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SAFE OPERATION OF TRAINS WITH A DEVICE FOR CONTROLLING THE POSITION OF THE WHEELSET ON THE RAIL TRACK

Driving characteristics are the most important characteristics that determine the functional properties of passenger and freight cars. The driving performance indicators of cars mainly depend on their dynamic characteristics, but in each specific case, when it comes to compliance with traffic safety conditions, it is necessary to take into account the design features and the state of keeping the track.

One of the main indicators of driving performance for the rolling stock of the track 1520 mm is the derailment stability factor of the wheelset, which determines the conditions for the safe movement of the car to provide for conditions under which there is a threat of derailment of the wheelsets.

The design of the freight car bogie model 18-100 is considered and the reasons are investigated when the wheel can roll onto the rail head and the wheelset derails. That is, when the critical speed is reached, there is a direct threat to traffic safety. It has been established that in order to improve the smoothness of the movement of trains, reduce the intensive wear of the wheel flange and reduce the risk of wheels entering the rails, it is necessary to constantly monitor the position of the wheelset on the track.

In the study of the multifactorial problem of a car derailment, the question of the optimal ratio of geometric dimensions in the wheel-rail pair was also taken into account. The ratio of geometric dimensions between the rail track and the wheel track determines the conditions for the movement of the crew in straight sections of the track and the conditions for their fitting into curved sections.

Based on the results obtained, a design and technological solution is proposed - a device for monitoring the position of the wheelset on the track, which will monitor and timely assess the position of the wheelset on the track, as well as identify the mechanical risks of rolling stock derailment to improve traffic safety. The proposed approach to assessing the risk of rolling stock derailment is recommended to be used to quickly determine the significance of derailment factors and form reasonable requirements and real actions that ensure a guaranteed level of train traffic safety.

Key words: *railway transport, freight car, spring suspension, wheel set position, traffic safety.*

Relevance of the research. Railway transport of Ukraine is the most important in the transport and road complex, which provides the main volume of cargo and passenger transportation. Today, Ukraine ranks third in Europe for the length of the railway network (22,05 thousand km). The Ukrainian railway network is the most extensive on the eastern part of the country as well as on the western part of the country. Total length of railway lines of general use – 22,3 thousand km, of which 10,1 thousand km are electrified, 8,5 thousand km are double- and triple-track. There are six main railway lines in Ukraine, which run through all regions of the country. In terms of transportation volumes, Ukrainian railways rank fourth on the Eurasian continent, behind China, Russia and India. The load factor (annual tonnage transported per 1 km) is 3-5 times higher than that of the developed European countries [1, 2].

The leading role of railway transport in the unified transport system of Ukraine will remain for a long time to come. Ukrainian railways, as the national carrier of mass shipments, have unrivaled advantages in terms of speed and regularity of communication, low costs of transport services, high level of safety and minimal negative impact on the population.

Statement of the problem. The priority task of Ukraine is the realization of its transport potential as a land bridge between Europe and Asia. The strategic focus is the export of transport services, not the wealth of production. That is why the development of international transport corridors in Ukraine is considered to be the main way of integration of Ukrainian railways into the international transport system. The new system of criteria for safe operation of rolling stock (locomotives, passenger and freight cars) was developed taking into account the experience of numerous field tests under various operating conditions.

The most important characteristics that determine the functional properties of the wagons are their running properties. Indicators of car performance mainly depend on their dynamic characteristics. At the same time, it should be noted that in each particular case, when it comes to compliance with the running safety conditions, it is necessary to take into account the design features and the condition of the stake keeping.

Objective of the work. Conducting research to identify the main causes of derailment of the wagon, the need for continuous monitoring of the position of the wheelset on the track wheels and, based on the results obtained, to develop a device for monitoring the position of the wheelset on the track wheels, which will control and independently evaluate the position of the wheelset on the rail track, as well as identify the mechanical risks of the driving stock drift from the rails to improve the safety of driving.

The main material of the research. One of the main indicators of driving performance for the manual stock of 1520 mm wheels is coefficient of stability of the wheelset from the rail k_{st} (for the conditions of the incursion of the wheel on the head of the rail) [3].

The coefficient of stability of the wheelset against derailment from the rails is used k_{st} determine the safety conditions of the car operation. For the conditions, in which there is a risk of the wheelsets derailing from the rails, their stability in the railroad track is checked by the value of k_{st}

Allowable values of the coefficient of stability coefficient of the wheelset from the rails $[k_{st}]$ are accepted as equal [4]:

- for thermal-thermal wagons $[k_{st}] = 1,4$;
- for other freight cars $[k_{st}] = 1,3$.

