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Road and Rail Infrastructure II

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DEMAND FOR WAYSIDE TRAIN MONITORING SYSTEMS IN THE NETWORK OF SLOVENIAN RAILWAYS

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Abstract

The Ministry of Transport, Railways and Cableways Directorate, Sector for Investment and Upgrading engaged the Vienna University of Technology, Institute of Transportation, Research Centre for Railway Engineering to carry out two studies on the demand of wayside train monitoring systems in the network of Slovenian Railways (SZ). One is covering the requirements for weighting systems and flat wheel detection (so called axle load checkpoints) and the other one for hot box detection systems. This article contains the results for both studies. It deals with the demand analysis based upon the accident data base of Slovenian Railways (SZ) under consideration of the defined protection goal. The technical requirements for the sensor systems are also listed. The choice of location is done by an analysis of risky elements in the network of Slovenian Railways (SZ). Finally it gives an outlook on recommendations for the practical implementation.

Keywords: wayside train monitoring systems, hot box detection, axle load checkpoints, risk analysis

1 Introduction

The following fault states in railway operation [2] were previously defined by the ministry of transport and had to be considered in this work:

- Faulty brakes: Due to failures in the control value of the pneumatically driven brake system, the brake shoes or blocks of an axle may not be released. In the majority of cases, the friction is not big enough to block the whole axle. Hence, there will be a continuous heating of the brake discs (for disc brake systems) or of the wheel (for block brake systems). Moreover, the blocked brakes can cause fires in the bogie construction due to sparks. These sparks can also enkindle vegetation besides railway lines. In the residual cases of massive friction the axle won't rotate and will sliding on the rails.
- Faulty box: As the result of missing lubrication or of mechanical damage of parts of an axle bearing, the increased friction heats the bearing during the drive. Hence, a good and proven indicator for damaged bearing is the temperature of the box itself.
- Flat wheel: The term defects describe many different irregularities, which can occur on the running surface of a wheel. For instance, flat spots are flattenings of the round wheel, whereas reweldings are similar to little metal bumps. Beside there are out–of–roundnesses, and material eruptions. All lead to short force peaks with increased amplitudes during the run of the train and effect additional stress in the rail and in the wheel. Thus, such wheels can damage the rail and should therefore be rejected.
- Overload: If the load of the wagon is too heavy, all underlying components of the wagon (body, bogie, axles, wheels and the rails) are overstrained. This overloading state results in increased wear and should be prevented.

- Axle breakage: There can be two types of broken axles identified. A cold axle breakage is influenced by metallurgic reasons (material defects, etc.). In contrast to the cold type, if there is a massive heat exposure, the properties of the material can be affected negatively (warm axle breakage). In combination with high mechanical stress, such a weakened axle can break and the guidance property, which is obligatory for rail–bound traffic, is lost.
- Displaced or unbalanced cargo (left/right, back/front): If cargo is not fixed correctly, the load can be displaced during the run of the train. Similar can happen, if the condition of the fixing material is bad and thus, the fastener can disrupt. Moreover some cargo car might be unbalanced due to wrong placement of cargo in the car.

