Article citation info:
Jakubowski A, Kustosz J, Goliwąs D. Railway brake control system for wagons pulled by a road-rail machine. Rail Vehicles/Pojazdy Szynowe. 2025;1-2:18-26. https://doi.org/10.53502/RAIL-209590

Rail Vehicles/Pojazdy Szynowe

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Railway brake control system for wagons pulled by a road-rail machine

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ARTICLE INFO

Received: 25 June 2025
Revised: 10 August 2025
Accepted: 17 August 2025
Available online: 29 August 2025

KEYWORDS

Railway
Pneumatic brake
Road-rail machine
Dual-track vehicle

Article presents the railway brake control system for wagons pulled by a road-rail machine developed as a part of the research and development project no. 0205/L-12 co-financed by the National Centre for Research and Development under the LIDER XII programme. Both the conceptual assumptions and functionalities of this system were presented, emphasizing its innovativeness and impact on safety in the railway sector. The paper also includes experimental results aimed at verifying the key functionalities of the system and confirming its effectiveness in ensuring safe operation.

1. Introduction

Road-rail vehicles are machines capable of moving both on roads and railway tracks. Currently, they are an alternative to traditional shunting locomotives, offering the possibility of pulling wagons, transporting materials to construction sites and shunting wagons on railway sidings. Thanks to this, they contribute to reducing operating costs.

In a situation where a road-rail machine pulls wagons, it is necessary to provide the operator with the ability to control the braking system of these wagons. This is due to the need to effectively stop the significant mass of the set, which the machine brake alone may not be able to slow down.

In response to the challenges related to effective braking of wagons pulled by road-rail vehicles, a decision was made to implement the project entitled: "Prototype of a railway brake system for road-rail machines pulling wagons". The project was co-financed by the National Centre for Research and Development (project number 0205/L-12) under the LIDER XII programme.

This paper presents the construction, operating principle and test results of the developed system for controlling the braking process of wagons pulled by a road-rail machine.

2. Literature review

This literature review aims to present the current state of knowledge and technological development in the area of dual-track machines, with particular emphasis on their ability to control the braking system of railway wagons..

A review of the literature covering both the braking control systems for railway vehicles and road-rail machines as an alternative to shunting locomotives was carried out.

Afshari et al. in 2013 presented a mathematical model of the wagon brake control unit [1]. Using this model, the authors investigated the influence of the air brake braking forces on the longitudinal dynamics of the train in different braking modes. The authors compared the data obtained from the mathematical model with experimental data.

The brake control system in modernized shunting locomotives was presented by Goliwąs and Małuśkiewicz [5] in 2015. This system is a pneumatic board containing microprocessor-controlled electro-pneumatic units and devices.

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Pielecha et al. in 2015 described the advantages of using road-rail vehicles in shunting work on railway tracks compared to the commonly used shunting locomotives powered by a diesel engine [11]. The article focuses mainly on ecological aspects, especially the emission of toxic substances from exhaust gases. The authors presented the results of the analysis of the impact of exhaust emissions from road-rail vehicles on the environment during their operation on railway tracks.

In 2016, Konstantin described automatic train braking control using fuzzy logic without the participation of the human factor [8]. The control is carried out in a non-linear system with feedback from the brake cylinders, which provides the system with information about the braking pressure. The author described the results of experimental numerical studies and compared them to the currently used solutions.

The process of homologation of road-rail vehicles taking into account their construction and purpose was described by Cichy [3] in 2017. The article presents the possibilities of meeting selected technical parameters affecting safety.

In 2018, Aimar and Soma presented the process of developing and testing a brake monitoring system for intermodal wagons [2]. The authors developed and conducted tests on a prototype on-board unit monitoring the parameters of the braking system. This unit collects data such as brake pad temperature, brake system pressure and vehicle acceleration.

In 2018, Cichy et al. presented the rules for the approval of road-rail vehicles for operation in Poland [4]. The article describes the requirements for rail vehicles in the context of road-rail vehicles, and in particular with regard to conducting durability tests in the vehicle type approval process.

In 2019, Medwid et al. [9] presented the concept of building a road-rail tractor intended for shunting work in open and closed areas, in cooperation with rolling stock. The article presents various variants of the braking systems of this tractor.

In 2020, Günay et al. reviewed the braking systems used in rail vehicles [6]. The authors described the operation of such systems as: pneumatic disc brake, dynamic, aerodynamic and electropneumatic brakes. The authors also described the results of numerical and experimental studies of the influence of brake disc geometry and friction lining properties on the braking efficiency of rail vehicles.

Muthu et al. in 2021 reviewed railway braking systems and described their development over the years [10]. The authors presented braking systems, described their advantages and disadvantages. In addition, the authors conducted an analysis of the influence of materials used for actuators of brake systems on noise emission, durability, performance and their efficiency.