For 60 years now, domestic freight cars have been equipped with bogie 18-100. This three-element unit (Fig. 1) has been tested over time and is widely used due to its advantages, which in conditions of mass production of railcars have a decisive influence on the choice of technical solutions [1, 4, 5, 7].

The advantages of the 18-100 models are as follows:

- simple design and, therefore, relatively low cost of production;
- high maintainability;
- The standard level of unification and standardization of parts.

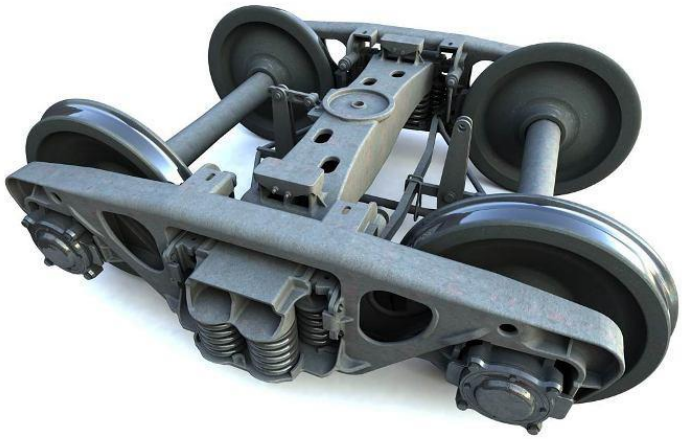

Fig. 1. Freight car bogie model 18-100

However, the desire to simplify the design of the vehicles as much as possible led to some shortcomings of a principle character, which turned out in the further operation. Of course, every transport accident is associated with the result of a number of unpleasant conditions, however, the main reason is always present. Low margin of safety of freight cars from derailment is often caused by their unsatisfactory dynamic properties. The latter is mainly due to the design features and technical condition of Model 18-100 railcars, on the basis of which many modern railcars were designed and built.

The significant discrepancy in the parameters of the reshoring suspension in relation to the size of the unrestricted support in the nodes of the dry bore is one of the most significant disadvantages of the bushings. Resor set (Fig. 2) of the model 18-100 is composed most often of seven double cylindrical springs.

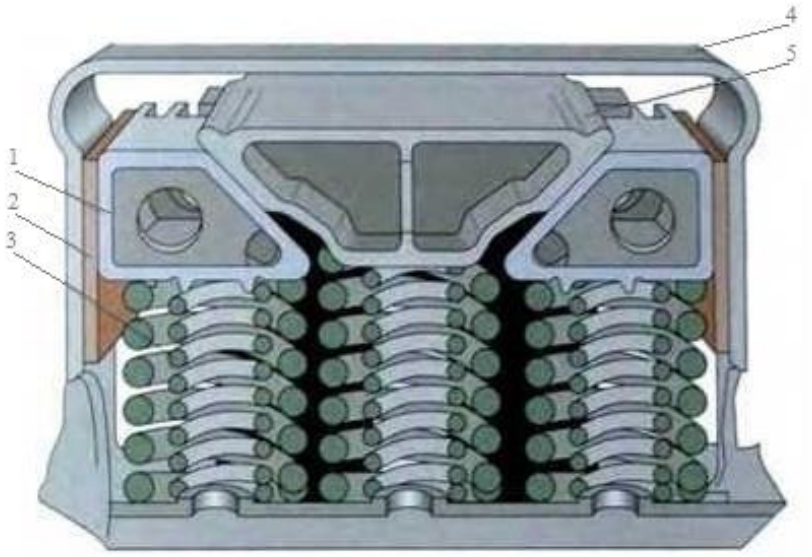

Fig. 2. Reshorn suspension of the loader of the freight car model 18-100

1 - friction wedge, 2 - friction bar, 3 - reshoring set, 4 - beam frame, 5 - suprasail beam

The middle row edge springs support the torsion damper wedges, which interact with the friction bars of the sides and the bent surfaces of the superstructure beam. The wrestling of the wedge damper is of open type. That is why the processes in the friction contact zone are significantly influenced by external conditions - humidity, temperature, filtration. As a result of these circumstances there is a significant variability in the values of the rubbing coefficient. Therefore, on the one hand, at low travel speeds in some cases, the reshorn suspension appears to be blocked through excessive rubbing in the wedge damper. The wedge damper then does not work as a shock absorber, but as a shock absorber when the operating force is increased, without properly performing the vibration functions.

