2. Dickerson, S.L., Lapin, “B.D.,Control of an omnidirectional robotic vehicle with Mecanum wheels”, in National Teleystems Conference Proceedings, p. 323-328, March 26-27, Atlanta, USA, 1991.
3. Mecanum wheels (Ilon wheel). – [Електронний ресурс] https://www.generationrobots.com/media/Mecanum-wheel-application.pdf

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IMPROVING THE SAFETY OF TRAMS BY IMPROVING THE STABILITY AND CONTROLLABILITY OF THE BRAKE

When designing vehicles, much attention is paid to active safety and braking control. Braking systems play an important role in ensuring safety.

Functionally, there are three braking modes:

service (under normal operating conditions);

emergency (for stopping in exceptional cases to prevent traffic accidents);

parking (to prevent uncontrolled movement under the influence of external forces).

Of great importance from the point of view of the operational performance of the brakes is the ability to brake without loss of stability of vehicles on the road surface. This question is also relevant when braking trams. But we are talking about maintaining their stability when braking on rails [1].

The following methods of braking are widely used in trams:

frictional, in which friction forces are created in braking mechanisms rigidly connected to wheel pairs;

electric, in which traction motors are switched to the mode of generators - current sources;

electromagnetic rail, in which the impact of brake shoes with electromagnets on the rails is carried out.

Trams operated in Belarus are equipped with the mandatory braking systems:

working (mechanical brake — drum pad or disc brake mechanism with a solenoid or hydraulic drive acting on braking — mechanical braking)

auxiliary (electric brake — electric braking);

additional (electromagnetic rail brake — magnetic rail braking).

With mechanical and electrical braking, the braking force is realized through the coupling of the wheels with the rails, since the mechanisms of these types of braking somehow affect the traction transmission and the wheelset of the tram.

Unlike railway, which is fenced off from traffic with the help of special technical means, the tram takes a mediocre part in it, especially in cases when the rail track is laid in the middle of the carriageway. In order to respond in a timely manner to constantly changing traffic conditions and road conditions, it is necessary to increase the amount of deceleration during braking and maintain it within relatively constant limits [2, 3].

There are two ways to do this:

1. Using electrical or mechanical braking, increase the coefficient of adhesion, for example, by feeding sand to the rails;

2. Apply other types of braking that realize the braking force without the participation of a pair of "wheel–rail".

The latter is possible only on rail transport and is achieved by using an electromagnetic rail brake, which allows you to realize a braking force that is not limited by the coupling of the wheel with the rail, and, in combination with other types of brakes, to develop high decelerations during emergency braking.

The effectiveness of the rail brake largely depends on the condition of the surface of the rails and the tips of the poles. With good contact of the tips with the surface of the rail head, the force of attraction is about 40..50 kN. With wavy and other types of rail wear, the force of attraction of the rail brakes decreases (sometimes by more than 2 times).

Under unfavorable traffic conditions caused by the polluted condition of the track, the adhesion of the tram wheels to the rails deteriorates sharply, while the tram is significantly subject to braking. It is known from practice that in order to remove the tram from the yuz, you can use the tram control method "re-braking", when the driver first turns off the braking mode, and its subsequent activation is performed with less braking force (braking current) and is accompanied by the supply of sand to the rails. However, in conditions of urban traffic, this method is not always justified and safe.

In this regard, it is more preferable in the event of a yuz is the use of a brake that constructively implements the braking force directly between the tram body and the rail track.

However, in many trams, the brakes are controlled as follows: the

electric brake is activated by installing the controller handle in the zone corresponding to the electric braking,

changing the angle of the controller handle within the electric braking zone, setting the desired value of the braking current is achieved;

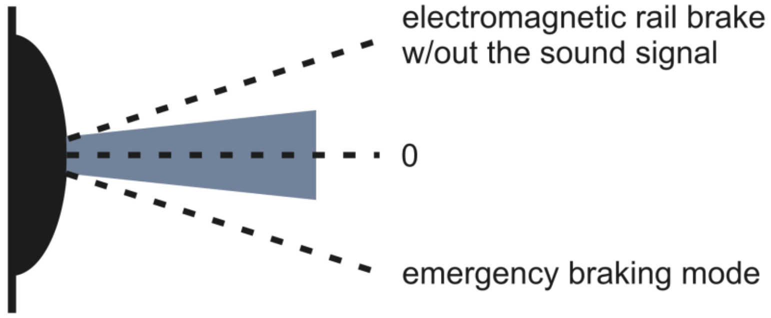
the mechanical brake is actuated by setting the controller handle to the mechanical braking position, which is located behind the electric braking zone, followed by switching the controller handle to the "0" position to achieve maximum braking effect (or by pressing the "brake" button on the driver's console);

the electromagnetic rail brake is activated only by setting the controller handle to the emergency braking position or when the safety pedal is released.

