DEVELOPMENT OF WIRELESS SYSTEM FOR TEMPERATURE MEASURING IN AXLE-BEARINGS OF RAILWAY VEHICLES

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Abstract: *The constant increase in the speed of transport and the constant tendency to optimize and reduce transport costs conditioning that the reliability of technical systems becomes one of the key requirements. Failures of such systems can cause very serious consequences for the environment, safety and health of people, and therefore it is very important to pay special attention to the efficiency of their functioning. One of such systems is the railway, which is among the most complex technical and technological systems. The basic requirements for railways are to be reliable, efficient and cost-effective compared to the other modes of transport. Railway failures do not happen often, but when they happen, the consequences are derailments followed by extensive material damage and loss of human life. In addition, there are large economic losses due to downtime and repair of railway infrastructure. One of the frequent causes of derailments is malfunction of axle-bearings of railway vehicles, which is manifested by an increasing in their temperature. In this sense, this paper presents the development of a new method of temperature detection in the axle-bearings of railway vehicles.*

1. INTRODUCTION

Interest in the problem of derailment of wagons due to overheating of axle-bearings arose at the request of the thermal power plant "Nikola Tesla" (TENT) from Obrenovac, Serbia. Namely, coal is transported from the mines to the thermal power plant by rail. The Fbd wagons are used for this transport, which are composed of two 2-axle units that are rigidly connected to each other (Fig. 1).

The coal transportation process is extremely intensive and annually in TENT Obrenovac amounts to about 25 million tons. In the process of exploitation of railway vehicles, axle-bearings are among the most loaded elements (Figures 2 and 3). Their correctness and reliability directly affect the correctness and reliability of the entire train. The failure of the axle-bearing in a large number of cases causes the train derailment (Fig. 4), which is accompanied by enormous material damage, and often with human casualties.

Fig. 1. Fbd wagon for transporting coal

The failures can occur due to irregularities in the installed axle-bearings, due to lack of lubrication, mistakes during the repair of the axle-bearings, etc. Mechanical damages and other defects in the axle-bearings cause increased friction between the axle journal and the bearings, which leads to an increase in the temperature of the bearing. This phenomenon is particularly characteristic of the freight wagons that are used in extreme operating conditions [1–4].

Fig. 2. Connection of axle journal with bearing

Fig. 3. Bearings of railway vehicles

By analyzing the accidents of freight wagons in TENT Obrenovac, it is founded that the most often there is an increase in the axle-bearing temperature, as a result of which the axle journal softens, and it can be broken (Fig. 5). Failure of the axle journal causes the derailment of railway vehicle, so special attention was paid to this problem.

Fig. 4. Derailment of wagons for coal transportation

Fig. 5. Failure of axle-bearing

Therefore, the problem of derailment is one of the most important problems on the railway and it is very widely studied. Especialy is important finding new solutions for experimental determination of certain parameters in wheel-rail interaction [5–8].

By considering the existing system solutions for the early detection of temperature rise in Serbia and in the world, we found that most of the existing techniques are based on the application of stationary non-contact temperature measurements, i.e., wayside systems [9–13].

Measuring points are placed at certain positions along the railway. Usually these positions are near the railway stations. Their role is to detect the overheating of the axle-bearings of the wheelsets during the passage of the train. The big disadvantage of this system is that overheating can occur very quickly, where the temperature can rise from a normal level to a critical value in just a few minutes. If this happens at a time when the train is between measuring stations on the track where there is no possibility of detecting the temperature rise, the axle-bearing failure and the derailment occur very quickly [14]. In addition, the accuracy of the measurement is affected by the speed of the train passing by the measuring point, the heating of the brake shoes, the outside temperature, the sun, etc. In such cases, the existing temperature detection techniques do not provide adequate results and certain accidents are not avoided.

That is why, recently, intensive work has been done on the development of systems that perform continuous monitoring of the axle-bearing temperature of the wheelsets. This enables immediate detection of temperature rise and timely reaction in order to prevent derailment. The conceptual solution of one such system is being presented in this paper.

2. WIRELESS TEMPERATURE MEASURING SYSTEM

The basis of the wireless system for measuring the temperature of the axle-bearings of a four-axle wagon is a transmission sensor unit. The transmission sensor unit for temperature measurement (Fig. 6) is installed in each axle-bearing of the wagon.

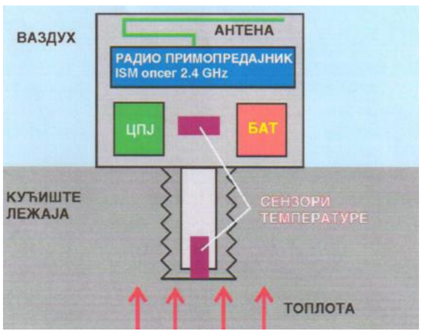

Fig. 6. Schematic of transmission sensor unit for temperature measurement

The number of transmission sensor units can vary depending on the type of wagon, that is, the number of axles per wagon. In this case, the number of sensor units is adapted to the four-axle wagons transporting coal in the Obrenovac TENT. Signals from the sensor units, which are placed in the axle-bearing, are sent to the transceiver units. On each side of the wagon, the signals are sent to one transceiver unit. Therefore, there are eight transmission units and two transceiver units per wagon (Fig. 7).

