Wayside Dynamic Weighing and Flat Spot Detection at Austrian Railways

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Abstract: The introduction of the new ÖBB management operation system has to result in an increase in reliability and quality. At the same time, operational costs are to be reduced. These goals can only be achieved by concentrating the responsible staff on a few locations. Consequently, the traditional train supervision has to be replaced by a technical solution, the so-called Checkpoints. Checkpoints can be defined as trackside locations where trains are examined to detect any deviation from nominal condition. In February 2003, the project "Checkpoint systems and their integration into solid state interlockings for automatic train supervision" was officially started. It is supported by the Austrian Federal Ministry of Transport, Innovation and Technology (bmvit). In autumn 2004, the Checkpoint prototype has gone into operation on the railway line between Vienna and the Austrian-Hungarian border where several different components for dynamic weighing and flat spot detection are installed.

Keywords: Checkpoint, Train supervision, Dynamic Weighing, Flat Spot Detection

1 Introduction

As a result of the ongoing reduction of station inspectors, the railway system has lost a decisive link of well-established organisational and technical processes. The consequences of this changes were mitigated against by the introduction of technical solutions. The new processes are subsequently less labour-intensive and more efficient. The role of the traditional train supervision is, however, a good example to demonstrate that technical solutions, currently available on the market, do not provide the whole solution.

Originally, station inspectors were not the only employees among those responsible for the operation of trains who had to deal with train supervision. Interlocking, block and/or level-crossing attendants had to monitor the condition of the rolling stock, too. The locations for this task had been defined alternately, thus enabling train supervision to be carried out on both sides of the track. The disappearance of mechanical signalling equipment led first to a reduction of posts for the supervision of trains. Technological progress resulted in a further acceleration of this trend. By introducing management operation systems, the network of posts to observe trains, which was initially very dense, was reduced again.

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Due to the gradual implementation of this strategy, aiming at a higher productivity, manual train supervision will not exist in the near future. Therefore, this task has to be taken over by technical systems.
Such systems enables checking train properties beyond the abilites of human train inspectors (e.g. inspect both sides of a train at the same time). Thus, their locations do not have to be set up according to the original locations for traditional train supervision. These advantages will result in a lower number of locations needed for automatic train supervision. In addition to that, the technical systems used for automatic train supervision are able to detect faulty conditions of the rolling-stock which can not be discovered even by well-trained station inspectors. Therefore, these technical systems are very important with regard to early accident identification and will bring about higher productivities, too.

2 Sensor Components

Checkpoints can be defined as trackside locations containing an accumulation of technical systems, which are required to enable the substitution of the traditional train supervision [1]. From today’s point of view, seven sensors are needed for this task. They can be divided into two groups: Damage-reducing and/or event-avoiding systems. For both groups, all environmental requirements have to be met taking into consideration that these systems will be passed by trains with a speed of up to 250 km/h. Even under harsh environmental conditions, these systems have to supply reliable information regarding the train state. In addition to that, all data collected must be processed in the shortest time possible by using appropriate tools for analysis.
Several dynamic scales are currently passing the transition phase from a prototype development to a series production. As a rule, these systems obtain the necessary data from strain gauges, which are mounted either on the rail or in the sleeper. Their distortion can be used for the calculation of the rolling-stock’s weight and/or the detection of displaced cargo. Moreover, certain dynamic scales can detect flat wheels and various other irregularities in the contact area of wheel and rail. Hot box detection systems, including an add-on for stuck and/or disc brake detection, were installed on a large proportion of the Austrian high-level network during the last few years. The system used can measure the temperatures of wheels, disc brakes and wheel bearings by means of infrared sensors. These installations are to be integrated into the Checkpoint concept, as well as already existing train gauge monitoring systems. Objects exceeding the train gauge profile are detected by optical measuring systems.

