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# EVALUATION OF SERVICE BRAKE BRAKING OF SELECTED GROUP OF VEHICLES DEPENDING ON WEAR OF BRAKE SYSTEM'S PARTS

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The paper deals with the evaluation of service brake braking of a selected group of vehicles depending on the wear of brake system's parts. During the research, the technical condition of brake systems, the degree of wear of brake discs, brake pads, and the measurement of braking forces using a roller brake tester was monitored and evaluated on a sample of 16 intercity buses for a period of three years. The measurement was carried out on 2 selected intercity buses SOR C 10.5 and IVECO Crossway. The maximum braking forces on both axles of buses were measured using a roller brake tester. Then, the percentage braking of the vehicle was calculated and compared with the minimum required braking according to applicable legislation. Based on the inspection of technical condition of brake pads and discs, it was possible to detect the wear and tear of these elements of the brake system (which was manifested during the inspection of the vehicle on the roller brake tester), and it was also possible to record the insufficient value of the required minimum braking during the calculation.

**Keywords:** brake disc; brake pad; pneumatic brakes; braking; intercity bus

An integral part of every vehicle is its braking system that ensures braking. Braking is defined as a deliberate reduction of vehicle speed (Huang et al., 2020). Service braking must enable an efficient and quick deceleration or stopping of the vehicle at the speed reached on any inclined plane during vehicle operation (Zulhilmi et al., 2020). The braking effect is most often achieved by applying a braking torque to the wheels of the vehicle, which causes horizontal force reactions between the wheels and the road, acting against the direction of their movement (Popa et al., 2020) and (Wei et al., 2022). When the vehicle brakes, kinetic energy is reduced and transformed into heat (Mădălin-Florin and Nikolae, 2019) and (Kumar and Kumaran, 2019). When decelerating to a complete stop (neglecting the effects of vehicle resistance during driving), the calculated amount of energy is converted into heat and escapes without other use into the external environment (Mondal and Nandi, 2023). As stated by Leontiev et al. (2022) and Beloev (2021), braking systems must ensure basic tasks such as reducing vehicle speed, stopping the vehicle, preventing unwanted acceleration while driving down a slope, and keeping the vehicle stationary. In terms of road traffic safety as well as the safety of the crew, brakes are the most important device of the vehicle. As stated by Straky et al. (2003) and Kuchar et al. (2022), the effectiveness of braking systems is influenced by several factors, such as the condition of road or tires, the technical condition of vehicle's braking system and, last but not least, vehicle operation. The wear of friction components of the brake system, such as brake pads and discs, has a significant effect on the efficiency of the brake system, which is manifested in the stationary tests of the brake system (Mohammed et al., 2023). As a result of the significant wear of brake's components, there is a decrease in braking forces manifested in the tests of the brake system using a roller brake tester (Toma et al., 2017).

The paper focuses on the pneumatic brake system, which is used as a service brake of buses and trucks. The pneumatic brake system is defined by Miller and Cebon (2010) and Zheng et al. (2018) as a system filling medium of which is compressed air created by a compressor. The pneumatic system is used together with a brake booster, which can be strengthened by a hydraulic or vacuum booster depending on the filling medium of brake system when driver's power is insufficient (Zhang et al., 2021) and (Gerlici et al., 2020). The aim of this paper was to carry out a stationary test of the brake system and subsequent braking evaluation of the service brake of 2 intercity buses depending on the wear of brake system's parts. Based on braking forces and calculated braking, it can be seen that the worn elements of the braking system have a significant impact on the proper functioning of the braking system and its reliability.

## Material and methods

The technical condition of the brake system was monitored in a group of 16 intercity buses with different mileage conditions. The objective of research was the evaluation of the technical condition of the brake system and operating fluids for the last 3 years of operation. In order to achieve the set goals, 2 intercity buses were selected from the set of vehicles, which have driven 470,084–492,548 km since they were put into operation. These are the types of buses most often used in this region. A comprehensive history of operation and maintenance of the brake systems of the mentioned buses has been recorded since the beginning of operation. Depending on classification on the type of line, these buses have a different number of kilometres driven per year of operation. The technical parameters of the buses are listed in Tables 1 and 2.