On the other hand, the wedge system is weakened by wear and tear of the wear couples (friction bar, vertical and bent wedge faces, surface of supra-corner beam). And when empty, the strut can partially or completely lose its damping properties due to weakening or complete exclusion from work of the vibration dampeners. This changes the rigidity of the drive's suspension in a downward direction. For example, if the nominal stiffness of the suspension (one set) of the drive is 8490 kN/m, with unloaded wedge springs decreases to 6060 kN/m [6]. As a consequence of this the intrinsic frequency of vertical wagon wobbling - galloping and bouncing - decreases. Also, velocity of motion decreases, at which unnecessary negative phenomenon - resonance occurs.

Periodic turbulence, which causes resonance modes of railcars, is caused by both periodic nerves of wheels and defects of wheels such as rolled nerves, damage, bruises, welds, etc. Under operating conditions such defects often occur on the surfaces of wheels bending. Therefore, in the spectrum of stresses that affect the wagon, there are always some components with the frequency of turning of the wheelsets. These components, even at permissible defects of the wheels are sufficient for development of resonance phenomena, when the speed of car movement reaches critical value at the time of convergence of frequencies of wheel pair wrapping *fK* with one of natural frequencies *fi*, i.e. *fK = fi*.

The most dangerous for an empty car is the speed range of the train, when resonance modes occur. This leads to the complete loosening of the wheels through a lack or absence of damping. Then under the influence of horizontal frame forces there is a real danger of wheelsets derailing from the rails. At a certain gap of horizontal loads acting on the wheelset, one of the wheels crests begins to move down on the side face of the lath, and the wheel can tilt over the lath head.

Thus, one of the causes of the van derailing (especially in empty state) is the appearance of resonance modes through the loosening of the V-belt suspension system of the car.

Another principal disadvantage of the design of the 18-100 railcar is the fact that its design scheme and parameters do not meet the requirements of the car stability, the critical speed is low. The critical speed of the car is the speed at which its run becomes unstable through the formation of non-negative fluctuations in the horizontal plane.

On a straight track wheels as a result of consistency of wheels receive transversal displacement and the order of driving along the wheel performs folding motion on the vertical axis [3]. Such a complex motion is called twisting or wiggling in the plan. Since the link between the overhang beam and the lateral frame is not sufficiently tight, at relatively low running speed (for an empty car within 70 km/h) horizontal oscillations of the running parts are self-excited, which have the nature of autocollisions. Stability of driving is lost and the phenomenon, unlike resonance, does not disappear with increase of driving speed. However, the intensity of autocollisions of the rolling stock, as a rule, increases with speed increase and even increases due to the influence of nerves of the collision. When there is a loss of steadiness on a straight track, the wheel crests are constantly hitting the vertical sides of the rails. Transverse frame forces are substantially increased. In the crash the wheel may run into the lath head and the wheelset will be disconnected from the lath. Thus, when the critical speed is reached, there is a direct threat to the safety of driving [8, 9].

Moreover, the order of resonance modes in conditions of insufficient or absent damping, self-driven horizontal oscillations of the running gears pose a serious threat to the safety of the vehicle. Together these two factors are the most likely cause of derailment of the wagon from the rails.

The probability of overturning increases for some cars, such as tanks, due to their design features - high center of mass, short base.

Another, no less serious, problem of wagon derailment is the result of the work of lateral restraining forces in the train. It affects empty or not fully loaded cars. The train is a complex mechanical system in which there are dynamic processes caused by a number of factors - changes in the locomotive traction force, the profile of the train, the galvanizing processes, gaps in the elements of the motorized equipment.

Delivery wagons are equipped with non-corrosive motor vehicles. The longitudinal axles of two of these coupled cars are arranged in a vertical plane and are positioned in steps. As a result, the great positive force, which is transmitted in the train from the neighboring car or locomotive, is divided into vertical and transverse components. Because of this reason empty or not fully laden car, which has less gross weight compared with laden, in the course of the train tilts at the rail wheels, its wheels are lifted over the rails. The wheel crests are knocked onto the laths and their further displacement from the laths occurs. Such picture was repeatedly recorded by experimental investigations [8].