2.1 Fault States to Monitor by Dynamic Weighing

By using weighing sensor systems - available on the market - the following fault conditions with static character can be checked:

- One-sided loading
- Displacement of the load
- Flat spots
- Axle load, load per meter (overload)

For prevention a reasonable approach is to check trains at a location where many trains start or end. Mostly this happens in shunting yards near great junction stations. This kind of inspection can also be required at national boarders or the change of infrastructure operator. Furthermore there are some other hazards resulting from following rail car characteristics which can only be monitored with high technical and economic efforts but they are important to estimate the risk for a derailment of one vehicle:

- Buckling of vehicles
- Rolling of vehicles
- Torsional moment

- Instability
- Maximum load before track displaces sideways
- Wheel geometry

Additionally, during the run of one train the following rail car properties have to be monitored for safety reasons:

- Displaced cargos
- Flat spots
- Broken bearing surface
- Axle breakages

2.2 Functionality of Dynamic Weighing

The weight of the cargo is one of the most important values to be observed. Axle overload damages both the rolling stock and the rail. Load asymmetries (caused by skidding cargo) can lead to tilting of the whole wagon. Such effects must be recognized in time to carry out the necessary cargo rearrangements. Manual inspection of these effects is mostly not practicable due to the complexity of the examination (closed freight cars, etc.). Today's fully automatic scales perform these kinds of measurements effectively. But it has to be mentioned that there are considerable qualitative and functional differences among them which are also influencing the price. For instance, most of dynamic weighing systems are also in a position to detect flat spots by interpreting force vertex as an indicator for flat spots. Moreover some systems provide additional information to estimate further wheel characteristics. Generally the length of the measuring section depends onto the demands of the functionality and the achievable quality of the output. In view of free network access it is becoming more and more important for an infrastructure manager to check the wheel-rail-contact (loading, driving stability, out-of-roundness of wheels) of the trains running on a network. Using wayside equipment installed on transit tracks data, which is needed for the evaluation of every single vehicle, can be collected with respect to the mandatory regulations. The installation effort of weighing systems varies. Some need no special adaptation of the track and for others even parts of the superstructure has to be changed during the installation (sleepers, ballast bed). Most systems use strain gauges located on the web of the rail and/or at the base of rail [2]. Additionally or alternatively, the sleepers may be equipped with force measuring strain gauges.


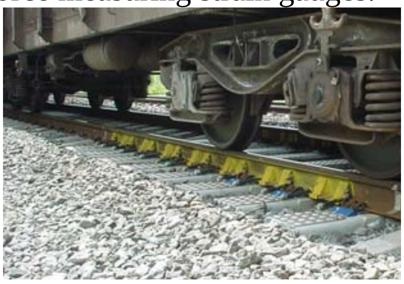


Figure 1 (left): Dynamic scale at the Checkpoint prototype. Manufacturer: SCHENCK PROCESS GmbH, Darmstadt (Germany).
Figure 2 (middle): Dynamic scale at the Checkpoint prototype. Manufacturer: Hottinger Baldwin Messtechnik GmbH, Vienna (Austria), on behalf of ÖBB Infrastruktur Bau AG, Vienna (Austria).
Figure 3 (right): Dynamic scale at the Checkpoint prototype. Manufacturer: ÖBB Infrastruktur Betrieb AG, Vienna (Austria)

Beside evaluation of wheel loads of the trains travelling at operating speed, the systems often acquire the whole dynamic condition of the wheel. Especially the flawless state of wheels is an important factor in rail traffic because rail surface is destroyed by unbalanced Y and Q forces. Equally to overload wheels, irregularities on the running surface lead also to damages at vehicles and stress the track and the rails excessively. Another aspect of flat spot detection is the acoustic emission because the noise factor gains importance more and more in European railways. For train observation by station inspectors the sound of running rail cars is also a criterion for recognition of flat spots. This mode of measurement by acoustics can also be realised in a technical way [3].

