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DETECTION OF OVERHEATING IN AXLE-BOXES OF RAILWAY VEHICLES

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Abstract *– The consequence of axle-bearing failure in railway vehicles is regularly derailment with huge material damage and often with human casualties. Because of the very serious consequences, railway aims to introduce appropriate techniques for early detection of overheating of axle-bearings or more precisely axle-boxes. The commonly used technique is based on application of stationary measurement stations or so called checkpoints. There is also an innovative technique based on the use of systems for on-line monitoring of axle-boxes temperature. The task of this paper was to explore these techniques in order to provide a critical analysis and guidelines for further development in this area. The main conclusions are that the technique of checkpoints has limited effectiveness in case when temperature increases rapidly, and that technique of on-line monitoring is far more efficient because it allows an immediate response in order to prevent derailment and accident.*

Keywords - Detection, overheating, axle-boxes, railway, wagons.

1. INTRODUCTION

The basic requirement that is seeking from the railway is to be reliable, efficient, and cost-effective compared to the other modes of transport. The main prerequisite for meeting these requirements is continuous and quality maintenance of railway vehicles and railway infrastructure [1]. The failures on railway does not happen often, but when it happens, the consequence is usually derailment accompanied with enormous material damage and loss of human life. In addition, there are a huge material losses caused by the interruption of the traffic and reparation of the infrastructure.

One of the most common causes of derailments is the failure of the axle-bearing [2–4]. It leads to the failure of the wheelset, which may cause derailment not only the one wagon but also the whole train. The consequences are regularly with huge material damage and often with human casualties. From that reason the railway pays special attention to this problem. It aims to introduce the appropriate techniques for early detection of overheating of axle-boxes. The main task is timely detection of defects in bearings and prevention of derailment and accident. The commonly used technique is based on application of stationary measurement stations or so called checkpoints, placed at certain points along the rail [5–10]. The checkpoints are usually equipped with the special sensors whose role is to detect an overheating in axle-boxes during the train passing above them. There is also an innovative technique based on the use of systems for continuous (on-line) monitoring of axle-boxes temperature. The task of this paper was to explore these techniques in order to provide a critical analysis and guidelines for further development in this area.

2. CAUSES AND CONSEQUENCES OF AXLE-BEARING FAILURE

The most responsible parts of any running gear of

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railway vehicles are not only the wheelsets, but also the elements for their connection on the bogie framework, called axle-bearings. In the process of exploitation of vehicles they are among the most loaded parts and their reliability directly influences on the reliability of the entire train. In practice there are many types of design of axle-bearing, but all they are based on the similar concept. All different types of axle-bearing must meet the requirements of international regulations and recommendations UIC, EN, ERRI, etc. Functionality of the assembly of axle-bearing depends of the correctness of the every its part. In practice this assembly is sealed and can be opened only with the presence of the authorized person. Its inspection and maintenance are also defined by the international regulations UIC, railway regulations, and instructions of individual manufacturer.

Causes of axle-bearings failures are very various. Some of them are: defects in material, errors in manufacturing (during the minting, pressure, hardening, cracks formed during grinding, errors in tolerances), incorrect assembly or installation of the bearing, incorrectly lubrication (lack of lubricant, too much lubricant, or inadequately lubricant), passage of current, the effect of moisture, mechanical impurities, etc [2]. The main characteristic of any defect is that it causes changes in performance and an increase in axle-bearing temperature. In many cases the final consequence is derailment, not only that wagon, but also entire train. This occurrence is very common, especially characteristic for the freight wagons used in extreme operating conditions such is for example transport of coal in thermal power plants. Figures 1 and 2 show the consequences of axle-bearing failure of one wheelset of wagon for coal transportation from Kolubara to the thermal power plant "Nikola Tesla" Obrenovac, Serbia.

Fig.1. Derailment caused by the axle-bearing failure

Fig.2. Typical damage of the axle and track

The accident occurred in 1995. in station Stubline. The direct consequence of this derailment was a huge material damage on wagons and infrastructure. However, much more serious were the indirect effects such as delay of rail transport of coal and threat of supplying of thermal power plant, and thus its normal functioning.

There are many such examples in technical practice. From the previous it can be seen how important is the proper functioning the axle-bearings and what consequences may result after its breakdown.

