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Train Location Detection Methods used in the Czech Republic

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***Abstract*—The objective of the paper is to acquaint the readers with the systems and technical devices for detection and tracking the position of trains including the detailed description of the devices that are used in the Czech rail network most frequently. The paper also presents some intelligent transport systems and telematics applications that are often used by these devices for their proper functioning. The final part of the paper summarizes pros and cons of the application of some of the detection and train position tracking devices and the possibilities of their further development are outlined.**

***Keywords*—axle counters, detecting train position, eurobalise, track circuits, magnetic information balise**

I. Introduction

Detection of train position is applied especially in the context of increasing demand for rail transport safety and increasing the capacity of the railway infrastructure. Currently, for train detection almost exclusively automatic or semiautomatic devices are used, which are further classified into point and line depending on their technical design and function. In the Czech Republic, there are four basic methods for detecting the position of trains – it is detection using so-called axle counter, track circuits, eurobalises and magnetic information balise (MIB).

The following part describes individual methods for detecting the train position used in the Czech and Slovak rail network, including a brief characteristic of the pros and cons of their practical application [1].

II. Axle Counters

Axle counter is a device that is used to detect the railway vehicles in a specific section using point elements, that is, wheel detectors [2]. This is thus a point detection device for detecting train position. Axle counter is made up of inner and outer parts. The outer part consists of the above mentioned wheel detectors, the inner part consists of a device which, based on the information from the outer part, evaluates whether a track vehicle is or is not in the given section of the track.

A. *Principle of Functioning*

At the start and the end of each monitored section of a track, there is a pair of wheel detectors that serve to detect the axles entering or exiting this section. The detectors must be placed in pairs so that besides detecting the axles, the direction of their movement is identified and on the basis of the direction detected, these axles are either counted (in case the railway vehicle moves towards the monitored section) or subtracted (if the railway vehicle moves outwards from the monitored section). The data detected by the axle detectors are transmitted to the inner part of the axle counter where the axles are added or subtracted to the number of axles already recorded in the memory [3]. On the basis of the number of axles in the memory, occupancy or vacancy of the monitored section of the track is determined, as well as the length of the train located in this section. If the number of the axles in the axle counter memory zero, the axle counters sends a signal indicating the vacancy of the section. In all other cases, the signal indicating the occupancy of the section is sent. A simplified scheme of axle counter is showed in Fig. 1.

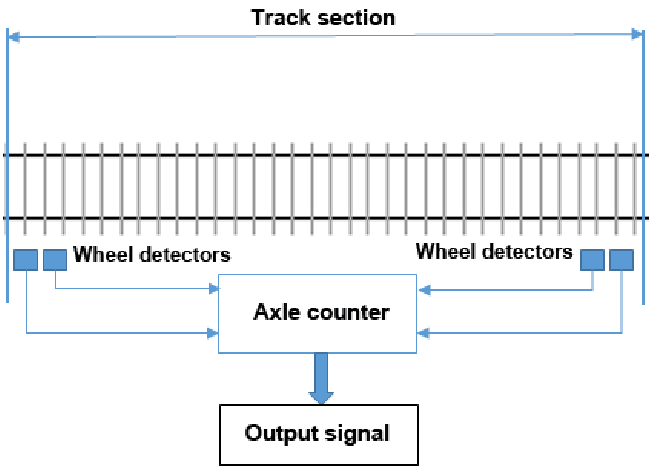

Fig. 1. Axle counter scheme. (*source: authors*)

B. *Wheel Detectors*

Wheel detectors are devices that are used for recording the passage of railway axles through a specific section of railway track. Wheel detectors work on two principles, mechanical or electromagnetic [4]. Working on mechanical principle means there is a “pedal” attached to the rail. The pedal protrudes above the top of the rail. When a train is passing, the pedal is pushed down by the individual axles, thereby connecting the electrical contact and thus adding or subtracting the axle to the axle counter. In the case of electromagnetic principle, a detector is placed at the rail that continuously detect electromagnetic field and that is able to record changes in this field caused by the passage of railway axle. The axles are then added or subtracted by the axle counter [5]. Such a detector indicating the passing railway vehicle is showed in Fig. 2.

Fig. 2. Wheel detector. (*source: authors*)

III. TRACK CIRCUITS

Track circuit is used to detect railway vehicles in a track section by means of an electric circuit and changes of electrical relation in it. It is a line device for detecting train position and each track circuit consists of track rail and trackside equipment. Track rail consists of superstructure, where rails are conductors and sleepers and gravel are insulators [6]. The attached trackside equipment contains, among other things, the necessary electronic devices to ensure the proper functioning of track circuit. At both edges of a conventional track circuit, there are insulated joints instead of usual railway couplings. These insulate the adjacent rails electrically from each other and thus separate the individual track circuits (Fig. 3.). There are two basic types of track circuits. These are series and parallel circuits. Both types work on the principle of the magnitude change in electric current that take place in electrical circuit [7]. The components of track circuit consist of source of electric energy Z, adjustable resistor and a relay with internal safety J. Internal safety relay consists in relay armature that drops out when the supply of electric current is interrupted.