Ivanov et al. in 2023 described the developed method of adaptive control of braking pressure in passenger trains [7]. This method is based on monitoring the coefficient of friction between the brake pad and the wheel and selecting the optimal braking pressure on this basis. The main objective of adaptive brake pressure control is to improve train braking efficiency and eliminate the phenomenon of wheel set blocking during braking.

Pudovik and Menaker in 2023 presented a diagram of the automatic control system for the pneumatic brake of a freight train [12]. This system is based on the actual speed of the train. The authors presented the results of numerical tests of the system, which show that the proposed system ensures the appropriate quality of vehicle speed control during a long descent, which increases the technical speed of movement.

3. Air brake

The road-rail machine pulling the wagons constitutes a train. The basic braking system of this train is an air brake. This type of brake, which uses compressed air to control the braking force on each wagon, is fundamental to the safe and efficient operation of rail transport. Its operation is based on the use of compressed air to transmit braking signals and generate braking force. The main elements of this system are compressed air main reservoir, pneumatic lines, control valves and brake cylinders mounted on the axle of each wagon.

Compressed air is distributed to the individual wagons via pneumatic lines. Control valves (distributor valves), responding to changes in air pressure, control the air flow to the brake actuators. When the machine operator activates the brake, the pressure in the system decreases, which causes the actuators to activate and press the brake pads against the wagon wheels or the friction linings against the brake discs, generating braking force.

The air brake in trains performs two main functions: service braking and emergency braking. Service braking, used to slow down a train, is usually initiated by the driver (or road-rail machine operator) using the braking system. Its main purpose is to ensure a smooth and safe stop of the train. Emergency braking, activated in critical situations, is used to immediately stop the train in the event of unforeseen events or hazards on the tracks. This function is used in situations where a quick response is necessary to prevent potential accidents or collisions. The operator can activate emergency braking by pressing an emergency valve. This braking is also activated automatically when it is detected that the operator is not reacting to the sound and light signals emitted by the so-called active deadman system. The third situation causing emergency braking is when the braking system detects a significant leak in the main line, caused for example by a break of the trainset.

4. Concept of a railway brake for a road-rail machine

4.1. Functional requirements

To ensure safety and efficiency in rail transport, it is crucial that the operator of a road-rail machine has the ability to perform service and emergency braking of the wagons it pulls. This requires that the machine's braking system is not only compatible with the wagons' air brake, but also enables the operator to precisely control the braking force depending on current operational needs.

The basic functions that this system must perform are the ability to activate emergency and service braking of the pulled wagons. It is also required that the emergency brake is activated redundantly via two independent channels. Both emergency and service braking must be performed by controlling the pressure in the Brake Pipe of the pulled wagons. In addition, the railway brake system for a road-rail machine must meet the functional requirements specified in Table 1.

Table 1. Functional requirements

Requirement	Parameter
Tightness	The air loss after shutting off the system must not exceed 20 kPa/5 minutes
Nominal pressure in the Brake Pipe	505 ±5 kPa
Emergency braking	Reducing the pressure by at least 150 kPa within 3–6 seconds, and then stabilizing the pressure at 160–180 kPa below this pressure
Service braking	Activation of the first braking stage causes the pressure in the Brake Pipe to drop by 30–60 kPa. Activation of the subsequent braking stages causes the pressure in this line to drop by less than 20 kPa until full braking is achieved, which corresponds to a pressure of 160–180 kPa below the initial pressure.

Fulfilling the described functional requirements is a key factor ensuring safety in rail traffic.

4.2. Developed concept

The developed concept of the braking control system for wagons pulled by a road-rail machine is presented in Fig. 1. The central element of this system is the operator panel, which is integrally built into the cab of the dual-track machine, which allows the operator to directly and intuitively control the wagon braking system. This panel is connected to an electric control unit which can be mounted, for example, in the body of a dual-track machine. This assembly contains all the necessary electrical, electronic and pneumatic components responsible for processing the signals issued by the operator and then transmitting them further – via brake couplers – to the braking systems of individual wagons.

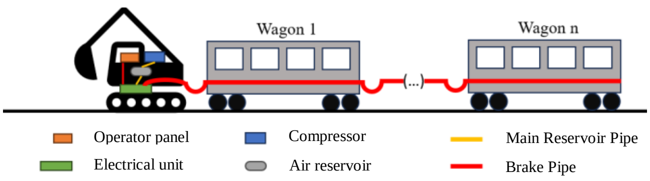

Fig. 1. Railway brake system diagram

The structural concept of the developed braking control system for wagons pulled by a road-rail machine is shown in Fig. 2.