**Table 1** Technical parameters of vehicle 1

| **Mark** | **SOR** |
|---|---|
| **Trade name** | C 10.5 |
| **Kind** | intercity bus |
| **Type/variant** | SOR C 10.5/1CD2DM1FX |
| **Year of manufacture** | 2017 |
| **Category** | M3 |
| **Brake system** | pneumatic |
| **Mileage status** | 492,548 |
| **Operating weight (kg)** | 9080 |
| **The largest permissible total weight (kg)** | 15,000 |
| **The largest permissible weight per axle 1/2 (kg)** | 5500/9500 |

**Table 2** Technical parameters of vehicle 2

| **Mark** | **IVECO** |
|---|---|
| **Trade name** | Crossway Low Entry |
| **Kind** | intercity bus |
| **Type/variant** | CBLE 400/4C |
| **Year of manufacture** | 2015 |
| **Category** | M3 |
| **Brake system** | pneumatic |
| **Mileage status** | 470,084 |
| **Operating weight (kg)** | 10,675 |
| **The largest permissible total weight (kg)** | 17,900 |
| **The largest permissible weight per axle 1/2 (kg)** | 6300/11,600 |

### Measurement of brake discs and brake pads

The width of the brake discs of the investigated sample of vehicles was measured using a digital micrometer, as shown in Figs 1 and 2. When measuring the brake lining of the front axle, access to the individual brake pads was very complicated due to little space. Therefore, it was necessary to use a special measuring tool, which shows the size of the brake lining together with the width of the brake disc. It is also possible to determine the thickness of the brake linings on the rear axle of the bus in the same way.

**Fig. 1** Measuring brake disc thickness using a digital micrometer


**Fig. 2** Measuring the thickness of the brake pads

### Roller brake tester MAHA MBT 4200 LON W Classic

The measurements of the maximum braking forces were carried out using the MAHA MBT 4200 LON W Classic roller brake tester. The roller brake tester is equipped with an electric roller drive, which is provided by two electric motors with a power of 11 kW. Table 3 shows the technical data of MAHA MBT 4200 LON W Classic.

**Table 3** Technical data of the roller brake tester MAHA MBT 4200 LON W Classic

| Parameter | | Value |
|---|---|---|
| **Axle load (kg)** | | 4000 |
| **Driving power (kW)** | | 2 × 11 |
| **Test speed (km·h$^{-1}$)** | | 4.6 |
| **Length of rollers (mm)** | | 1000 |
| **Diameter of rollers (mm)** | | 202 |
| **Axial distance of rollers (mm)** | | 400 |
| **Voltage supply (V; Hz)** | | 3–400; 50 |
| **Protection (A)** | | 63 |
| **Coefficient of friction of rollers** | dry/steel | 0.9 |
| | wet/steel | 0.7 |
| **Dual analogue display (mm)** | | 870 × 910 × 300; scale Ø 2 × 350 |
| **Switchboard (mm)** | | 800 × 950 × 300 |
| **Differential display** | | digital/optical |
| **Display range (kN; mm)** | | 0–4/0–40; 0–100 |

The resulting values of braking forces of the service brake are recorded in the protocol from the roller brake tester. These values are further processed for an indicative calculation of the effect of the service brake with an expression of vehicle's percentage braking. The percentage braking of the vehicle at test weight is calculated according to methodological instruction no. 74/2018 for carrying out inspections of the brake systems of vehicles of categories M2, M3, N2, N3, O3, and O4 during technical inspections.

$$Z = 10.2 \frac{\sum B_{vi}}{m_s} \quad (\%) \tag{1}$$

where: $\sum B_{vi}$ – the sum of braking forces on the circumference of the wheels of the axle *i* (N); $m_s$ – test weight of the vehicle (kg)

If the roller brake tester does not allow the test weight of the vehicle to be determined, it is assumed that the test weight of the vehicle without load is equal to either the curb weight increased by 75 kg or the operating weight, depending on which of these data is indicated in the vehicle document submitted. If for braking Z compared to the prescribed minimum braking $Z_{min}$ for the service brake holds:

$$Z \geq Z_{min} \quad (\%) \tag{2}$$

then, it is considered proven that the vehicle is able to achieve the prescribed minimum braking effect with the service brake. Otherwise, if

$$Z < Z_{min} \quad (\%) \tag{3}$$

the vehicle does not achieve the minimum braking effect prescribed by the service brake. For the M3 category, according to applicable legislation, the minimum braking value is 50%.