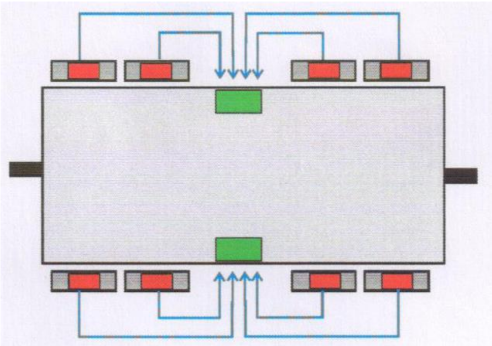

Fig. 7. Installation diagram of eight transmission sensor units for temperature measurement and two transceiver units on the wagon

The signals are sent wirelessly from the wagon transceiver units to one transceiver unit located in the locomotive (Fig. 8). The transceiver unit in the locomotive collects data on the temperature of all the train's axle-bearings and shows the alarming condition with sound and light. In addition, the information about the temperatures of the axle-bearings remains permanently recorded in the computer for subsequent analysis.

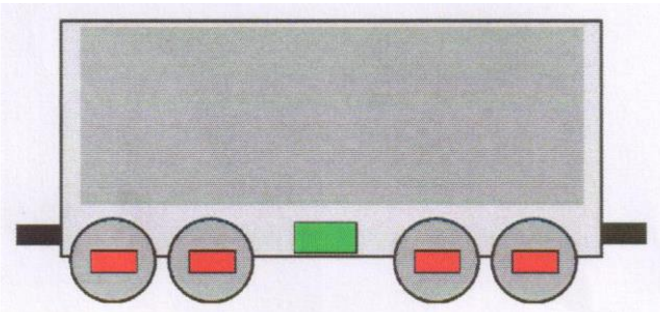

Fig. 8. Schematic of the transceiver unit in the locomotive

3. STATIC TESTING OF EXPOSED SYSTEM

Static testing of the system for continuously measuring the temperature of the heating of axle-bearings was carried out on wagons of the Wagon Factory Kraljevo, as shown in Figures 9 and 10. The sensor unit was placed on the bearing cover, and the axle assembly housing was heated by artificial means. The functionality and accuracy of the system were demonstrated and tests of the functioning of the constituent components were performed. It has been confirmed that the system is conceptually very well structured and that, after tests on the composition in motion, it can enter mass application on industrial and commercial railway lines.

Data from all transceiver units on the wagons via a wireless sensor network (Fig. 11) are grouped in the receiver unit, which is located in the locomotive. This unit collects data on the temperatures of the axle-box bearings, processes them and displays alarm conditions in case of exceeding critical values.

As the railway composition moves, it is necessary to match the operating frequencies of the wireless system with the frequencies on which the security services work. This is necessary so that there are no disruptions in the operation of the railway and security system.

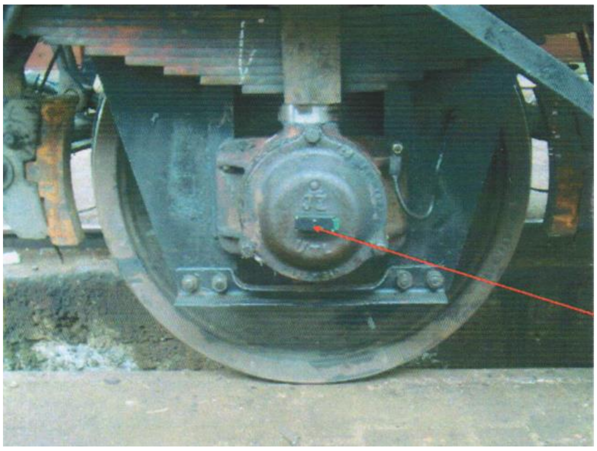

Fig. 9. Testing of transmitting sensor unit on axle-box bearing

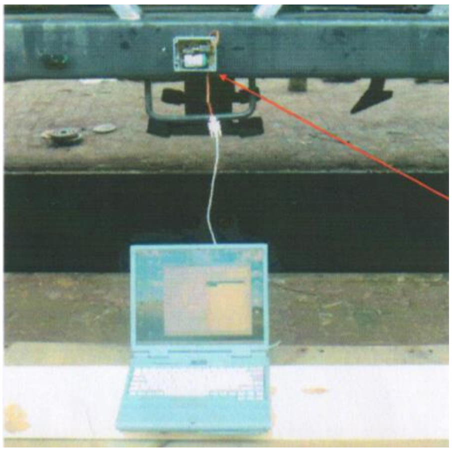

Fig. 10. Testing of transceiver sensor unit on one side of wagon

Fig. 11. Wireless sensor network

4. CONCLUSION

One of the most serious causes of derailments of railway vehicles is caused by overheating of axle-bearings of wheelsets. The largest number of existing prevention systems is based on the application of stationary measuring stations, i.e., wayside systems, placed at certain distances along the tracks. If the rise in the bearing temperature occurs very quickly, when the train is moving outside the measuring points, the stationary measuring stations cannot register the rise in the temperature of the axle bearings and some accidents cannot be avoided.