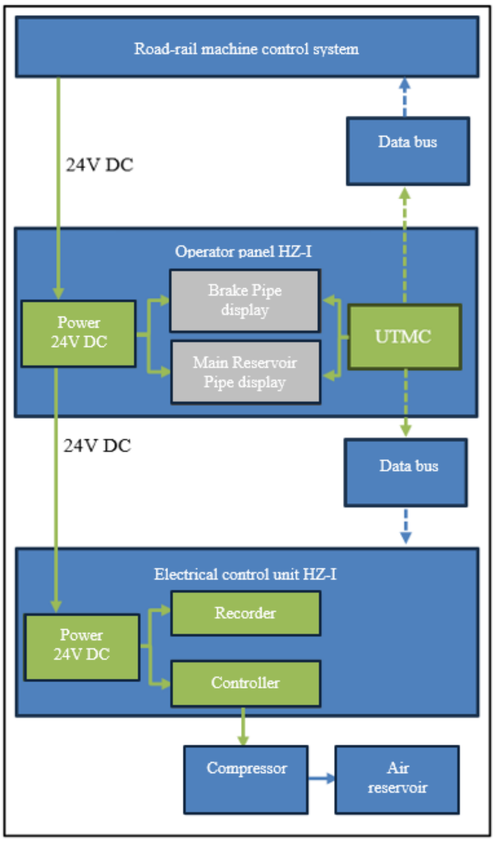

Fig. 2. Block diagram of a railway brake system: UTMC – universal CAN data bus terminal

The mentioned operator panel includes: a 24V DC power supply, a Brake Pipe parameter display, Main Reservoir Pipe parameter display and a universal CAN data bus terminal. This panel communicates with the dual-track machine control system and with the electrical control unit. This unit consists of a 24 V DC power supply, recorder and controllers. The signal from the controllers reaches the compressor unit built into the road-rail machine.

The conceptual pneumatic diagram of the developed system is shown in Fig. 3.

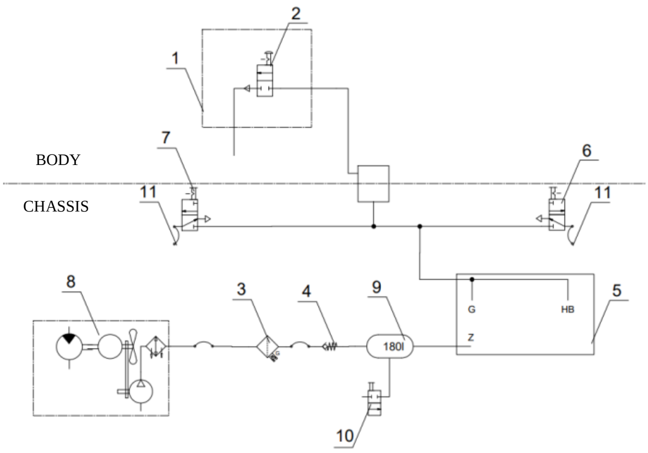

Fig. 3. Ideal pneumatic diagram: 1 – operator panel HZ, 2 – emergency brake valve, 3 – separator, 4 – check valve, 5 – electrical control module, 6 – end cock – left, 7 – end cock – right, 8 – compressor unit, 9 – 180 dm^3 air reservoir, 10 – ball shut-off valve, 11 – brake coupler

The process of generating a pneumatic signal starts in the compressor (8), which pumps compressed air to the separator (3), which separates water from the working medium. The air then flows through the check valve (4), which prevents the pressure from flowing back into the compressor. The next element of the system is an air reservoir (9), equipped with a shut-off valve (10), which allows for periodic drainage of condensed water.

The dried and compressed air is fed to the electric control module (5), from where the pneumatic signal is transmitted to the operator panel of the dual-track machine (1). The brake system is additionally equipped with end cocks (6 and 7) and brake couplers (11), enabling the machine to be connected to the pneumatic brake system of the wagons.

The entire system is controlled by means of the HZ operator panel (1), which contains an emergency brake valve (2). This valve enables, in emergency situations, the main line to be quickly emptied of compressed air, which results in stopping the tractor and the towed wagons at a safe distance.

4.3. Electric control module

One of the main components of the braking control system for wagons pulled by a road-rail machine is the electric control module, the prototype of which is shown in Fig. 4. This panel consists of devices whose operation is controlled by a 32-bit microprocessor controller (1). The system is controlled by binary voltage signals sent by the air brake manipulator located in the operator panel. These signals control the operation of the valve terminal (2). Depending on the deflection of the manipulator handle, they reduce or increase the pressure in the control chamber (3) of the relay valve (4) of the Brake Pipe. This relay valve is responsible for regulating the pressure in the Brake Pipe according to the currently desired degree of braking or release. This panel also includes an emergency braking valve (5), which is used by the road-rail machine operator to initiate emergency braking by quickly dropping the pressure in the Brake Pipe. The electro-pneumatic valves (6) are responsible for regulating the pressure in the Brake Pipe.