In the scheme of operation under consideration, when the electromagnetic rail brake is activated, electric braking occurs with the maximum setting of the braking current, mechanical braking and the electromagnetic rail brake itself are in full force, in addition, sand is fed to the rails and the bell is turned on. Due to the fact that the mechanical brake will act in full force, blocking the wheel pairs, it will contribute to the further development of the process of clutch failure and the formation of sliders on the surface of the rolling wheel. In addition, in existing tram designs, it is possible to disable the mechanical brake (operating at full strength) only by switching the tram into running mode. Thus, the use of an electromagnetic rail brake to remove the car from the yuz becomes ineffective: only magnetic rail braking will be carried out, while wheel pairs blocked by a mechanical brake will "slide" along the rails, failing.

In such a scheme of operation, the use of an electromagnetic rail brake is possible only in emergency braking mode. At the same time, the advantages of the rail brake are not used.

Considering the above, the solution of installing an independent electromagnetic rail brake control handle in the right part of the driver's console is relevant. The handle must have at least three positions. When installing the handle in the upper position, the electromagnetic rail brake must work (the sound signal is turned off). When installing the handle in the lower position, the emergency braking mode (electric brake, electromagnetic rail brake, sandbox) must be activated. It is also possible to provide additional positions of the handle, which will ensure the separate inclusion (on trolleys) of the shoes of the rail brake.



Picture 1 – Brake control handle

With the proposed scheme, in the case of service braking, it will be enough for the driver to apply braking with an electromagnetic rail brake for a short period of time, including it with short pulses, shifting the handle to the "up" position. As a result of a decrease in the speed of the tram, an artificial increase in its coupling weight, the tram will "exit the yuz", after which the use of an electromagnetic rail brake can be stopped.

To increase the reliability of the tram brake systems, it is also proposed to provide for the redundancy of the rail brake system by allocating and connecting control devices, actuators, coils of the rail brake shoes through additional circuit breakers directly to the tram battery.

The solution implemented in Minsk has justified itself and can be used in the design of other models of trams and their operation in other cities.

List of sources

1. Kapsky D. Predicting accidents in road traffic: monograph / Kapsky Denis. - Minsk: BNTU, 2008. - 242 p. - Text : direct.
2. Kapsky D. Methodology of improving the quality of road traffic / Kapsky Denis; Belarusian National Technical University. - Minsk: BNTU, 2018 - 370 p. - Text : direct.
3. Tram system of Minsk: problems and prospects / E. Kot, S. Semtchenkov, V. Romeyko // Socio-economic problems of development and functioning of transport systems of cities and zones of their influence: materials of the XXIV International scientific and practical conference / international editorial board: D. Kapsky (as chairman), etc. - Minsk: BNTU, 2018. - pp. 197-222.

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CLASSIFICATION OF ROUTE VEHICLES WITH ELECTRIC DRIVE AS THE BASIS FOR THE CHOICE OF VEHICLES TO WORK ON ROUTES

The development of the transport sector leads not only to positive changes in the life of cities and settlements, increasing convenience and comfort for residents, but also worsens the ecology and the environment of their residence. The "profitable-safe" dilemma can be solved by the approach of an environmentally oriented choice of the type of route passenger transport and decision-making in favor of electric route passenger transport. Therefore, the use of route vehicles with electric drive continues to gain popularity [1]. Currently, more than 100 electric buses of four models and about 1500 trolleybuses are in operation in the Republic of Belarus, including about 200 trolleybuses that have the ability to run independently from the overhead contact network, 300 trams.

Currently, the classification of route vehicles with electric drive is known, which provides for four main schemes:

1. Powered trolleybuses in motion (IMF) that need a contact network along the entire length of the route

2. Trolleybuses with charging in motion (IMC) and the possibility of autonomous running from the contact network