The process of empty car derailing from the rails is also facilitated by the circumstance that the wedge damper of the carriage body jerks hard to absorb the lateral dynamic forces, which are transmitted to the runway from the body of the car [7]. On a curved section of the stake the probability of this negative phenomenon increases, because there is an additional transverse horizontal force *PN*, which is applied to the car frame in the area of the rear thrust couplers of the car body.

In addition to the named factors that contribute to the derailment of the car from the racks, the scheme of the train shaping should be included. The most unpleasant scheme is when all empty or low-loaded cars are located in the

main part near the locomotive. It is more favorable to have empty cars behind the loaded cars with a greater gross weight in the rear part of the train. In this case, the empty cars will be subjected to considerably reduced posture forces, although the weight of the train remains unchanged.

As shown by the research [3, 6, 8], the highest values of compression forces in the train only due to its heterogeneity (both empty and loaded cars in the composition of the train) increase by 35-45 %. When the train is galvanized, with the gaps of automobile equipment within 65 mm, the compression force is two to three times greater than when the gaps are absent.

Thus, in the case when the empty or low-loaded car is dislodged from the train and its further displacement from the rails, it is the great compression forces, but not the speed of the car's movement that are decisive [4].

Considering the big factor problem of carriage derailment, it is necessary to take into account the optimal ratio of geometrical dimensions in the «wheel-rail» pair (fig. 3).

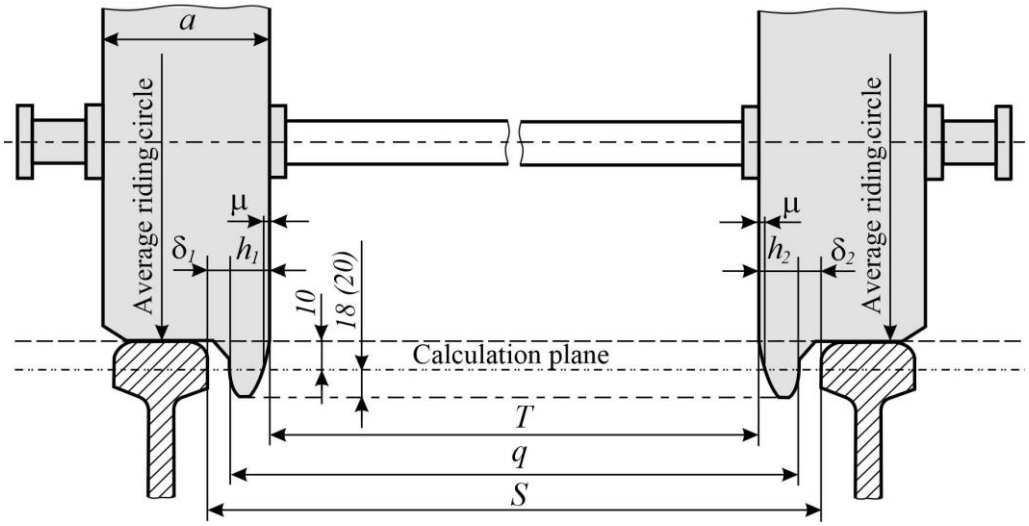

Fig3. Scheme of the position of the wheel pair on the rail track

However, it should be noted that the introduction of the standard of the stake width S=15209(+6,-4) mm instead of S=1524(+6,-4) mm in the straight sections of the stake and curves of radius R>350 m was introduced on the USSR railways in 1971 after a long-lasting research of the scientists, carried out together with the operating specialists. The main result of this implementation was the improvement of conditions of interaction between the rail wheels and the rolling stock pairs at the expense of the reduced clearances between the wheels and the rails, which resulted in the reduction of transverse displacements of the rolling stock at operation.

The ratio of geometrical dimensions between the rail wheel *S* and wheel *q* (Fig. 3) determines the driving conditions of the vehicle in straight sections of the wheel and conditions of their writing into curves of the sections. That is why the conventional term «wheeled stake» [4] was introduced. In essence, the distance between the outer faces of the wheels of one wheel pair. The size *q* is taken in the horizontal dimension at 18 mm from the top of the wheel crest (Fig. 3).

The sizes *S* and *q* are determined by formulas:

$$S = q + \delta_c \tag{1}$$

$$q = T + 2d + 2\mu - \varepsilon_q \tag{2}$$

de δ_c is the marginal clearance between the wheels crests and the working vertical faces of the rails;
T - distance between the inner faces of the wheels;
d - thickness of the comb at 18 mm from the top;
μ - structural size, μ = 1 mm;
ε_q - sounding of the wheelset due to their bending at the action of the load from the loaded body. For freight cars ε_q = 3-4 mm.