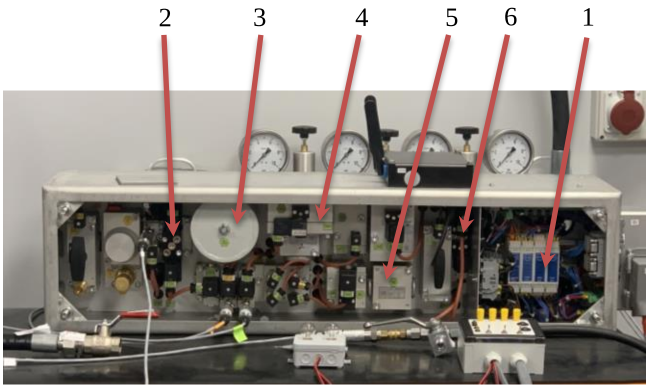

Fig. 4. Prototype of the electric railway brake control unit 254ZH 02-1: 1 – 32-bit microprocessor controller, 2 – valve terminal, 3 – control chamber of the relay valve, 4 – relay valve, 5 –emergency braking valve, 6 – electro-pneumatic valves

4.4. Operator panel

In addition to the above-described electric control module, the main component of the developed braking control system for wagons pulled by a road-rail machine is the operator panel. The prototype of the operator panel developed within the project is shown in Fig. 5.

The operator panel consists of an air brake pulse manipulator (2), an emergency brake valve (3), and displays for reading the pressure in the Brake Pipe (4) and the Main Reservoir Pipe (5). The lighting of the green diode (9) located in the panel indicates that the compressor is switched on, while the lighting of the red diode (10) informs about the travel prohibition signal transmitted to the control system of the dual-track machine. The system is controlled by a PLC controller.

The operator panel is also equipped with elements of a system supervising the psycho-physical activities of the road-rail machine operator. This system emits sound signals through a buzzer (6) and light signals thanks to a built-in diode (8). The operator must respond to the signals emitted by this system by pressing a dead man's button located on the manipulator. Lack of operator reaction results in automatic activation of emergency braking by this system.

The system designed and constructed in this way was subjected to experimental functional tests, the results of which are presented in Chapter 5.

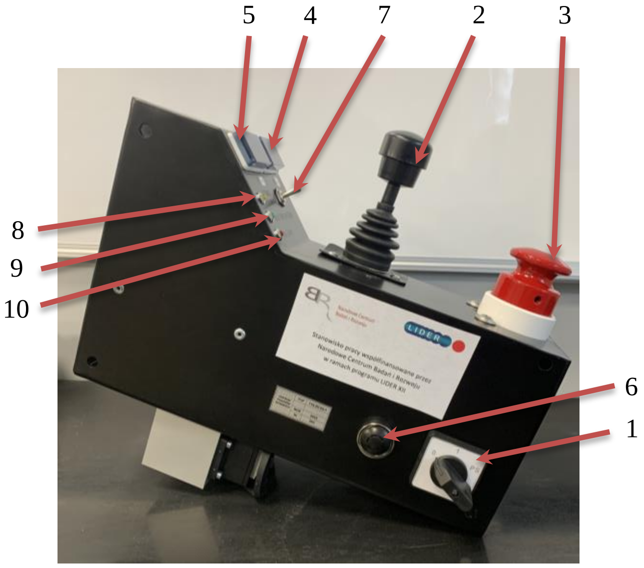

Fig. 5. Prototype of the railway brake operator panel of the road-rail machine type 115ZH 03-2: 1 – switch, 2 – air brake pulse manipulator, 3 – emergency brake valve, 4 – brake pipe pressure display, 5 – main reservoir pipe pressure display, 6 – buzzer, 7 – active deadman system switch, 8 – yellow diode, 9 – green diode, 10 – red diode

5. Tests objective and method

5.1. Tests objective

The aim of the tests was to assess whether the control system meets the requirements presented in Table 1.

5.2. Tests method

The experimental functional testing method was used to verify the correct operation of the system. The tests were carried out on the constructed test stands shown in Fig. 6 and Fig. 7. The first one was used to test the prototype of the electric control module, and the second one was used to test the operator panel.

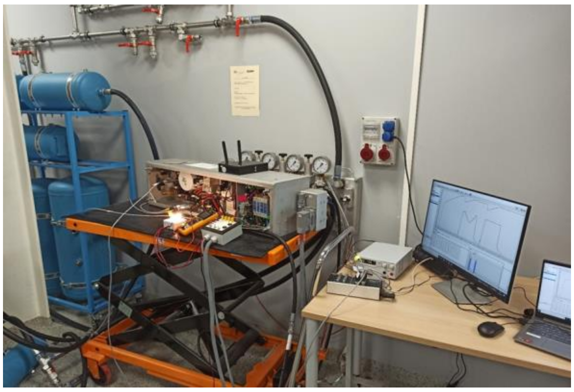

Fig. 6. Test stand for the prototype of the 254ZH 02-1 railway electric brake control module

These stations consist of a source of compressed air, pressure reservoirs, a control panel, a recorder and a computer with software enabling the recording of pressure changes over time.