## Results and discussion

In the first measured intercity bus SOR C 10.5, the current mileage is 492,548 km, and regular inspections of the technical condition of the brake system were carried out after approximately 30,000 km of mileage. From Table 4, it can be seen that the maximum braking forces during the inspection of the technical condition of the brake system during the mileage 435,911 km were insufficient, and a braking value of 39.01% was calculated, which is less than the minimum braking value according to applicable legislation. This condition was caused by the wear of the brake lining and damage to the control mechanism of the brake calliper on the front and rear axles. For this reason, the brake pads and also the brake discs on both axles of the vehicle were replaced.

**Table 4** Values of the maximum braking forces and braking of vehicle 1

| Parameter | Value | | | | |
|---|---|---|---|---|---|
| **Mileage run (km)** | 371,214 | 406,893 | 435,911 | 466,404 | 492,548 |
| **Max. braking force on the 1st axle (kN)** | 17.97 | 17.35 | 9.54 | 16.70 | 19.10 |
| **Max. braking force on the 2nd axle (kN)** | 35.66 | 28.66 | 25.47 | 29.81 | 30.72 |
| **Braking (%)** | 59.75 | 51.26 | 39.01 | 51.82 | 55.51 |

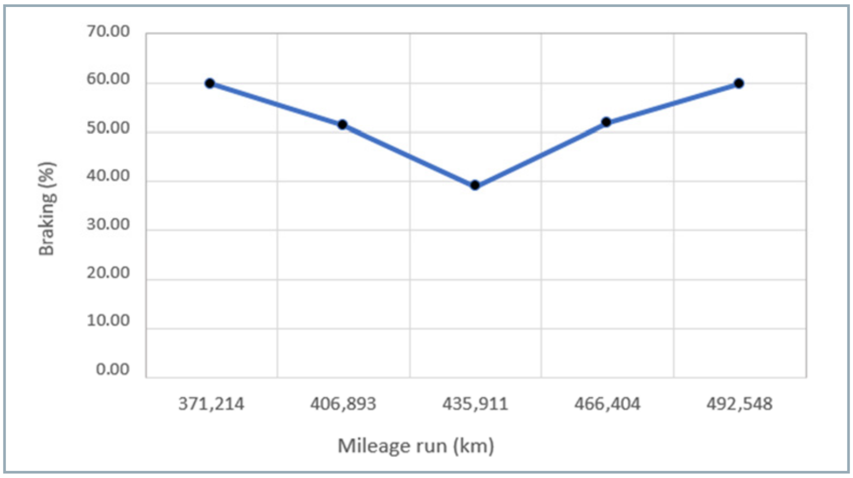


**Fig. 3** Graphic dependence of percentage braking and mileage of vehicle 1

Table 5 indicates the monitored values of the width of the brake pads and their gradual wear depending on the number of kilometres travelled. With a mileage of 435,911 km, a significant wear of the brake pad on the rear axle on the left was detected during the inspection, while the extent of wear of the brake pads on the front axle, together with the wear of the right rear brake pad, was significantly higher than the standard wear recorded after driving 30,000 km. Based on the control measurement carried out in accordance with the technical-safety control methodology established by the bus operator, it was found that there was damage to the control mechanism of the brake calliper, which controls the movement of the brake pads. By measuring the width of the brake disc, a gradual wear of the disc was detected, while even damage to the control mechanism of the brake calliper did not affect the increase in the wear of the brake disc. When checking the condition of the brake disc, the operator sets the minimum width of the disc to a value of 36.5 mm. For this reason, the brake discs on the front and rear axles of the bus were replaced. After dismantling the brake discs, the ovality of the brake disc was measured with a negative result. Figure 3 shows a significant reduction in braking, which was caused by primary damage to the control mechanism of the brake calliper, which caused a secondary wear of the brake pads and increased ovality of the brake discs. Figure 4 shows the measured thickness of the brake pad.