3. DETECTION OF OVERHEATING

Because of very serious consequences, railway is introduced a certain techniques for early detection of overheating of axle-bearings or more precisely axle-boxes. The main task is timely detection of defects in bearings and prevention of derailment. The most commonly used techniques are based on the application of stationary measurement stations or so called checkpoints. There are also a modern techniques that are based on the use of systems for on-line monitoring of axle-boxes temperatures.

3.1. The checkpoints for detection of axle-boxes overheating

The wide use of stationary measuring stations or checkpoints is started in the last twenty years on many world railways. In addition to axle-boxes overheating detection, the modern checkpoints simultaneously detect the overheating of the wheels, brake discs, dimensions of the vehicle, lateral movements, axle loads, flat seats on the wheels, noise, impacts, etc. This technique is based on the installation of a certain number of checkpoints at the certain mutual distances along the railway line. The main problem in design of contemporary checkpoints when it comes to detection of axle-boxes overheating is how to provide a high-speed measurement. Overheating of axle-boxes has to be detected even at the highest speeds of the train that goes up to *200 km/h*. For example, if train is moving at a speed of *200 km/h*, axle-box which is about *220 mm* width will pass a fixed point on the track for approximately *0.004 sec* or *4.0 msec*. Therefore, in this case the duration of measurement must be maximal *4 msec*, and obtaining the temperature state of axle-box is very complex problem. In contemporary solutions of checkpoints for detection of overheating of axle-boxes the infrared temperature detectors are used. They allow obtaining the adequate temperature profile of axle-boxes on each wagon in moment of train passing. Some of modern solutions allow detecting overheating even when the train speed is up to *500 km/h*. One of the most important problems in use the technique with the checkpoints is how to determine the distance between two checkpoints. That calculation is based on the risk-analysis where the speed of increase of the temperature is takes into account. In most axle-bearings normal operating temperature is *55-60°C*, and alarms from checkpoints will be started if temperature of axle-boxes is about *80-90°C*. The question is how fast the temperature increases if there is some defect in axle-bearing. Overheating may be to the certain temperature which is not dangerous for the normal function of the bearing, but it creates disorder of bearing performance and after a certain period of time may leads to the failure. On the other side, the overheating can be very rapid, while the temperature increases to the critical value for only *30-60 sec*, and the failure is coming very soon. If overheating occurs per second scenario, on the section of the track between two checkpoint, it is very debatable whether in this case the checkpoints will be able to detect overheating, or derailment may occur even on the so-equipped track. Accordingly, the question is, will the temperature rise be detected before bearing failure and occurrence of derailment.

In accordance with the previous observations a simple model of system of checkpoints along the one railway line is analyzed. Checkpoints are located at the mutual distances of 3 to 15 kilometers as shown in Fig. 3. The similar system of trains observation is used on the Austrian railways OBB [5].

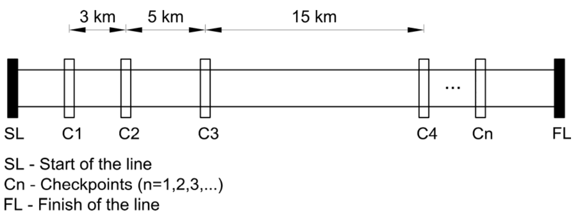

Fig.3. The system of checkpoints along the one railway line

The motion of one wagon or more precisely one wheelset between two checkpoints at a distance *L* was analyzed, where the train speed is *V*.

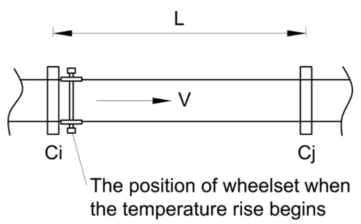

Fig.4. The analysis of overheating on one wheelset between two checkpoints

Also, it was assumed that an increase in temperature occurs immediately after the passage of observed wagon (wheelset) through the first checkpoint *Ci* (Fig. 4). This critical case means a maximum time for axle-box temperature increasing, until passing through the next checkpoint *Cj*, when this increase can be detected. The time that elapses from the moment of passing through the first checkpoint *Ci* until the moment of passing through the second checkpoint *Cj* is $t=L/V$. Table 2 gives the comparative review of time *t* for different combination of distance between checkpoints *L* and train speed *V*.