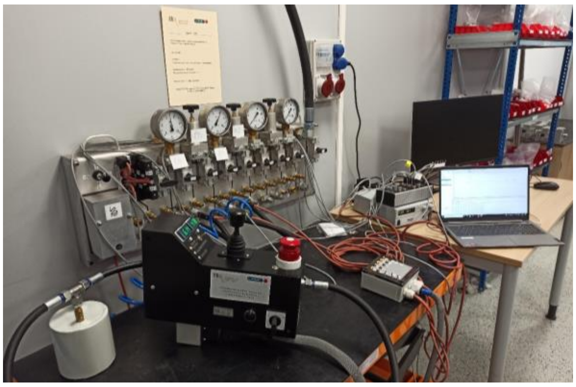

Fig. 7. Test stand for the prototype of the railway brake operator panel 115ZH 03-2

6. Tests results

6.1. Tightness

The first parameter of the developed system that was tested was its tightness.

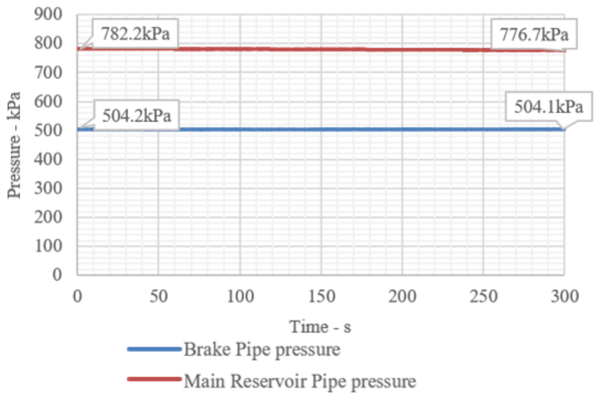

Fig. 8. Pressure change as a function of time during the tightness test of the prototype electrical unit type 254ZH 02-1

Figure 8 shows the pressure changes as a function of time recorded during the system tightness test. The pressure in both pipes (Brake Pipe and Main Reservoir Pipe) is constant during the measurement. The pressure in the Brake Pipe remains at approximately 504.2 kPa, while the pressure in the Main Reservoir Pipe is higher and is approximately 782.2 kPa at the beginning and 776.7 kPa at the end of the measurement. This means that the pressure in the MRP dropped slightly during the measurement. These results confirm that the electric control unit is tight as the air loss in both pipes did not exceed 20 kPa for 5 minutes.

The tightness of the operator panel prototype was also tested and the results are shown in Fig. 9. The system pressure was stable throughout the test, starting at 501 kPa and ending at a slightly lower value of 496 kPa. It shows that the pressure in the BP dropped by 5 kPa within 5 minutes. This means that the system is tight as the maximum pressure loss criterion (20 kPa/5 min) has been met.

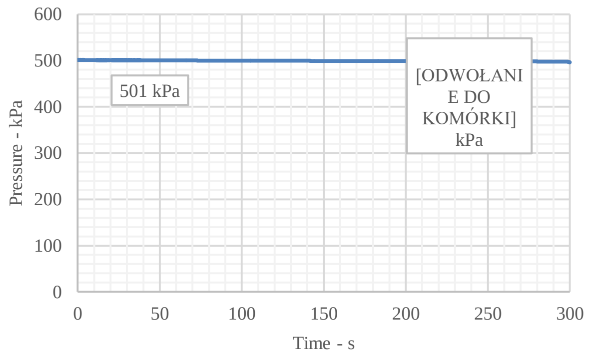

Fig. 9. Change of pressure in the system as a function of time during the tightness test of the pneumatic panel system

6.2. Nominal pressure in the Brake Pipe

Ensuring adequate pressure in the BP is crucial for proper brake operation. The developed system is equipped with an automatic pressure equalization function in the BP, the purpose of which is to achieve a value of 505 ±5 kPa.

The recorded pressure course in the BP as a function of time is shown in Fig. 10. The graph shows that activating the automatic pressure equalization function caused the pressure in the BP to increase to 515.7 kPa and then drop to 504.2 kPa. Initiation of the first braking stage (pressure drop to 452.7 kPa) and subsequent activation of the complete brake release function caused the pressure to stabilize at 507.2 kPa.