The difference between the rack and the stake is δ_c:

$$\delta_c = \delta_1 + \delta_2 \tag{3}$$

δ_1, δ_2 - clearances between the working faces of the laths and the first and other wheels accordingly.

At different normative ratios of the lath width (from S_{max} to S_{min}) and laths (from q_{max} to q_{min}) there will be minimum δ_{min} and maximum clearances δ_{max} between the laths and laths:

$$\delta_{max} = S_{max} - q_{min} = S_{max} - (T_{min} + 2d_{min} + 2\mu - \varepsilon), \tag{4}$$

$$\delta_{min} = S_{min} - q_{max} = S_{min} - (T_{max} + 2d_{max} + 2\mu). \quad (5)$$

(for the calculation δ_{min} the soundness of the wheel pair is ε_q assumed to be equal *0*).

$$\Delta = \delta_{max} - \delta_{min} . \quad (6)$$

The change in the clearance size determines the behavior of the manual stock in the bellows. The greater the clearance value δ_{max} (and accordingly the greater Δ), the greater lateral displacement and wiggling of the rolling stock in the collar. In practice, the smallest value of the minimum clearance between the wheel crest and the operating face of the rail will be at one of the wheelset crests pressed against the rail, i.e. $\delta_{min} = 0$. Therefore, practically transverse displacement and twisted rotation of the wheelset will be carried out within the range of change of clearance from δ_{min} to δ_{max}.

When designing the rail wheels it is necessary to reduce the clearance value between the wheels and rails, so it is necessary to introduce more rigid tolerances on the geometric dimensions of the width of the wheels (*S*) and the wheelset (*T, d, q*). This is especially important when designing the rail track for high travel speeds because these lines have the toughest requirements for smooth running, i.e. for horizontal and vertical displacements and acceleration.

Design tolerances for the width of the wheelset nozzle are rather tight: T = 1440±3 (at travel speeds V<120 km/h). Therefore, the main parameters due to which the smoothness of the vehicle can be improved (relative to the transverse displacement and swivel) when implementing the high-speed running, is the width of the rail track *S*, tolerances for its size and the ratio of its size to the dimensions of the wheel track *q*, which varies over time depending on the change in the thickness of the comb *d*.

The width of the wheel track *q* can significantly change from q_{max} to q_{min} when the drift of the wheels from the nominal thickness d_0 = 33 mm to the minimum thickness d_{min} = 25 mm (for travel speeds V=120 km/h) or to d_{min} = 28 mm (for travel speeds V=120-140 km/h) [4].

The analysis of the correlation between the sizes of the rail and railway stake on foreign and domestic railways shows, The domestic standards for the construction of the railroad stake and the size distribution of the stake and railroad stake are the best, because they create the greatest opportunities for cross-section wobbling of the rolling stock.

In current world practice, the maximum clearance between the wheels and bars δ_{max} is 28-31 mm (Germany - 30 mm, Hungary - 28 mm, Czech Republic and Slovakia - 31 mm, France - 30 mm, Japan - 31 mm). The value of the minimum clearance δ_{min} on foreign railways is 6-7 mm. Thus the variation of clearance Δ between wheels and rails on European railways is 22-25 mm, and the maximum clearance, within which the transverse displacement and wagging of the carriages takes place, Δ_{max} = 28-31 mm.

On the domestic railroads there is such a ratio of dimensions:

1) with the width of the stake that existed before 1971 *S* = 1524(+6,-4) mm:

- the maximum clearance δ_{max} for the van cars is 44 mm;
- minimum clearance δ_{min} = 9 mm;
- maximum gap change δ_{max} = 44 mm;

2) at the width of the stake *S* = 1520(+6,-4) mm set in 1971:

- maximum clearance δ_{max} = 40 mm;
- minimum clearance δ_{min} = 5 mm;
- maximum gap change δ_{max} = 40 mm.

Thus, when the new stake width *S* = 1520 mm (instead of *S* = 1524 mm) was introduced in 1971. The new stake width *S* = 1520 mm (instead of *S* = 1524 mm) with the same +6, -4 mm tolerances as before, the clearances for lateral displacements and the rolling stock were reduced by 4 mm, But they remained very large compared to the foreign lines (δ_{max} = 40-39 mm on the Ukrainian lines, as opposed to δ_{max} = 30-31 mm on the foreign ones). The clearance for lateral displacement and wiggle δ_{max} on the domestic railways at the width of the stake 1524 (+6,-4) mm was initially adopted by 13-14 mm more than foreign, but when the introduction of the stake 1520 (+6,-4) mm, this gap remained greater than that of the foreign lines at 9-10 mm.

