щей $P_{дин}$ жестко-ударного характера. Этим объясняется то, что применяемые и большое количество вновь разрабатываемых устройств, удерживающих тормозные колодки от наклона и опирания верхней кромкой в колеса, в эксплуатационных условиях показывают малый ресурс и, как правило, оказываются неэффективными.

Выполненные исследования позволили теоретически обосновать направления практического решения задачи, которые дали бы возможность устранить выявленные недостатки и создать принципиально новые технические предпосылки к модернизации тормозной системы для тележек грузовых вагонов (патент UA № 87764 от 10.08.2008).

Кафедра «Вагоны» Украинской государственной академии железнодорожного транспорта совместно с Крюковским вагоностроительным заводом проводит расширенные эксплуатационные испытания модернизированных тормозных систем тележек модели 18-100 на одном вагоне хоппер-дозаторной вертушки в течение четырех лет (пробег более 80 тыс. км) и на десяти полувагонах на протяжении более двух лет (пробег около 200 тыс. км). Периодические обследования тормозных систем этих вагонов и накопленный статистический материал доказывают их устойчивую работоспособность.

Гарантией высокой эффективности теоретически обоснованной модернизации тормозной системы тележек является то, что путем изменения характера действия гравитационных сил последние не наклоняют тормозные колодки до опирания в колеса, а разработанная конструкция направляющего устройства обеспечивает строго равномерное удержание тормозных колодок относительно образующей поверхности катания колес. Повышенная надежность достигается простотой конструкции и нейтрализацией разрушительно действующего момента сил.

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# ON THE MODERNIZATION OF THE BRAKE SYSTEM OF FREIGHT CARS


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## ABSTRACT


The intensification of works to improve the running parts of freight cars in recent years is associated with significant deficiencies in the design of bogies. Extensive research is conducted, entirely new designs are created, existing systems are upgraded, and performance tests are conducted in the Russian Federation, the United States, China, the Ukraine and other countries. Components and spare parts, affecting driving performance of cars, are mainly exposed to changes and much less attention is paid to a brake system of bogies, which is very important in terms of train safety. In some innovative types of bogies attempts are made to improve the brake system with a variety of additional devices. However, during field tests this modernization shows often unsatisfactory results and its implementation is rejected due to lack of efficiency and reliability. The main problem is the inability to achieve complete return motion of the brake shoes from wheels during brake release. Three-piece bogie brake system, which is currently in use (including for innovative options) was developed in the 30s of the last century [4] so that the amendment of the design changes entails a violation of dimensional chains, to which the main parameters of brakes performance are related. Because of this, researchers and designers are still unable to find an effective solution for increasing the reliability of brake systems of bogies.

The objective of the authors is to investigate some theoretical and practical issues of modernization of brake systems of freight cars, using mathematical and engineering methods.

The article results in a theoretical justification of negative properties associated with uneven return motion of brake shoes from wheels in the brake system of three-piece bogies. Besides kinematic analysis reveals the conditions under which innovative solutions are possible. The guarantee of high efficiency of theoretically grounded modernization of the brake system of bogies is that by changing the nature of gravitational forces the latter do not incline the brake shoes to mounting in wheels, and developed design of the guide device provides a strictly uniform keeping of brake shoes relative to the forming wheel tread. Improved reliability is achieved by simplicity of design and the neutralization of destructive force moment.

Keywords: railway, freight car, brake system, kinematics, negative properties, uneven return motion of brake shoes, modernization, efficiency.

**Background.** *The intensification of works to improve the running parts of freight cars in recent years is associated with significant deficiencies in the design of bogies. Extensive research is conducted, entirely new designs are created, existing systems are upgraded, performance tests are conducted in the Russian Federation, the United States, China, the Ukraine and other countries. Components and spare parts, affecting driving performance of cars, are mainly exposed to changes and much less attention is paid to a brake system of bogies, which is very important in terms of train safety.*

*With some innovative types of bogies (models 18–578 the Russian Federation [1], 18–4129 the Ukraine [2], ZK1 China [3], etc.) attempts are made to improve the brake system with a variety of additional devices. However, during field tests this modernization shows often unsatisfactory results and its implementation is rejected due to lack of efficiency and reliability.*

*The main problem is the inability to achieve complete return motion of the brake shoes from wheels during brake release. Because of this, when the trains move without braking, braking shoes are inclined, clearance gaps relative to the wheel are often uneven and absent, the upper edges of brake shoes rest on wheel tread that creates the harmful friction on rotating wheels. A local effacement is formed on the upper parts of the friction surface, which not only significantly reduces the service life of brake shoes, but also leads to deterioration of braking efficiency due to the reduction of the area of the working contact and eccentric redistribution of brake application effort on wheels. Motion resistance and corresponding spending of traction power increase, as well as the likelihood of thermomechanical damage on the wheel tread.*

*Three-piece bogie brake system, which is currently in use (including for innovative options) was developed in the 30s of the last century [4] so that design changes entail a violation of dimensional chains, related to main parameters of brakes performance. Because of this, researchers and designers are still unable to find an effective solution for increasing the reliability of brake systems of bogies.*

**Objective.** *The objective of the authors is to investigate some theoretical and practical issues of modernization of brake systems of freight cars and to offer the description of the newly designed device.*