In Tables 5 and 6 with a condition of 466,404 km travelled, there are higher values of the thickness of the brake pads and brake discs on the front and rear axles of the bus due to their replacement during a previous check of the technical condition of the brake system.

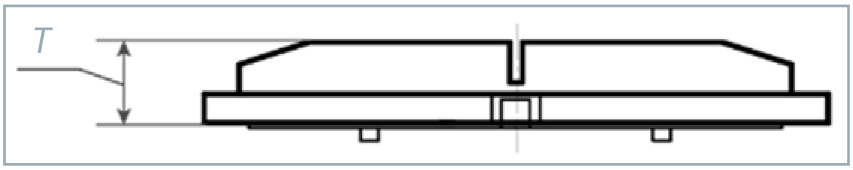


**Fig. 4** Measuring the thickness of the brake pad

**Table 5** Values of the thickness of brake pads on vehicle 1

| Mileage run (km) | Thickness of brake pads *T* (mm) | | | |
|---|---|---|---|---|
| | 1st axle | | 2nd axle | |
| | left side | right side | left side | right side |
| **371,214** | 17.3 | 17.5 | 16.2 | 16.5 |
| **406,893** | 16.2 | 16.3 | 14.5 | 14.6 |
| **435,911** | 10.7 | 11.6 | 7.9 | 11.8 |
| **466,404** | 19.6 | 19.4 | 19.8 | 19.7 |
| **492,548** | 18.1 | 18.1 | 19.4 | 19.4 |

**Table 6** Values of the thickness of brake discs on vehicle 1

| Mileage run (km) | Thickness of brake discs *D* (mm) | | | |
|---|---|---|---|---|
| | 1st axle | | 2nd axle | |
| | left side | right side | left side | right side |
| **371,214** | 40.1 | 40.4 | 40.8 | 40.6 |
| **406,893** | 39.2 | 39.4 | 39.5 | 39.7 |
| **435,911** | 38.5 | 38.6 | 38.7 | 38.8 |
| **466,404** | 44.5 | 44.7 | 44.8 | 44.6 |
| **492,548** | 43.5 | 43.2 | 43.6 | 43.7 |