Fig. 3. Track circuit with insulated joints. (*source: authors*)

A. *Series Track Circuit*

In the case of series track circuit, the source of electric energy Z is connected in series to the relay. If there is no railway vehicle in the monitored section, the circuit is broken, ensuring that the relay armature is dropped out due to action of gravity. In the case that a railway vehicle enters the monitored section, the circuit is closed by means of conductive axle of the vehicle (so-called conducting bridge is created). Electric current then starts to flow in the circuit, which causes attraction of the armature that connects and sends the information on the occupancy of the section [7]. When the vehicle exits the track section, the circuit is open and the armature drops out due to gravitation and the relay sends the information of the vacancy of the section. Scheme of series track circuit is showed in Fig. 4.

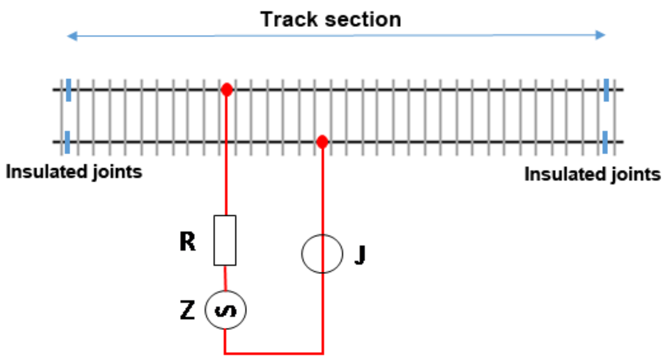

Fig. 4. Series track circuit. (*source: authors*)

B. *Parallel Track Circuit*

In a parallel track circuit, electric current flows from the source of electric energy Z through the first side rail, relay coil and it is closed over the second side rail. Compared to series track circuit, the electric circuit in parallel track circuit remains closed. If there is no vehicle in the track section, the current is strong enough to keep the relay armature attracted. In this position, the relay sends the information on the vacancy of the section. When a vehicle enters the tract section, the overall circuit resistance is increased due to the resistance of axles, resulting in reduction of the electric current passing through. This current is not strong enough to keep the armature attracted to the relay, and it will drop out due to gravity [8]–[9]. As a result, the relay sends the information on the occupancy of the section.

When the vehicle exits the track section, there is an increase in the current; the current attracts the relay armature and thus the information on the vacancy of the section is sent. It is obvious that it is basically the opposite principle than in the case of series track circuit. This seems to be a safer alternative, since in the case of blackout, the relay armature drops out and the relay thus sends the information on the occupancy of the track section [10]. In contrast, series track circuit would send the information on the vacancy of the track section in the case of blackout, which could in extreme case lead to a collision. Parallel track circuit is showed in Fig. 5.

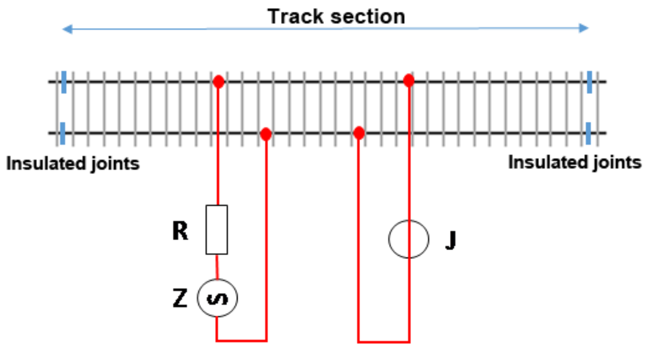

Fig. 5. Parallel track circuit. (*source: authors*)

IV. Eurobalise

In this case, the train position is detected by means of so-called eurobalises, point elements that serve for inductive information transmission between the vehicle and track within the European Train Control System (ETCS). Some eurobalises contain the information on their exact location and serve as a point of reference for passing railway vehicles.

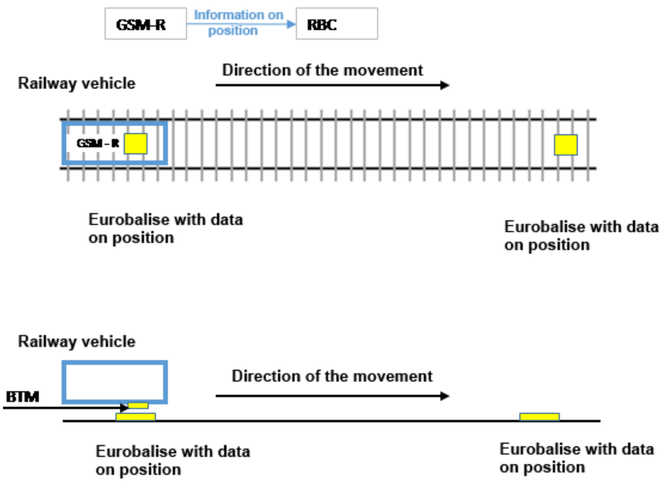

Fig. 6. Eurobalise – principle of detecting train position. (*source: authors*)