In 1996 the Ukrainian railways (since 19.11.1996) without sufficient technical and economic conditions were set even larger (compared to the previous one) tolerances for the rack-wheel width *S* = 1520(+8,-4) mm [4]. With the new normative parameters for the rail track bar width *S* which remained unchanged since 1996 the railways began to have such a correlation of the rail track bar dimensions and rail track bar dimensions:

- maximum clearance δ_{max} = 42 mm;
- minimum clearance δ_{min} = 5 mm;
- maximum gap change δ_{max} = 44 mm.
- maximum clearance δ_{max} = 42 mm;
- minimum clearance δ_{min} = 5 mm;
- maximum gap change δ_{max} = 44 mm.

Therefore, when the new tolerances of +8,-4 mm were introduced, the conditions for the movement of the rolling stock deteriorated and came close to the movement conditions at the old width with the size *S* =1524 (+ 6,-4) mm. At the same time the clearance for lateral displacement and wiggle δ_{max} was 10-12 mm greater than the foreign norms. But almost simultaneously with the introduction of new tolerances +8, -4 mm to the width of the rail wheels Ukrzaliznytsia

introduced a permit (18.09.1995) to operate the wheels of freight cars with the smallest possible thickness of the comb of one of the wheelset d_{min} = 23 mm with the maximum thickness of the comb d_{max} = 33 mm. At the same time, the width of the minimum wheelset q_{min}decreased by 2 mm and became equal to q_{min}=1484 mm. As a result, the value of the maximum clearance between the wheels and the rails for the van wagons decreased to the size δ_{max} = 44 mm. Thus the conditions for the smooth running of the freight cars in the rail track at implementation of the minimum thickness of the wheel comb d_{min} = 23 mm have reached the absolute best level in comparison with all previous standards existing on Ukrainian railways.

The maximum clearance δ_{max} = 44 mm is more than half of the rail head width, which is 13-16 mm worse than the foreign standards. This is inadmissible for normal and safe operation of the rolling stock. With such standards are extremely large transverse oscillation of the wagons during driving, there is a danger of penetration of wheels comb on the rails and the subsequent derailing of rolling stock, there is wear of the wheels and rails. Therefore, in order to improve smooth running of trains, decrease intensive wheel crest wear and reduce the risk of wheels driving into the lane, it is necessary to constantly control the position of the wheelset on the lane wheels [4, 7, 8, 10].

For an essential solution of this problem, we propose a device for controlling the position of the wheelset on the rail [11, 12, 13, 14], the general view of which is shown in Fig. 4.

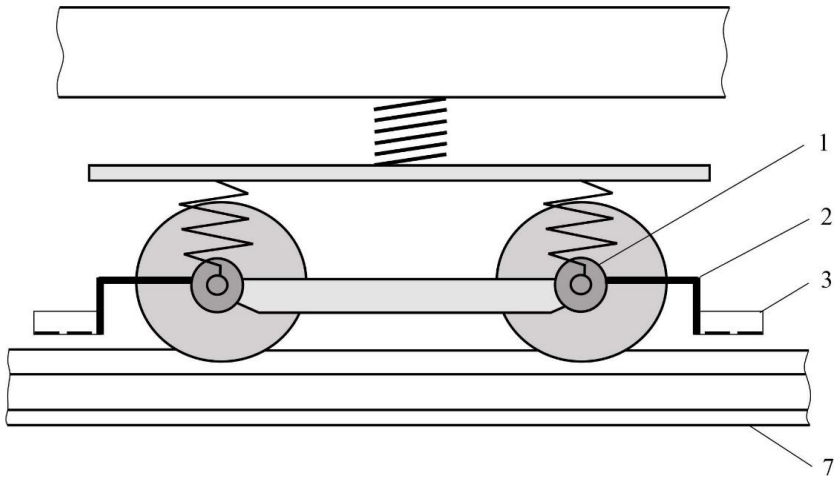

Fig. 4. General view of the device for controlling the position of the wheelset on the rail track

The device for control of the wheelset position on the rail wheels consists of rigid frames 2 attached to the axle box 1, on which the sensor boxes 3 are bolted together. Impeller plates 4 and 5 and vortex-jet transducer 6 are mounted in the grooves of the sensor boxes 3. Impeller plates 4, 5 are positioned against the rail head 7, and vortex-jet transducer 6 is in the center of the rail head 7. Each of the flange plates 4, 5 creates a capacitor on the surface of the rail 7 (Fig. 5).