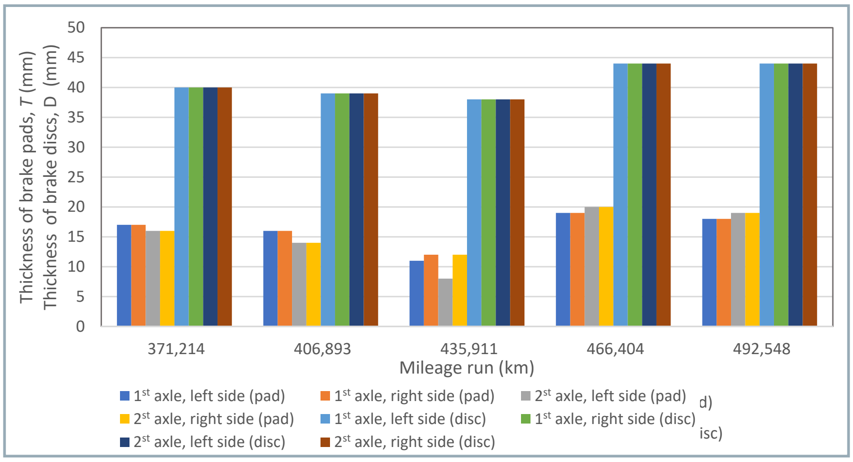


**Fig. 5** Graphic evaluation of the wear of brake pads and discs on vehicle 1

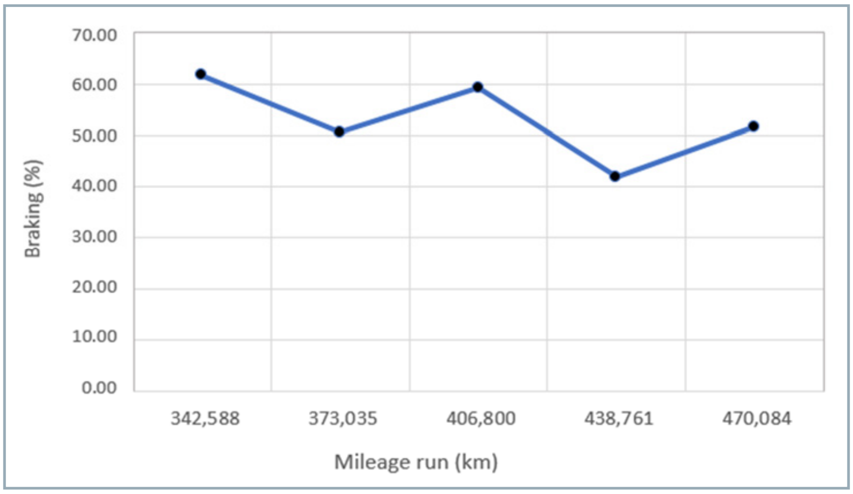


**Fig. 6** Graphic dependence of the percentage braking and mileage of vehicle 2

In Fig. 5, it is possible to see the linear wear of the brake pads and discs up to the mileage of 435,911 km where lower maximum values of braking forces were detected during the technical inspection, which was caused by damage to the brake calliper control mechanism and increased wear of the brake pads.

In case of the second measured IVECO Crossway intercity bus with a current mileage of 470,084 km, regular inspections of the technical condition of the brake system were also carried out after approximately 30,000 km. In Table 7, the braking forces on the front and rear axles of the bus are recorded. During the operational measurement when checking the technical condition of the braking system with a mileage of 438,761 km, insufficient braking forces were measured. In Fig. 6, when calculating the braking, a value of 41.93% was calculated, which is less than the value of the minimum braking according to applicable legislation. This condition was caused by the wear of the brake lining on the front axle, as shown in Tables 8 and 9. For that reason, the brake linings and also the brake discs were replaced on the front axle of the vehicle, the condition of which corresponded to the replacement based on the established methodology of the bus operator. For brake discs, according to service's internal regulation, the minimum

**Table 7** Values of the maximum braking forces and braking of vehicle 2

| **Parameter** | **Value** | | | | |
|---|---|---|---|---|---|
| **Mileage run (km)** | 342,588 | 373,035 | 406,800 | 438,761 | 470,084 |
| **Max. braking force on the 1st axle (kN)** | 23.02 | 17.11 | 19.56 | 15.52 | 21.92 |
| **Max. braking force on the 2nd axle (kN)** | 41.98 | 36.14 | 42.83 | 28.67 | 32.37 |
| **Braking (%)** | 61.67 | 50.52 | 59.19 | 41.93 | 51.51 |

**Table 8** Values of the thickness of brake pads on vehicle 2

| **Mileage run (km)** | **Thickness of brake pads *T* (mm)** | | | |
|---|---|---|---|---|
| | **1st axle** | | **2nd axle** | |
| | **left side** | **right side** | **left side** | **right side** |
| **371,214** | 13.3 | 13.4 | 19.2 | 19.5 |
| **373,035** | 12.5 | 12.6 | 18.3 | 18.6 |
| **406,800** | 11.2 | 11.8 | 17.4 | 16.7 |
| **438,761** | 10.1 | 10.3 | 13.8 | 16.1 |
| **470,084** | 19.3 | 19.5 | 12.2 | 14.3 |

**Table 9** Values of the thickness of brake discs on vehicle 2

| Mileage run (km) | Thickness of brake discs *D* (mm) | | | |
|---|---|---|---|---|
| | 1st axle | | 2nd axle | |
| | left side | right side | left side | right side |
| **342,588** | 40.7 | 40.8 | 44.6 | 44.7 |
| **373,035** | 40.2 | 40.4 | 43.5 | 43.3 |
| **406,800** | 39.6 | 39.7 | 42.6 | 42.7 |
| **438,761** | 37.9 | 37.4 | 42.1 | 42.2 |
| **470,084** | 44.2 | 44.4 | 41.4 | 41.5 |