Table 2. The comparative review of time t for different combination of L and V

CASE	*L* [km]	*V* [km/h]	*t* [sec]
A1	3	160	67.5
A2	3	200	54
B1	5	160	112.5
B2	5	200	90
B3	10	160	225
B4	10	200	180
C5	15	160	337.5
C6	15	200	270

From Table 2 it can be seen that the observed wagon the distance between two checkpoints, at best case A2, passing for *54 sec*, while the train speed is *200 km/h* and distance between checkpoints is *3 km*. Based on data from Table 2 it can be noted that scenario of temperature increasing for *60 sec* to the critical value, can be eventually detected in case A2, where the time to reach the following checkpoint is less and equal to *54 sec*. In addition, when take into account the speed of reaction and stopping the train, it is very debatable whether in this case accident may be avoided. If, for example an increase in temperature occurs in the middle of the distance between two checkpoints *Ci* and *Cj*, and reach the critical value for *60 sec*, in that case the overheating can be detected at the $V=200$ *km/h* and $L=3$ *km*. For the same situation, if the distance between checkpoints is $L=10$ *km*, the overheating can not be detected before the failure.

Thus, the checkpoints can give some results and can detect overheating in some cases. However, all is based on randomness and a combination of particular circumstances. Despite the large investment of funds in the installation of checkpoints, quite a high risk of their inefficiency is always there. This is confirmed by the technical practice which shows that despite the implementation of a modern checkpoints, some derailments did not avoided.

3.2. On-line monitoring of axle-boxes temperature

Because of limited efficiency of checkpoints, in recent years there is a need to develop techniques that enable continuous (on-line) monitoring of axle-boxes temperature. This technique involves continuous monitoring of temperature of each axle-box of each wagon in the train. This means that every axle-box of every wagon in the train must be equipped with the special sensor unit for temperature monitoring. For example, one four-axled wagon must be equipped with the eight sensor units, as shown in Fig. 5. If the train is composed, for example, of 100 wagons, the number of sensor units would be 800.

Fig.5. The sensor units for on-line monitoring of axle-boxes temperature of one four-axled wagon

The main problems of this technique are transmission of data and power supplying of sensor units. Usually the problem of data transmission can be solved by using the wireless network connection. This is the most suitable solution because of large number of sensor units. In that case, the one sensor unit must be equipped with the box, sensor, antenna, radio transceiver, central processing unit, and power supply. The data from all sensor units must be collected in one receiving unit and must be processed in real time. This receiving unit should be placed into the locomotive. Its task is to collects data on the temperatures of all axle-boxes, processes them in accordance with the appropriate algorithm, and displays an alarm in case of exceeding the normal values. In the case of temperature increase in any axle-box, engine driver is immediately alerted and can react to stop the train. Therefore, this technique allows a timely response in order to prevent derailment and accident. Its importance is especially pronounced when takes into account the continuous trends for increasing of trains operating speed and increasing the safety and security on the railway.

4. CONCLUSION

The failures of axle-bearings are among the most dominant causes of derailment, especially in railway vehicles that are used in extreme working conditions. The commonly used prevention technique is based on application of stationary measurement stations – checkpoints placed at certain points along the rail. They are equipped with special infrared sensors whose role is to detect an overheating in axle-boxes during the train passing. Checkpoints can give some results and can detect overheating in some cases, especially when the temperature rise is slower. However, all is based on randomness and a combination of particular circumstances. Despite the large investment of funds in the installation of checkpoints, quite a high risk of their inefficiency is always there. This is confirmed by the technical practice which shows that despite the implementation of a modern checkpoints, some derailments did not avoided. There is also an innovative technique based on the use of systems for on-line monitoring. It involves continuous monitoring of temperature of each axle-box of each wagon in the train. In the case of temperature increase in any axle-box, engine driver is immediately alerted and can react to stop the train. This technique allows a timely response in order to prevent derailment and accident. Therefore, its efficiency is far greater than the effectiveness of technique with checkpoints. By proper engineering solutions of data transmissions and power supplying of sensor units, this technique can be customized for the specific mass use in industrial and commercial rail lines. Of course, before the widespread use a detailed testing of the system in exploitation conditions should be done. When it comes to techno-economic feasibility of introducing a systems for on-line monitoring, it should be taken into account that detection of every overheating prevents derailment with huge material damage and human casualties.

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