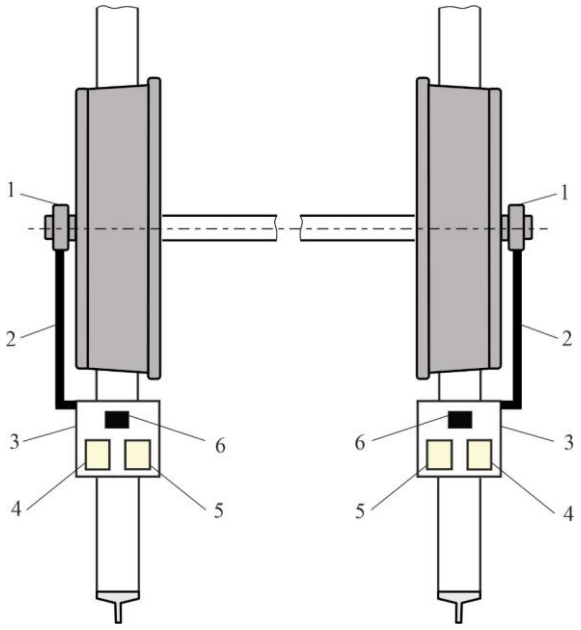

Fig. 5. Schematics of installation of elliptical plates and vortex-jet transducer in sensor boxes

Annular plates 4, 5 are interconnected with the total-receiving unit 8 of the measuring apparatus, which includes blocks 9, 10, 11 and 12 that register the wheel pair integral displacement (block 9), the side rotation of the wheel pair in

the horizontal plane (block 10), distance between the rail heads (sub-unit 11) and the gap between the non-contact transducers and the surface of the rail head 7 (sub-unit 12) as well as the generator with an electronic knob 13 and houses the arrester system 14 (Fig. 6).