2 Demand Analysis

Generally the estimation of risk is a difficult task because an accident data base only provides indicators. Dangerous situations in operation which did not lead to an accident are normally not stored in an accident data base, although these situations are important for the risk estimation. To compensate this missing information the judgement of operational experts is very important. Of course, the first task is always to have a closer look on the accident data base if there are reliable values available for the risk estimation. Therefore it is necessary to know details about the history of an accident. Sometimes a predefined categorisation is not suitable for a specific accident. On the other hand the accident data base gives a first indicator for the potential risk. The specific view on the accident data base is given by the aspect if it is possible to recognise one fault state by some wayside monitoring system. So the fault states which are in the focus of such an analysis must be car related and appear for a certain time to be measured by some equipment [4].
The calibrated risk matrix can be used to put in the car related fault states which may destroy the infrastructure of the infrastructure manager. Therefore it is necessary to check if all well known fault states are considered. For each fault state an analysis based upon the national accident data base was carried out to estimate the risk caused by each fault state for the infrastructure manager. The result of the workshop was a filled out risk matrix for Slovenian Railways which shows the specific demand for wayside train monitoring on their network.
Risk is always defined as a product of probability and severity. For practical work with the term of risk a common understanding is necessary. Moreover a suitable layout has to be chosen. The European standard EN 50126 [3] offers the possibility to deal with different risks by usage of a risk matrix. The layout of a matrix provides the possibility to deal with different risks coming from different car related fault states in railway operation. The usage of the risk matrix in signalling issues is state–of–the–art. For the operational application the qualitative descriptions of probability and severity must be quantified. The calibrated matrix must cover the range of operational scope.

Weekly	0,48	4,8	48,0	480,0
Monthly	0,12	1,2	12,0	120,0
Quarterly	0,04	0,4	4,0	40,0
Annually	0,01	0,1	1,0	10,0
Once in 10 years	0,001	0,01	0,1	1,0
Once in 100 years	0,0001	0,001	0,01	0,1
	10.000 €	**100.000 €**	**1.000.000 €**	**10.000.000 €**

Figure 1 Risk matrix for demand analysis for Slovenian Railways in Mio. €/a

3 Requirements

Due to the field of application, both sensor systems have to comply with several general requirements:

· Operating conditions: all outdoor parts of the system has to be designed for operation with an extended temperature range of -40 to +85°C and for dealing with further varying climatic conditions (humidity, dust, etc.).
· Power supply: the systems have to be able to operate with common power supply of Slovenia (230V/50Hz).
· Varying measurement objects: as mentioned in chapter 1, both sensor systems have to detect fault states reliable independent of vehicle type (freight and passenger cars) and of the direction of train drive.
· Maximum speed of the passing vehicles: the systems must not claim on braking to specific passing speed of the vehicles. Thus all trains have to be allowed to drive up to the specified track speeds (up to 250km/h on high speed tracks).

Minimum speed of passing vehicles: due to the need of recognizable peaks of dynamic forces for flat spot detection, axle load checkpoints require a minimum passing speed of 30km/h. In contrast, the measurement principle of hot box or hot brake detection allows temperature measurement even at very low speeds. But they need a minimum average speed before passing the measurement site for friction–based warming of defect bearings or of parts of the brake system. Without sufficient friction, defects systems won't be able to recognise these fault states. Thus, the requirement on the minimum passing speed of hot box and hot brake detection for measurement can be reduced to 5km/h, whereas the minimum average speed before measuring has to be significant higher (recommendation: normal driving speed of vehicles on the following track section).

3.1 Hot Box Detector and Hot Wheel Detector

The measurement system has to monitor all kind of passing vehicles. As a consequence, the hot box detection has to deal with varying types of axle bearings. For correct interpretation of the bearing condition, the system has to provide a reliable temperature acquisition, regardless of the bearing type. The past has shown that due to their construction especially a temperature measurement of bearings on RoLa (intermodal transport) and on freight cars with the widely–used Y25 bogies or with 'Schlieren' type bogies are a challenge for several systems. The crucial factor to gain all–purpose hot box detection is the arrangement of the sensors in the measurement cross–section relative to the bearings. Thus, systems on the market vary in this point, whereas two general approaches can be identified [1]:

· Single–beam sensors (one sensor with one beam)
· Multi–beam sensors (one sensor with several beams)
· Multi sensor with single–beam (several sensors with single–beams)