When a vehicle passes over the balises, the information on its position is transferred to the vehicle using transmission module placed on the railway vehicle. Vehicle on-board unit processes the information and by means of odometer continuously evaluates the position of the train in relation to the last balise being passed [11], [12]. At higher levels of ETCS, the data on the position received from the balises are transmitted via the GSM-R wireless communication system to Radio Block Centre (RBC), where this information is evaluated and thus the overview of the position of all vehicles in ETCS is obtained independent of other devices for train position detection [13]. At lower levels of ETCS where the data are not transmitted via GSM-R, the information on the position from the balises is used only for the purposes of railway vehicle (Fig. 6.).

There are two basic types of eurobalises – fixed data balises or switchable data balises. Fixed data eurobalises contain information on their position, permanent changes of speed and other constant characteristics of the track. Switchable eurobalises transmit the information on signals and temporary changes of speed. Eurobalises are placed in the centre of the track and are grouped into so-called balise groups that can consist of 1 – 8 balises. Since eurobalises are not able to detect the direction of the train movement by themselves, they are mostly placed in pairs [14]. Balises function on the basis of electricity; they therefore need to be recharged regularly. They are recharged contactlessly, using transmission module placed on the railway vehicle. The module thus serves for communication with balises as well as to their recharging in each passage of the train over the balise. Eurobalise and balise transmission module (BTM) are showed in Fig. 7.

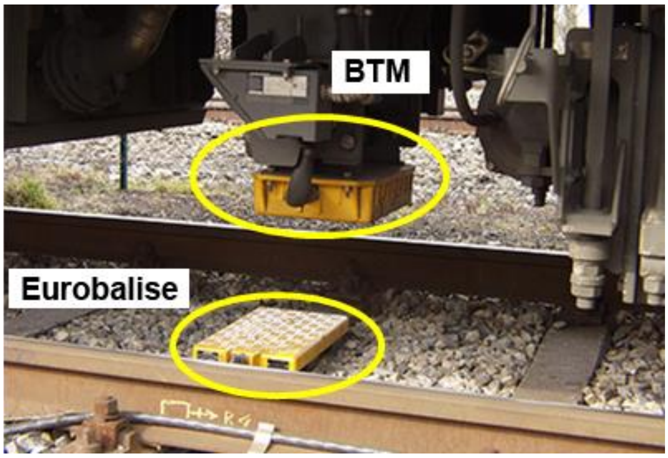

Fig. 7. Eurobalise and Balise Transmission Module (BTM). (*source: authors*)

V. Magnetic Information Balise (MIB)

Magnetic information balise serve for detection of railway vehicle position within the “central vehicle regulator” (CRV) and “automatic train operation” (AVV) systems. Information on position obtained via magnetic information balises are intended exclusively for the CRV and AVV systems. This method of train position detection has thus only one use. Magnetic information balises contain encoded data on their exact position by means of a combination of magnets placed at different locations [15]. The data are transmitted to the railway vehicle during its passage over MIB via detectors placed on the vehicle.

A. Principle of Functioning

MIB consist of two wooden or plastic beams that are placed parallel between the rails. In each beam there are 6 holes that are intended for placing eight permanent magnets [16], [17]. The magnets can be combined in the beams and thus a code indicating the position of MIB is created. During the passage of a railway vehicle equipped with a CVR or AVV, this code is transmitted to the vehicle and by comparing with the code database the exact position of the vehicle is detected. In order to determine vehicle position, MIB is used for determining the direction of its movement. The individual magnets are scanned consecutively by the vehicle and therefore their placement creates a code determining the direction of the vehicle movement. Since a permanent magnet is used for transmitting the data, it is a zero-maintenance device that does not need to be recharged. Both Magnetic Information Balise (MIB) and MIB sensor are showed in Fig. 8.

Fig. 8. Magnetic Information Balise (MIB) and MIB sensor *(source: [4]–[18])*

VI. Conclusion

The above mentioned devices for detecting and tracking train position in the Czech and Slovak Republic differ especially by the level of security and the related cost of implementation. Compared to other methods of vehicles detection, axle counters are distinguished by their simple installation and construction, lower operational costs and maintenance requirements [19]–[25]. However, in terms of safety, they are the least safe, since they do not take into account the physical presence of the vehicle but are based on the difference in input and output values in the monitored track section. In contrast, track circuits and other methods of vehicle detection are based on the physical presence of a vehicle in the given section [26]. Nevertheless, since they are technically more demanding solution, this is reflected especially in high acquisition and operating costs of these devices.

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