The wireless system for measuring the temperature in the axle-bearings of railway vehicles, presented in this work, allows the rise in temperature in the axle-bearings to be detected at a very early stage and to react in a timely manner in order to prevent accidents. It enables continuous monitoring and detection of temperature rise on each axle-bearing of the railway vehicle, as well as timely response in order to prevent accidents. It can be easily adapted for specific mass applications on industrial and commercial railway lines. In relation to stationary systems, these systems enable much safer railway traffic.

In further work, it is necessary to determine the critical value of the axle-bearing temperature, after which the system should indicate an alarming state. In addition, the system can be improved to measure vibrations and the impacts in the wheel-rail contact [15], to determine the GPS coordinates of the wagon, to measure the weight of the wagon [16] and to establish a GPRS connection of each railway composition with the central office. Until the final appearance on the market, the system remains to be tested in real conditions on a composition in motion.

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REFERENCES

[1] Eror S., Organization of railway traffic, Faculty of Traffic and Transport Engineering, Belgrade, 1988, in Serbian.
[2] Rakanović R., Petrović D., Šoškić Z., Simović T., Testing of mechanical structures, Faculty of Mechanical Engineering in Kraljevo, Kraljevo, 2006, in Serbian.
[3] Stamenković D., Maintenance of railway vehicles, Faculty of Mechanical Engineering Niš, Niš, 2011, in Serbian.
[4] Petrović D, Aleksandrov V., Railway Vehicles – Basics, Faculty of Mechanical and Civil Engineering in Kraljevo, Kraljevo, 2013, in Serbian.
[5] Atmadzhova D., On the method of determining safety criteria against rolling stock derailment, International scientific conference ''Science and Higher Education in Function of Sustainable Development – SED 2019'', Drvengrad, Serbia, May 24-25, 2019, College of Applied Sciences Užice, 2019.
[6] Atmadzhova D., Experimental determination of the "wheel-rail" contact forces of railway vehicles, Annual University Scientific Conference 27-28 May 2019, "Vasil Levski" National Military University, Veliko Turnovo, 2019.
[7] Nenov N., Dimitrov E., Vasilev V., Nikolov V., Examination of the Signal Recorded by Micro Sensor System for Detecting Damages on Rail Vehicle Undercarriage, 35th International Spring Seminar on Electronics Technology "Power Electronics", May 9-13, 2012, Bad Aussee, Austria, 2012.
[8] Atmadzhova D., Sensor for Measuring Horizontal Lateral Force of Railway Vehicle Wheelsets, Annual University Scientific Conference 27-28 May 2019, "Vasil Levski" National Military University, Veliko Turnovo, 2019.
[9] Job R., Railway bearings: an investigation of causes of hot boxes in railway service, and methods for their prevention, Journal of the Franklin Institute, Volume 149, Issue 6, pp. 439–448, IN1, IN3, 449–450, 2003.
[10] Gerdun V., Sedmak T., Sinkovec V., Kovse I., Cene B., Failures of bearings and axles in railway freight wagons, Engineering Failure Analysis, 14, pp. 884–894, 2007.
[11] Schöbel A., Pisek M., Karner J., Hot box detection systems as a part of automated train observation in Austria, http://publik.tuwien.ac.at/files/pub-bi_5916.pdf
[12] Bepperling S.L., Schöbel A., Estimation of Safety Requirements for Wayside Hot Box Detection Systems, FORMS/FORMAT 2010, Part 2, pp. 135-143, doi: 10.1007/978-3-642-14261-1_14, 2011.
[13] Hot box and hot wheel detections system, Phoenix MB, voestalpine, http://www.voestalpine.com/vae/en.html
[14] Bižić M., Tomić M., Đinović Z., Petrović D., Detection of failures of axle-bearings of railway vehicles, Tehnika 71(5), pp. 702-709, doi:10.5937/tehnika1605702B, 2016. in Serbian.
[14] UIC 518, Testing and approval of railway vehicles from the point of view of their dynamic behavior - Safety - Track fatigue - Running behavior.
[15] Report 11/04, Testing of reconstructed three-axle double-decker wagon DDam for transporting passenger cars, Faculty of Mechanical Engineering in Kraljevo, Kraljevo, 2004, in Serbian.