The first and second category of hot box detection systems enable measuring only in radial direction from the installation position of the infrared sensor. The third category by contrast allows arranging the sensors on different positions and measuring with arbitrary angles. The only indication of an advantage of such an arrangement for detection of hot boxes on Y25 bogies may be concluded from a typical multibeam scanning configuration. Here, the multibeam is not able to detect the inner ranges of such a bearing construction, whereas dual beam systems with an appropriate sensors arrangement may have this ability. However, there is no serious information available about the reliability of these approaches for which reason verifiable experiences of such systems become more importance. Only the first category does not comply with the state of the art and can be excluded from these considerations.
In general, all brake components of an axle are controlled by an only one common valve. Due to the fact, that stuck brakes results almost always from defects of such control valves, the

temperature of both wheels or of all brake discs will raise similarly. Thus, for hot wheel and for hot brake disc detection only two infrared sensors are sufficient for reliable fault state recognition. The arrangement of sensors has to ensure the reliable temperature acquisition of different wheel diameters and different brake disc configurations. Moreover, sensor arrangements which imply measuring mat surfaces should be preferred, because metallic bright structures lead to low infrared radiation and thus to faulty temperature results.

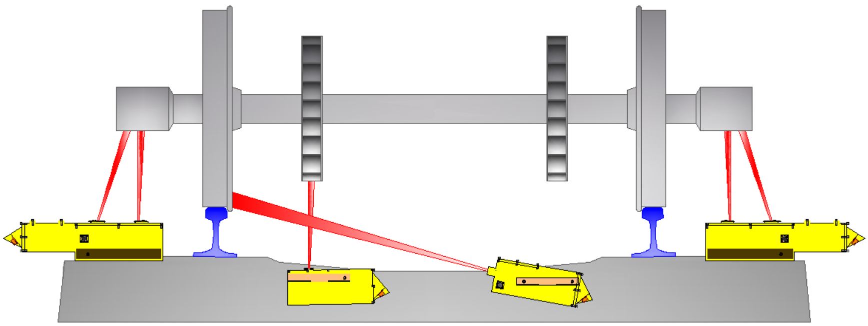

Figure 2 Measurement geometry of Hot Box Detector TK99 [5]

3.2 Weighting Systems with Flat Wheel Detection Function (Axle Load Checkpoints)

Axle load checkpoints measure forces, which are exerted by the vehicles wheels on the rails. In general, this contact–based measurements use either the bending characteristic of the rail between the sleepers or load cells between rails and sleepers to determine the wheel loads. Also a combination of these approaches is sometimes applied. Thereby following aspects have to be considered:

- Type of sensors: the sensors for acquisition of the elastic deformation (of the rail or of the weighing element within the load cells) have to be robust against the harsh environmental conditions (climate changes, electromagnetic fields, etc.). Because resistance strain gauges fulfil these requirements, they have prevailed in the field of wayside axle load measurements. Other systems also use laser technology for measuring the bending of rails, but the practical application was not satisfying customer requirements so far. For instance, in Switzerland SBB tested several axle load checkpoints from different suppliers. Finally they decided to build up their own system based upon strain gauges.
- Length of measurement section: for reliable detection of fault states regarding the running surface of wheels, always the whole wheel circumferences have to be examined. Thus, the measurement section has to cover at least one complete circumference of the largest diameter of the expected vehicle wheels (common wheel diameters are not larger as 1m, which yields minimum sections of approximately 3,2m). A further increase of the measurement section length often allows more extensive averaging of the measurement data, which may lower the influence of dynamic effects and which may reduce measurement errors of axle loads and of the running surface faults. Thus, many systems feature a section length of 8m and beyond.

4 Choice of Location

Wayside measures cannot be located at every place where once an accident occurred or will possibly happen. After an event has occurred, it is quite simple to design the optimal position for detection and minimising loss in this specific case. But this empirical method will not fulfil economic boundary conditions.