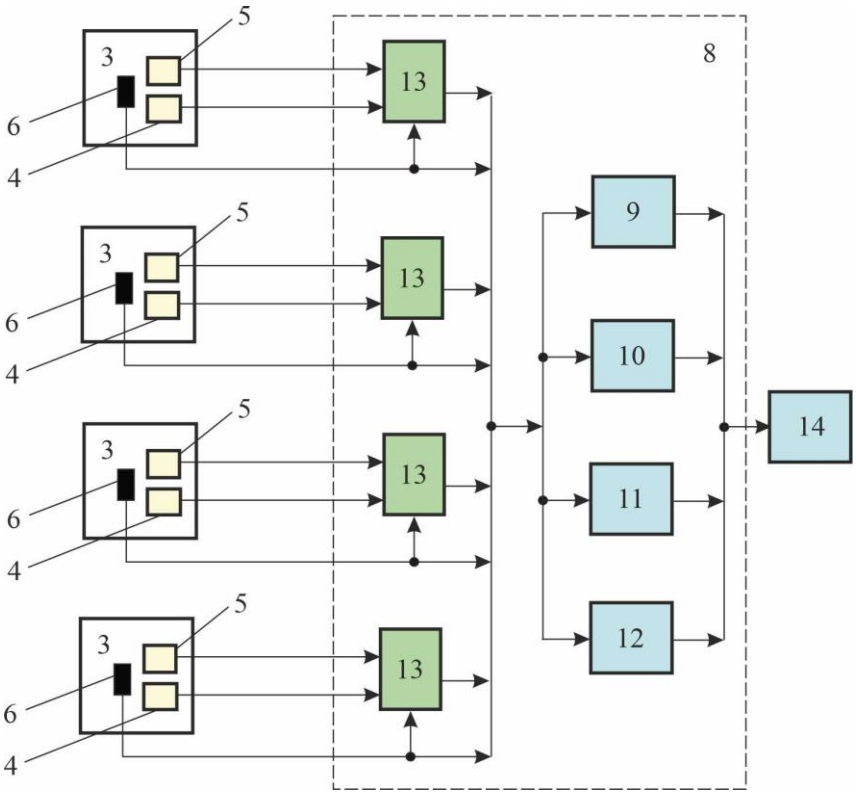

Fig. 6. Functional block diagram of the device

While driving the rail vehicle, the rigid frame 2 design allows adjusting the position of induction plates 4, 5 and vortex-jet converter 6, which are fastened in the transducer boxes 3 by means of bolted connections, in three directions: towards the track axis, across the track axis, as well as the height control in relation to the heads of laths 7. Impulse plates 4, 5 are attached to the generators, which feed vibrations to the electronic module 13. The principle of operation of the transformer is based on the change of electric capacitance of the capacitor created by the taper surface of the lath 7 and capacitor plates 4, 5 placed above it. When the capacitor plates 4, 5 are moved relative to the rail head 7, the value of one capacitance increases and the other one decreases in the horizontal plane. Thus, the capacitance plates 4, 5 indicate the displacement of the wheelset in the horizontal plane. Then, signals from the electronic knobs 13 are fed to the inputs of the drive units 9, 10 and 11, whose outputs form the constant flow voltage proportional to the linear displacement of the symmetric plates 4, 5. Vortex-jet transducer 6 measures the size of the gap between the transducers and the surface of the rail head 7. At this, when the gap is increased and the wheel pair is in one-time shimmy, the Vortex Imager 6 generates a signal, which is fed to the gain control input of the electronic knob 13, electronically compensating for the increase in the gap and automatically reducing the level of information signals. In addition, this signal from the output of the twin-screw transducer 6 goes to the unit 12, which additionally registers the gap between the non-contact transducers and the surface of the rack head 7, which can occur when the wheel crest hits the surface of the rack head 5.

Reaching the maximum value of difference between the capacities of both plates 4, 5 and a certain value of the gap indicates that the wheel rim is displaced from the rail head 7 by a critical distance. This is the reason for the alarm system 14 to signal a possible emergency situation due to the wheelset derailing from the rack and pinion. If this displacement reaches a critical value, the galvanic traction system is automatically actuated.

Conclusions. The suggested design and technological solution which conceptually controls and assesses the position of the wheelset on the rack and also identifies the mechanical risks of the tire structure convergence from the racks in a proper way. It is recommended to use the suggested approach to assess the risk of the rolling stock convergence from the racks for operative determination of the significance of the convergence factors and formation of reasonable requirements and real actions to ensure the guaranteed level of safety of the trains [13].

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Ходові якості є найважливішими характеристиками, які визначають функціональні властивості пасажирських та вантажних вагонів. Показники ходових якостей вагонів головним чином залежать від їхніх динамічних характеристик, але у кожному конкретному випадку, коли йдеться про дотримання умов безпеки руху, необхідно брати до уваги конструктивні особливості та стан утримання колії.

Одним з основних показників ходових якостей для рухомого складу колії 1520 мм належать коефіцієнт запасу стійкості колісної пари від сходу з рейок, який визначає умови безпеки руху вагона для передбачення умов, за яких виникає загроза сходу колісних пар з рейок.

Розглянуто конструкцію візка вантажного вагона моделі 18-100 та досліджено причини коли колесо може вкотитись на голівку рейки і відбудеться схід колісної пари з рейки. Тобто, коли досягається критична швидкість, наступає пряма загроза безпеці руху. Встановлено, що для покращення плавності руху поїздів, зниження інтенсивного зносу гребеня колеса і зменшення небезпеки в'їзду коліс на рейки необхідно здійснювати постійний контроль положення колісної пари на рейковій колії.

При дослідженні багатофакторної проблеми сходу вагона з рейок, прийнято до уваги і питання щодо оптимального співвідношення геометричних розмірів у парі «колесо-рейка». Співвідношення геометричних розмірів між рейковою колією та колісною колією визначає умови руху екіпажа в прямих ділянках колії й умови їх вписування в криві ділянки.

На основі отриманих результатів запропоновано конструкторсько-технологічне рішення – пристрій для контролю положення колісної пари на рейковій колії, який буде контролювати та своєчасно оцінювати положення колісної пари на рейковій колії, а також ідентифікувати механічні ризики сходжень рухомого складу з рейок для підвищення безпеки руху. Запропонований підхід щодо оцінки ризику сходження рухомого складу з рейок рекомендовано використовувати для оперативного встановлення значущості чинників сходження та формування обґрунтованих вимог та реальних дій , що забезпечують гарантований рівень безпеки руху поїздів.

Ключові слова: *залізничний транспорт, вантажний вагон, ресорне підвішування, положення колісної пари, безпека руху.*

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