Source: Authors

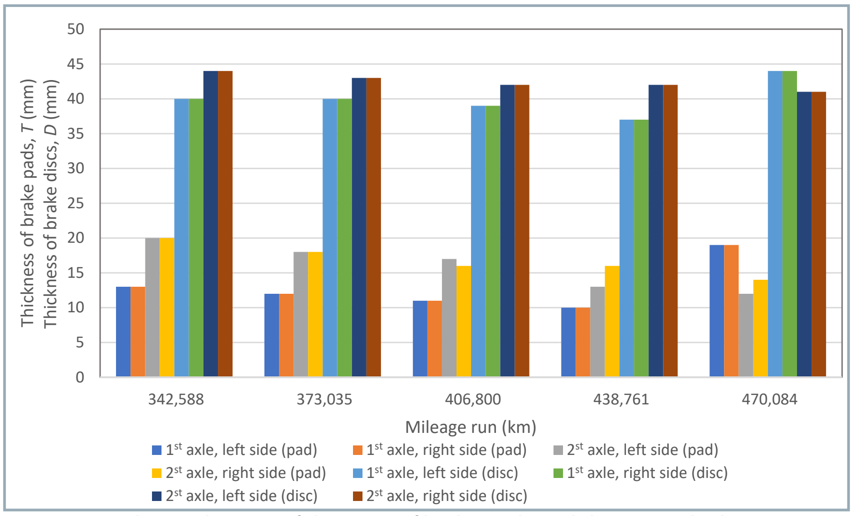


**Fig. 7** Graphic evaluation of the wear of brake pads and discs on vehicle 2

value of disc width for replacement is 36.5 mm.

In Fig. 7, it is possible to see the linear wear of the brake pads and discs up to the mileage of 438,761 km where lower maximum braking force values were detected during the technical check of the brake system due to the wear of the brake pads and brake discs. As stated by Świderski et al. (2019), Bogomolov et al. (2020), and Min et al. (2020), the wear of brake components and frequent exposure of friction groups to high temperatures for a long time with a stuck brake calliper has a great effect on the braking forces of the service brake. For this reason, it was necessary to check the extent to which the brake pads and discs are worn. According to Mačužić et al. (2015), Kolla et al. (2020), and He et al. (2023), when measuring the maximum braking forces on a roller brake tester, it is necessary to ensure that the braking of the wheel does not last longer than 10–15 seconds and also to ensure that the brake component does not heat up to a temperature of more than 80 °C because excessive heat generation will occur, which is the main factor in brake lining degradation.

## Conclusion

In the SOR C 10.5 vehicle, during the technical inspection performed at 435,911 km, damage was detected to the control mechanism of the brake calliper, which controls the movement of the brake pads on the front and rear axles. It had an impact on the values of braking forces from the roller brake tester. After recalculating the braking, it became clear that the vehicle does not comply with the minimum braking values set by legislation, and it was necessary to replace the brake discs and brake linings on both axles.

In the second IVECO Crossway vehicle, the wear of the brake discs and pads proceeded linearly. During the run of 438,761 km, the brake disc wore to limit values, while this wear was also demonstrated by a decrease in braking forces measured by the roller brake tester. Braking was insufficient, and it was necessary to replace the worn brake components of the front axle of the vehicle. Based on measurements and monitoring of the technical condition of the brake system, it can be concluded that, in case of a trouble-free operation of the brake system, the replacement of the brake pads is recommended after driving 180,000 km. Of course, the wear and tear of brake pads and brake discs is largely influenced by the operational use of the vehicle and the driving style of the driver, which cannot be evaluated objectively.

