rear wheel of Renault Kangoo. The node consisted of hub, bearing pivot and double ball bearing. During the study the vehicle was raised on lift. In order to put wheel in motion was used a special dynamic device which was able to accelerate the wheel to the vehicle speed of about 150km/h.

Figure 13 shows amplitude spectra of the vibration acceleration obtained from two bearings. One of them was new and the other was very damaged and was not suitable for further exploitation.

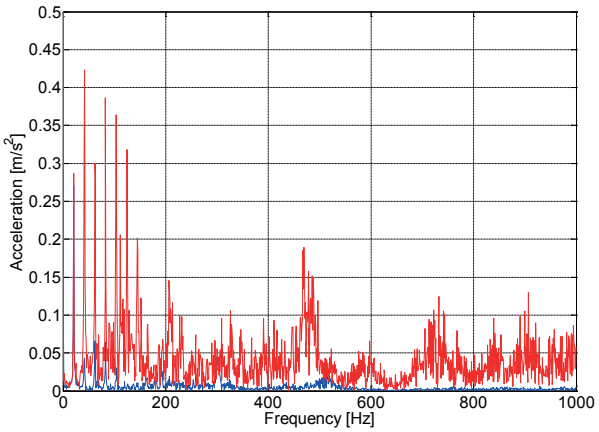

Fig. 13. Spectrums of vibration acceleration for new bearing and for completely destroyed bearing. Both bearings were mounted in Renault Kangoo vehicle (red line - unsuitable bearing, blue line - new bearing)

The amplitudes of vibration acceleration of bearing which was unfit for further exploitation reached the higher values from those obtained for new bearing. This confirms the effectiveness of that diagnostic method of bearings. This method uses the signals of the bearing obtained from measurements of vibration accelerations.

The next node from front wheel of Toyota Avensis vehicle also consisted of hub, pivot bearing and double ball bearing. Studies have been conducted in the same way as for Renault Kangoo vehicle. The vehicle was accelerated by the same method as previously, the vehicle reached speed of about 150 km/h.

In this case, was determined the spectral density of vibration acceleration for bearings both new and unfit for further exploitation. The unfit bearing had signs of destruction and extensive pitting hole.

The spectrum of it is shown on figure 14. The pitting holes often occur as a result of fatigue of raceway surfaces of bearing. The degree of destruction indicates on regular overloading the bearings.

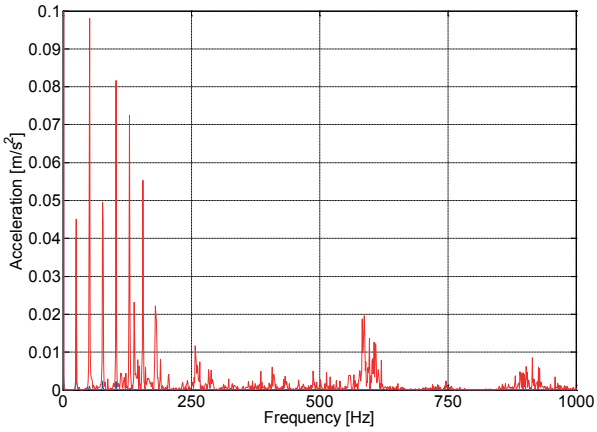

Fig. 14. Spectrums of vibration acceleration of new bearing and of unfit for further exploitation (red line - unsuitable bearing, blue line - new bearing)

The amplitudes of vibration acceleration of bearing that is unfit for further exploitation reached the higher values then those obtained for new bearing across the whole frequency range. This confirms the effectiveness of these diagnostic methods, using signals obtained from measurements of vibration acceleration.

The next was tested node bearing from front wheel of Fiat Panda vehicle. This node has the similar construction to previously described. The wheel was accelerated during test in the same way like previously.

The bearing had micro structural damages. In order to determine degree of destruction a model pulse may be used. Knowing the basic working parameters and dimensions of bearing is possible to calculate the characteristic frequency that is associated with the rolling elements which roll up along damaged raceway. Calculation is made for micro damage of raceway.

The next stage of verification of bearing condition consisted, on the determination of the spectrum and the spectral density of the recorded signals accelerations. Next, for micro-destruction of outer raceway were checked the characteristic increases in amplitude. Results again confirmed the effectiveness of the method of vibration diagnostics of the technical condition of bearings.

7. Summary

Diagnosis of rolling bearings used in vehicles is very limited. The diagnostic tools and procedures hat are used in the method mainly based on unreliable sense of hearing. So, diagnosis of this type is burdened with high unreliability due to the subjective nature of the method.

The bearing nodes of vehicles are very important from the standpoint of road safety. Dismantling of rolling bearings of wheel directly from vehicle is expensive. Additionally, it may lead to serious damages of bearings. Therefore, the only right recommended method is non-invasive diagnostic methods, based on vibration signals recorded. The basic parameter of vibration registered during this type of exams is the vibration acceleration. Basing on recorded time courses of vibration acceleration is possible to built different measures taking into account amount the others such parameters as the bearing load, rotation speed, direction of measuring accelerations and the individual design features of node tested. This everything is the main subject of further study of Authors.

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