Generally there are two different points of view, the line–oriented and the network–oriented. The line–oriented view allows the calculation of the nearest position to have enough time for stopping a train at a predefined position for further investigation. For the specification of these points where the train has to stop the network–oriented view is helpful. So there is the requirement to define all risky elements in a railway network which should not be passed by a train with irregularities. Furthermore the combination of measures depends on the strategy of an infrastructure manager, which can be described as a mix of event–avoiding systems and damage–reducing components.
With regard to their future locations, there are two fundamental concepts:
1 Whenever traditional train supervision is to be replaced, a technical equivalent has to be installed.
2 The number of locations and/or systems necessary for conducting train supervision can be optimised provided that they are based on cost–benefit considerations. In this case, the number of locations should be lower.
Due to economic reasons only the second approach is practically relevant and will be discussed in the following section.
The process in case of a detected fault on a train has to be carefully planned before going into operation. For vehicle–side detection the data transmission to an operation control centre of an infrastructure manager has to be specified. Wayside systems are exclusively the responsibility of an infrastructure manager for the planning of locations until the operational handover.
Modern signal box technology enables the integration of the monitoring system. This allows an automatic stop of trains with strong irregularities, whereby the classification of these fault conditions must be done by the infrastructure manager (e.g. an already derailed axle on a train leads to a stop at the next mandatory signal). Basically it can be distinguished between warning and alarm: A warning indicates only an overstepping of threshold value that can lead to a dangerous situation (e. g. overweight of one vehicle, warm box). In case of an alarm there has to be an immediate reaction because of an already existing hazard (e. g. hot box, derailed axle). Thus, only highly reliable, available and accurate technical solution will be integrated into operations control because otherwise the reliability of operation would be reduced dramatically. The local position in the railway system is defined according to the last stopping position ahead of a risky element of infrastructure.
Taking the time behaviour of an integrated sensor system into account, the local position can be calculated in the following way: Starting from the mandatory signal (or stopping point) the nearest location of each sensor component can be found in consideration of the allowed speed limit, the sight on the distant signal and the response time of the sensor component.

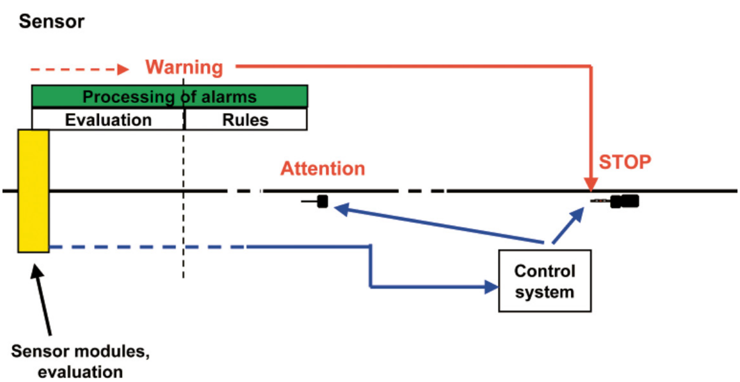

Figure 3 Calculation of position according to a predefined stopping point

The choice of location for wayside train monitoring is depending on the elements of infrastructure which are to be protected from hazard situations. Therefore it is necessary to define risky elements in a railway network. In accordance with the call for tenders only three categories of risky elements had to be identified in the network of Slovenian Railways:

- Gradient: a) > 15 ‰; b) 10–15 ‰
- Tunnel (longer than 1 km)
- Network entry

5 Outlook

Finally this article shall give some recommendations for the next steps in the implementation of wayside train monitoring systems in the network of Slovenian Railways. Besides the price for purchase the life cycle costs (LCC) should be considered. Therefore the devices should allow a condition based maintenance. Moreover the availability of the devices should be high to achieve operational acceptance by station inspectors and drivers. Of course, the validation rate of alarms and warning must be close to 100 %. This requires also the development of an operational procedure with predefined responsibilities for the handling of alarms and warnings. For every alarm or warning the result of the inspection by the responsible staff must be documented for statistical reasons. Based upon previous experience a prototype installation of a hot box detection system and a dynamic weighting (inc. flat wheel indication) in the network of Slovenian Railways is suggested. After a successful trial period a tender should be prepared to cover all risky elements in the network by wayside train monitoring systems.

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