## References


BELOEV, I. 2021. Development and evaluation of personal urban concept vehicle powered by a hydrogen fuel cell. In Acta Technologica Agriculturae, vol. 24, no. 3, pp. 112–118. DOI: https://doi.org/10.2478/ata-2021-0019

BOGOMOLOV, V. – KLIMENKO, V. – LEONTIEV, D. – RYZYH, L. – SMYRNOV, O. – KHOLODOV, M. 2020. Improving the brake control effectiveness of vehicles equipped with a pneumatic brake actuator. In Science & Technique, vol. 19, no. 1, pp. 55–62. DOI: https://doi.org/10.21122/2227-1031-2020-19-1-55-62

GERLICI, J. – KRAVCHENKO, K. – HAUSER, V. – GORBUNOV, M. – LACK, T. – MOGILA, V. 2020. Innovative technical solutions to improve the cooling efficiency of friction brake elements. In GOPALAKRISHNAN, K. – PRENTKOVSKIS, O. – JACKIVA, I. – JUNEVIČIUS, R. (eds). TRANSBALTICA XI: Transportation Science and Technology. TRANSBALTICA 2019. Lecture Notes in Intelligent Transportation and Infrastructure. Cham : Springer, pp. 341–349. DOI: https://doi.org/10.1007/978-3-030-38666-5_36

HE, Y. – WANG, Y. – WU, F. – YANG, R. – WANG, P. – SHE, S. –

REN, D. 2023. Temperature monitoring of vehicle brake drum based on dual light fusion and deep learning. In Infrared Physics and Technology, vol. 133, article no. 104823. DOI: https://doi.org/10.1016/j.infrared.2023.104823

HUANG, W. – FAN, Y. – YU, M. 2020. Research on loaded brake performance test of trucks. In International Journal of Heavy Vehicle Systems, vol. 27, no. 5, pp. 648–662. DOI: https://doi.org/10.1504/IJHVS.2020.111256

KOLLA, E. – ONDRUŠ, J. – GOGOLA, M. – ŠARIĆ, Z. 2020. Braking characteristics of the specified modern electric vehicle during intensive braking. In Advances in Science and Technology Research Journal, vol. 14, no. 3, pp. 125–134. DOI: https://doi.org/10.12913/22998624/122197

KUCHAR, P. – JANOŠKO, I. – HOLÚBEK, M. – ČEDÍK, J. – PEXA, M. 2022. The accuracy assessment of devices used for distance measuring in dynamic vehicle tests. In Acta Technologica Agriculturae, vol. 25, no. 3, pp. 150–156. DOI: https://doi.org/10.2478/ata-2022-0023

LEONTIEV, D. N. – BOGOMOLOV, V. A. – KLYMENKO, V. I. – RYZHYH, L. A. – LOMAKA, S. I. – SUHOMLIN, A. V. – KURIPKA, A. V. – FROLOV, A. A. 2022. About braking of wheeled vehicle equipped with automated brake control system. In Science & Technique, vol. 21, no. 1, pp. 63–72. DOI: https://doi.org/10.21122/2227-1031-2022-21-1-63-72

MAČUŽIĆ, S. – SAVELJIĆ, I. – LUKIĆ, J. – GLIŠOVIĆ, J. – FILIPOVIĆ, N. 2015 Thermal analysis of solid and vented disc brake during the braking process. In Journal of Serbian Society for Computational Machines, vol. 9, no. 2, pp. 19–26. DOI: https://doi.org/10.5937/jsscm1502019M

Mădălin-Florin, P. – NICOLAE, V. 2019. Study of brake system parameters for commercial vehicles. In BURNETE, N. – VARGA, B. (eds). Proceedings of the 4th International Congress of Automotive and Transport Engineering (AMMA 2018). Cham : Springer, pp. 686–694. DOI: https://doi.org/10.1007/978-3-319-94409-8_80

MILLER, J. I. – CEBON, D. 2010. A high performance pneumatic braking system for heavy vehicles. In Vehicle System Dynamics, vol. 48, no. 1, pp. 373–392. DOI: https://doi.org/10.1080/00423111003774472

MIN, K. – YEON, K. – JO, Y. – SIM, G. – SUNWOO, M. – HAN, M. 2020. Vehicle deceleration prediction based on deep neural network at braking conditions. In International Journal of Automotive Technology, vol. 21, pp. 91–102. DOI: https://doi.org/10.1007/s12239-020-0010-2