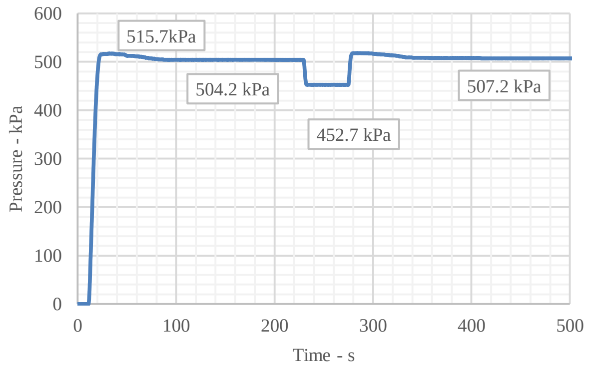

Fig. 10. Change of pressure in the Brake Pipe as a function of time during the nominal pressure test in the Brake Pipe

Based on the achieved results, it was found that the nominal pressure function in the Brake Pipe works properly.

6.3. Emergency braking

One of the most important functions of the developed system is the braking function in emergency situations. This function is activated automatically when, for example, a large leak occurs in the system, which may be caused by, for example, a train breakup. Additionally, emergency braking can be initiated by the operator of the road-rail machine by activating the emergency valve as a result of observed dangerous situations. In addition, the developed system was equipped with a system monitoring the psychophysical activity of the road-rail machine operator. This system can also automatically initiate emergency braking if the operator fails to respond to the light and sound signals.

The results of experimental tests of these three methods of initiating emergency braking by the developed system are described below.

6.3.1. Emergency braking caused by a leak in the Brake Pipe

Figure 11 shows the recorded pressure versus time during an emergency braking test caused by a BP leak.

This leak was simulated by opening a valve with a ø12 mm nozzle installed. This resulted in immediate activation of emergency braking. Within 2.4 seconds after occurrence of the leak in the BP, the pressure dropped by 200 kPa.

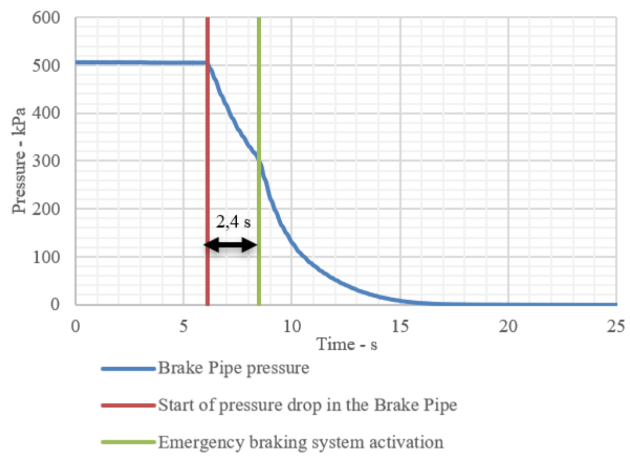

Fig. 11. Change of pressure in the Brake Pipe as a function of time during an emergency braking test caused by a leak in the Brake Pipe

On this basis, it was found that the emergency braking function caused by a leak in the BP works correctly, as the parameter was met, which states that activating this function should cause a pressure drop in the BP by 150 kPa within 3–6 seconds.

6.3.2. Emergency braking caused by activation of the emergency brake valve

Figure 12 shows the pressure versus time curve during the emergency brake valve operation test. After opening this valve, there was a rapid (0.8 s) drop in pressure in the BP from 500 kPa to atmospheric pressure.

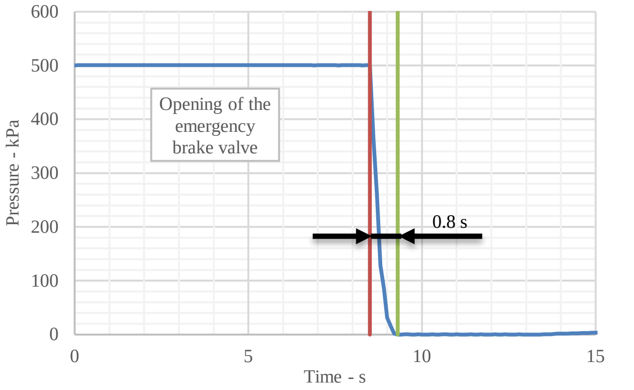

Fig. 12. Change of pressure in the Brake Pipe as a function of time during the emergency brake valve operation test

These results indicate that the emergency braking function via the emergency brake valve works correctly, as the above-mentioned parameter has been achieved.

6.3.3. Emergency braking triggered by the active deadman system

Initiating emergency braking by the system monitoring the psychophysical activities of the road-rail machine operator (active dead man's switch) consisted in deliberately failing to react to the light and sound signals emitted by the system.

Due to the lack of reaction to the sequence of light and sound signals, the system automatically initiated emergency braking.