3 The Technical Checkpoint Concept

Hot box detections systems can be considered as the Checkpoints' ancestor. With regard to its technical implementation they vary in three essential issues from a full Checkpoint system for automatic train supervision.

1. The collected data is – lacking additional technical systems – not linked to the data of other sensor components.
2. Hot box detection systems are in fact connected to a central unit, but there is no sub-system supervising the evolution of temperatures over several Checkpoints.
3. Currently, an alarm is simply visualised on the so-called operational level. The necessary actions have to be taken by the station inspector manually. By strictly following given instructions, it might be possible that considerable delays will arise. They can be avoided by automatically forwarding alarms to control systems and/or solid state interlockings.

The technical Checkpoint project takes into consideration all three of the above-mentioned issues.

3.1 Conjunction of Sensor Data

Each sensor system is used for the supervision of one or several train conditions. The significance of a single measurement can be increased by the conjunction of collected data. The average temperature of an intact wheel bearing is, for instance, related to the wheel load. In case the wheel load is high, a higher average temperature of the bearing and/or a faster increase of it have to be assumed. To avoid misjudgements of the actual bearing's condition, this physical correlation can be shown by calculating and evaluating a weight-compensated bearing's temperature. This means that stricter limits will be applied to bearings with low wheel loads. Consequently, the contrary will be carried out if the wheel load is high.

The core of each Checkpoint is the so-called data concentrator. A dedicated software package is available for the above-mentioned functionality. Data, which are transmitted from sensor components to the data concentrator after passage of a train, are converted into a uniform format. If necessary, additional sensor and/or environmental information are added. In doing so, abstract data objects are generated. Together with positioning data, they are displayed onto the train model, which serves as the basis for data conjunction. Then the results are compared with rules. In case a threshold is exceeded, actions defined by the infrastructure operator have to be set. The range of alternatives comprises a short message to the owner of the rolling stock, but also a signal showing a stop indication. This step can only be executed by means of the control system and/or the solid state interlocking. Assuming that a single sensor registers the exceeding of a threshold, the whole procedure will then be shortened. In this case, immediate measures are initiated.

3.2 Networked Checkpoints

In contrast to solid state interlockings, all sensor components mentioned in section 2 do not achieve the necessary reliability values. This shortcoming can be compensated by redundant or diverse measurements. An increase in data quality and an early detection of faulty conditions can be achieved by networking the various Checkpoints, too. In this case, all data concentrators are directly linked to the Checkpoint centre. There, important data of trains are analysed and stored whereas current and already finalised train routes are distinguished. The advantages of networked Checkpoints are obvious.

1. The technical Checkpoint concept is highly modular. Based on cost-benefit-considerations, the range of sensor components can vary from one Checkpoint location to another. Therefore, new or additional sensors can easily be integrated into the already existing structure. The same applies to data of virtual sensors. Assuming that Checkpoint B has no dynamic scale, data, which was collected at Checkpoint A, can be transmitted to the data concentrator of Checkpoint B via the Checkpoint centre. At Checkpoint B, this data can be used for conjunctions, too. This feature is limited to values, which are subject to no or not more than small changes, only (e. g. the weight of the rolling-stock).

2. Trend analysis is another feature of networked Checkpoints. On the one hand, critical situations can be detected at an early stage. This target can be achieved by supervising the evolution of important measured characteristics of a train while passing the infrastructure's network. On the other hand, these analyses enable a check to be made of the plausibility of data by comparing single measurements with the appropriate series.

3. In contrast to decentralised single systems, networked Checkpoints have a big advantage. The status of all data concentrators and their connected sensor components is permanently supervised. In case of troubles and/or failures, short messages are generated and automatically sent from the Checkpoint centre to the central trouble management system. The latter is responsible for arranging and managing all measures, which are required for the removal of the problems.

4. There are various other reasons for justifying networked Checkpoints. Software updates and the use of the collected data for the calculation of track access charges are considered to be another two important examples but they will not be discussed in this paper.