MOHAMMED, A. Q. – HUSSAIN, I. Y. – ALI, A. H. – ABDULLAH, O. I. 2023. Experimental and numerical analysis for thermal problem of frictional brake system. In Computational Thermal Sciences: An International Journal, vol. 15, no. 4, pp. 55–68. DOI: https://doi.org/10.1615/ComputThermalScien.v15.i4.50

MONDAL, S. – NANDI, A. 2023. Improvement of braking system towards maintaining constant brake pedal feel during vehicle deceleration. In Journal of the Brazilian Society of Mechanical Sciences and Engineering, vol. 45, article no. 237. DOI: https://doi.org/10.1007/s40430-023-04146-5

POPA, M. F. – CAPĂTĂ, M. S. D. – BURNETE, N. 2020. Experimental research on brake behavior for different types of commercial vehicles. In DUMITRU, I. – COVACIU, D. – RACILA, L. – ROSCA, A. (eds). 30th SIAR International Congress of Automotive and Transport Engineering. SMAT 2019. Cham : Springer, 406–413. DOI: https://doi.org/10.1007/978-3-030-32564-0_48

KUMAR, V. V. – KUMARAN, S. S. 2019. Friction material composite: types of brake friction material formulations and effects of various ingredients on brake performance – a review. In Materials Research Express, vol. 6, article no. 082005. DOI: https://doi.org/10.1088/2053-1591/ab2404

SLOVAK REPUBLIC. Act no. 74/2018 Methodical instruction for carrying out inspections of brake systems of vehicles of categories M2, M3, N2, N3, O3 and O4 during technical inspections.

STRAKY, H. – KOCHEM, M. – SCHMITT, J. – ISERMANN, R. 2003. Influences of braking system faults on vehicle dynamics. In Control Engineering Practice, vol. 11, no. 3, pp. 337–343. DOI: https://doi.org/10.1016/S0967-0661(02)00301-5

ŚWIDERSKI, A. – BORUCKA, A. – JACYNA-GOŁDA, I. – SZCZEPAŃSKI, E. 2019. Wear of brake system components in various operating conditions of vehicle in the transport company. In Eksploatacja i Niezawodność – Maintenance and Reliability, vol. 21, no. 1, pp.1–9. DOI: https://doi.org/10.17531/ein.2019.1.1

TOMA, M. – ANDREESCU, C. – MICU, D. 2017. Comparative study on the lateral run-out of friction surfaces measurement of brake discs using a brake roller tester and a dial gauge. In MATEC Web of Conferences. 21st Innovative Manufacturing Engineering & Energy International Conference – IManE&E 2017, vol. 112, article no. 07010. DOI: https://doi.org/10.1051/matecconf/201711207010

WEI, L. – WANG, X. – LIU, H. – LI, L. 2022. System modeling, experimental validation and pressure estimation of the pneumatic braking system. In Mechanical Systems and Signal Processing, vol. 187, article no. 109938. DOI: https://doi.org/10.1016/j.ymssp.2022.109938

ZHANG, Z. – SUN, N. – CHEN, Y. – AHMADIAN, M. 2021. Detailed modeling of pneumatic braking in long combination vehicles. In SAE International Journal of Commercial Vehicles, vol. 14, no. 3, pp. 245–258. DOI: https://doi.org/10.4271/02-14-03-0020

ZHENG, H. – MA, S. – LIU, Y. 2018. Vehicle braking force distribution with electronic pneumatic braking and hierarchical structure for commercial vehicle. In Proceedings of the Institution of Mechanical Engineers, Part 1: Journal of Systems and Control Engineering, vol. 232, no. 4, pp. 481–493. DOI: https://doi.org/10.1177/0959651818757877

ZULHILMI, I. M. – HEERWAN, M. P. – ASYRAF, S. M. – SOLLEHUDIN, I. M. – ISHAK, I. M. 2020. Experimental study on the effect of emergency braking without anti-lock braking system to vehicle dynamics behaviour. In International Journal of Automotive and Mechanical Engineering (IJAME), vol. 17, no. 2, pp. 7832–7841. DOI: https://doi.org/10.15282/ijame.17.2.2020.02.0583