6.4. Service braking

In addition to the emergency braking functions discussed above, the system must also enable the service braking to be activated, which is used under normal operating conditions. There are two types of service braking: full and gradual. The first one uses the maximum available braking force. Gradual service braking is used to control the vehicle's speed.

The results obtained from experimental studies are described below.

6.4.1. Full service braking

Figure 13 shows the recorded pressure versus time course during the full service braking test. It follows that the initiation of this braking at the moment t_1 = 18 s caused the pressure to decrease from p_1 = 507.5 kPa to p_2 = 337.3 kPa (Δp = 170.2 kPa). The pressure then reached 500 kPa again as a result of the brake release being activated. Reinitiation of full service braking caused the pressure to drop by Δp = 152 kPa from the value of p_3 = 506.5 kPa. This drop occurred in 5.3 seconds.

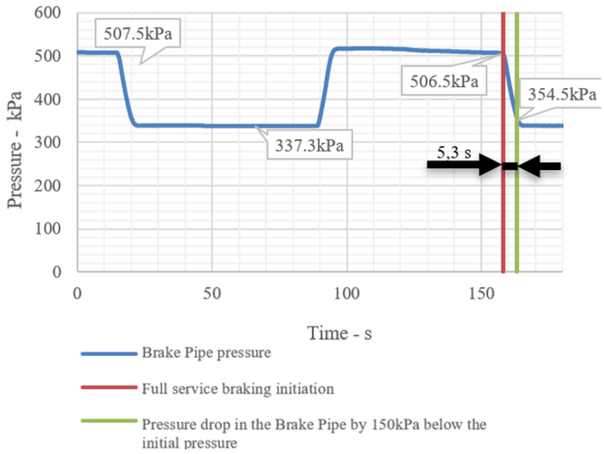

Fig. 13. Change of pressure in the Brake Pipe as a function of time during the full braking test

These results indicate that the full service braking function is performed correctly, as the pressure corresponds to the value of 160–180 kPa below the initial pressure..

6.4.2. Gradual service braking

The results of the gradual service braking test are shown in Fig. 14. Initiation of the first stage of braking caused the pressure in the BP to drop by 52.3 kPa, and within 1.5 seconds of initiation the pressure in this pipe dropped by 34.5 kPa.

Based on the recorded pressure vs. time course, it was found that the first stage braking function was performed correctly, as the pressure in the main line decreased by 30–60 kPa.

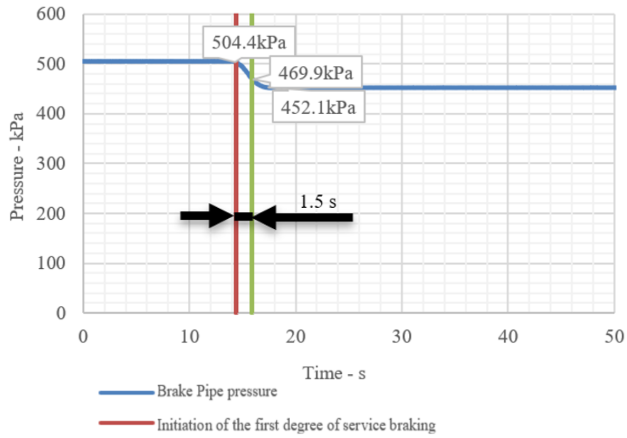

Fig. 14. Change of pressure in the Brake Pipe as a function of time during the first degree of service braking test

The implementation of the function of the subsequent braking degrees is shown in Fig. 15. Activation of subsequent braking stages resulted in a pressure drop in the BP by a maximum of 15 kPa. Activation of the last braking degree caused the pressure to drop to 168 kPa below the initial pressure.

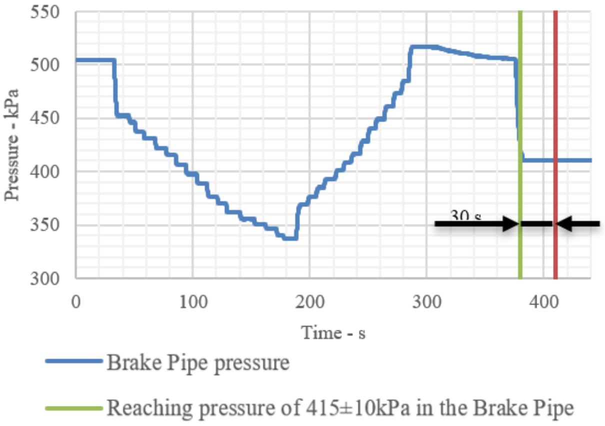

Fig. 15. Change of pressure in the Brake Pipe as a function of time during the gradual braking and gradual release test

The graph also shows the operation of the gradual release function. Activation of this function caused the pressure in the BP to increase by 32.5 kPa, and then by a maximum of 15 kPa.