3.3 The Integration Into The Control System And/Or Solid State Interlockings

When finalising the introduction of management operation systems and using sensor components for the supervision of rolling-stock, a small number of station inspectors will be responsible for a relatively large number of data concentrators. The idea of visualising alarms via the control system is rejected by the infrastructure operator. During peak time, it might be possible that the necessary measures cannot be initiated on time. Therefore, the integration of Checkpoints into the control system and/or solid state interlockings is a very important goal.

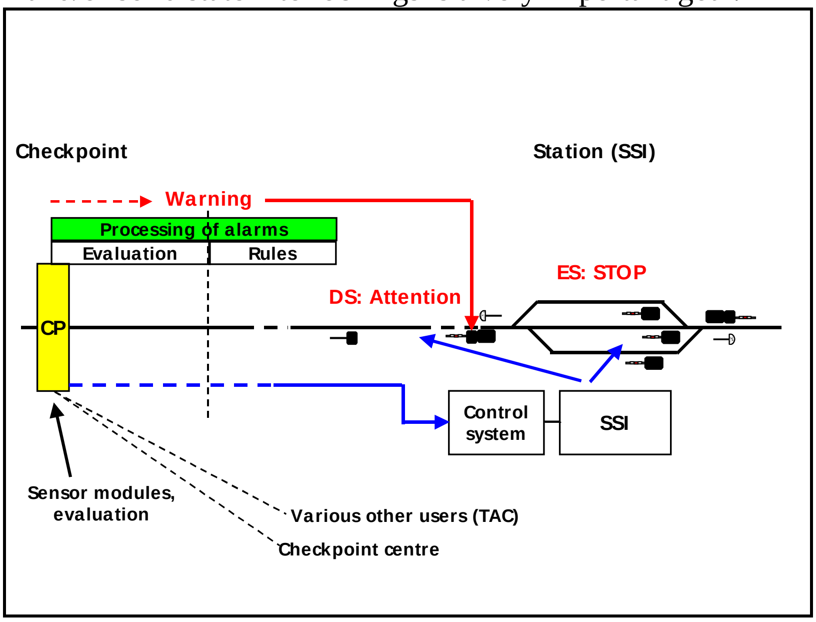

Figure 4: Technical Checkpoint concept: Integration into the control system and/or into solid state interlocking

Alarms requiring rapid intervention are transmitted from the data concentrator directly to the control system. In certain cases, these alarms can prevent the automatic continuation of the route setting. After the train has stopped, the station inspector will decide on the measures to be taken. Given that the train gauge has been exceeded, this procedure applies to possible oncoming trains, too.
All used sensor components have to meet the requirements set by the infrastructure operator. This is a prerequisite for a successful integration of Checkpoints into the control system and/or into solid state interlockings. Problems with railway operators have to be expected in case the number of failures is too high or alarms not being registered correctly lead to accidents. Events like these will result in a critical analysis of the investment. Therefore, as a first step, all alarms are to be displayed on the operational level. The development of the data concentrator is clearly orientated to the integration of Checkpoints into the control system and/or into solid state interlocking. This target is to be achieved as a second step.

4 Conclusions

Comparing Checkpoint systems with traditional train supervision, the technical solution provides a number of benefits.
1. In contrast to all employees involved in train supervision, sensor systems are able to check both sides of the train at the same time.
2. As result of their functionality, Checkpoints do not have to be set up according to the original locations for traditional train supervision.
3. Certain sensors used in the project are able to detect faulty conditions of the rolling-stock which cannot be discovered even by well-trained station inspectors.
As a result of this perspective, Checkpoint systems are urgently required by infrastructure operators. There is no doubt about it that they will form an integral part of a modern railway infrastructure in the foreseeable future. In Europe, the first invitations to tender, in which Checkpoint systems have to be quoted, are expected to arrive in the next few months.

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