Based on the conducted tests, it was found that the gradual braking and gradual release functions are performed correctly.

7. Summary

The article presents an innovative system for controlling the braking process of wagons pulled by a road-rail vehicle. The developed system enables both service and emergency braking, while maintaining compliance with standard requirements (including EN 15746-2 [14]). Functional tests confirmed that the system meets key technical parameters, such as tightness, pressure stability in the Brake Pipe and operational efficiency in various braking modes.

The following results were achieved during the project implementation:

– A concept was developed and a prototype of a railway brake system for road-rail vehicles was made
– Two key modules were built and tested: the operator panel and the control module
– Full functionality of the system was ensured in terms of:
  - emergency braking (including automatic activation in the event of a leak, lack of operator reaction, or activation of the safety valve)
  - service braking (full and gradual)
  - automatic pressure equalization in the Brake Pipe.
– Experimental functional tests were carried out to confirm compliance with the design requirements.

Further directions of development of the work include:

– Conducting operational tests in real railway conditions
– Integration of the system with modern railway traffic control systems (e.g. ETCS, GSM-R)
– Expanding the functionality with automatic diagnostics and analysis of the technical condition of the system.

The developed system is a step towards increasing the safety and efficiency of road-track machines in the railway environment.

Nomenclature

BP	Brake Pipe
ETCS	European Train Control System
GSM-R	GSM for Railways
MRP	Main Reservoir Pipe

Bibliography

[1] Afshari A, Specchia S, Shabana AA, Caldwell N. A train air brake force model: car control unit and numerical results. P I Mech Eng F-J Rai. 2013;227(1):38-55. https://doi.org/10.1177/0954409712447231
[2] Aimar M, Somà A. Study and results of an onboard brake monitoring system for freight wagons. P I Mech Eng F-J Rai. 2018;232(5):1277. https://doi.org/10.1177/0954409717720348
[3] Cichy R. Badania pojazdów szynowo-drogowych w aspekcie homologacji (in Polish). TTS 2017;12:56-63.
[4] Cichy R, Magnucka-Blandzi M, Nowicki M. Durability tests of road-rail vehicles to receive operation admission. Rail Vehicles/Pojazdy Szynowe. 2018;1:45-54. https://doi.org/10.53502/RAIL-138478
[5] Goliwąs D, Maluśkiewicz M. Układy sterowania hamulcami opracowane przez IPS „TABOR" dla modernizowanych lokomotyw manewrowych. Pojazdy Szynowe. 2015;2:34-44. https://doi.org/10.53502/RAIL-138805
[6] Günay M, Korkmaz ME, Özmen R. An investigation on braking systems used in railway vehicles. Engineering Science and Technology, an International Journal. 2020;23(2)421-431. https://doi.org/10.1016/j.jestch.2020.01.009

[7] Ivanov P, Dulskiy E, Khamnaeva A, Korsun A, Emel`yanov D. The adaptive brake pressure control system for passenger trains. AIP Conf. Proc. 2023; 2476(1):030021. https://doi.org/10.1063/5.0103053

[8] Konstantin Y. Automatic control of train brakes with fuzzy logic. In: Abraham, A., Kovalev, S., Tarassov, V., Snášel, V. (eds) Proceedings of the First International Scientific Conference "Intelligent Information Technologies for Industry" (IITI'16). Advances in Intelligent Systems and Computing. 2016;451. Springer. Cham. https://doi.org/10.1007/978-3-319-33816-3_34

[9] Medwid M, Daszkiewicz P, Czerwiński J, Jakuszko W, Kazimierczak E. Rail-road tractor with diesel-electric drive. Pojazdy Szynowe/Rail Vehicles. 2019; 3:15-23. https://doi.org/10.53502/RAIL-138536

[10] Muthu M, Mahesh Kumar U, Sivadasan VK. Review on braking system in railways. International Research Journal of Engineering and Technology (IRJET). 2021;8(7):2333-2339. www.irjet.net

[11] Pielecha J, Merkisz-Guranowska A, Andrzejewski M, Daszkiewicz P, Stawecka H. Ecological aspect of using road-rail vehicles for shunting operations. Rail Vehicles/Pojazdy Szynowe. 2016;(1):1-8. https://doi.org/10.53502/RAIL-138675

[12] Pudovikov OE, Menaker GM. Pneumatic brake control system of a freight train. Russ Electr Engin. 2023; 94:654-658. https://doi.org/10.3103/S1068371223090122

[13] UIC 541-03: "Standard wymiarów kół i osi kolejowych" (in Polish), Międzynarodowy Związek Kolei (UIC), 1984.

[14] PN-EN 15746-2 – Kolejnictwo – Tor – Maszyny drogowo-torowe i ich wyposażenie – Część 2: Ogólne wymagania bezpieczeństwa (in Polish).