**Methods.** *The authors use analysis, mathematical and engineering methods.*

**Results.** *Our analysis of the kinematics of the brake shoe extending from a wheel tread during brake release, showed that the pendulum suspension of shoes provides not only their translational motion away from the wheel, but also rotational motion relative to the center O (Pic. 1). The upper edge of the shoe moves along the arc of a small radius $r_u$, and the lower edge moves along the arc of a substantially larger radius $r_l$ that at the deflection of the pendulum suspension to the angle $\alpha$ involves backward movement of the middle part of the brake shoe from the wheel for a distance $\Delta_{mid}$, and of the upper and lower edges for significantly different distances $\Delta_u$ and $\Delta_l$.*

*For small values of the angle of deflection of the pendulum suspension (up to 3°), which takes place in real conditions, the values of such gaps can be approximated with accuracy sufficient for practical calculations by the following analytical expressions:*

– *For the upper edge of the brake shoe*

$$\Delta_u = \frac{\pi \bullet r_u \bullet \alpha}{180} \bullet \sin 45^o \quad ; \qquad (1)$$

– *For the middle part of the brake shoe*

$$\Delta_{mid} = \frac{\pi \bullet r_{mid} \bullet \alpha}{180} \quad ; \qquad (2)$$

– *For the lower edge of the shoe brake*

$$\Delta_l = \frac{\pi \bullet r_l \bullet \alpha}{180} \quad , \qquad (3)$$

*where $r_u$, $r_{mid}$ and $r_l$ are radii of the trajectories, on which the backward motion takes place respectively of the upper, middle and lower parts of the brake shoe relative to forming wheel tread; $\alpha$ is a deflection angle of the pendulum suspension during brake release.*

*The results of calculations of the clearance gaps to which the brake shoe is removed on the pendulum suspension during brake release from the forming wheel tread are shown in Table 1.*

*These data show that the upper edge removes from the wheel at the value $\Delta_u$, which is significantly less than the minimum permissible value set by the standards (5 mm), while the lower edge extends at the value $\Delta_l$, which is significantly greater than the maximum permissible of 8 mm [5]. Therefore, in the process of upgrading of brake system it is necessary to eliminate such unevenness and provide a condition where $\Delta_u = \Delta_{mid} = \Delta_l$.*

*Along with this negative property, inherent of a typical brake system of freight car bogies, there is yet another design flaw. It, like the first one, affects the uneven return motion of brake shoes from the wheels.*

*In order to justify the reasons for this, we consider the action scheme of the drive mechanism of a pair of brake pads belonging to one wheel set in the bogie (Pic. 2).*

*At brake release the brake cylinder eliminates the force of pressure of brake shoes to the wheels. The scheme shows that, due to significant weaknesses in the design of the drive mechanism, return motion of brake shoes from the wheels is distorted by the turn to mounting of the upper edges of the brake shoes into the wheels to form a reaction force R.*

*The analysis revealed that the vertical heavers 1 in the bogie are attached by cylindrical joints to the rod 2 of the brake beam through the hole 3 and by their mass violate the balance of the drive mechanism relative to its connection with the lower hinges of the pendulum suspension 4. The weight of the vertical heaver of parts attached to its upper and lower hinges (they are brake gears) creates a force moment*

$$M_p = P \cdot l_1, \qquad (4)$$

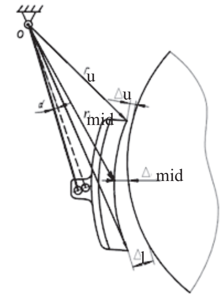
*where P is gravitational force, generated by the weight of the vertical heaver and details attached to it; $l_1$ is a distance between the axes of hinges of joining of the vertical heaver to the rod of the brake bean and the pendulum suspension.*

*As a result of action of the force moment $M_p$ at brake release rotation of all components of the drive mechanism to mounting of the upper edges in the wheels by the reaction*

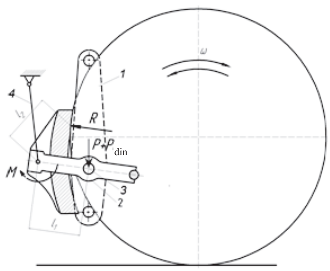
**Table 1**

**The calculated values of the clearance gaps between the brake shoe and the wheel depending on the angle of deflection of the pendulum suspension**

| Deflection angle of the pendulum suspension | The value of the formed gap, mm | | |
|---|---|---|---|
| $\alpha^\circ$ | $\Delta_u$ | $\Delta_{mid}$ | $\Delta_l$ |
| 1 | 1,9 | 5,3 | 8,5 |
| 1,5 | 2,9 | 8,0 | 12,8 |
| 2 | 3,8 | 10,6 | 17,1 |
| 2,5 | 4,8 | 13,3 | 21,3 |
| 3 | 5,7 | 15,9 | 25,5 |



***Pic. 1. Uneven return motion of a brake shoe from a wheel on a pendulum suspension.***



***Pic. 2. Scheme of the origin and of action of the forces in the mechanism of removal of the brake shoe from the wheel with the formation of the slope and the mounting of the upper edge of the brake shoe on the wheel.***

*force R occurs. To determine it, we form an equation of force moments relative to the lower hinge of the suspension 4, taking into account that the force P applied in the middle part of the brake beam is distributed to both of its brake shoes*

$P \cdot l_1 = 2R \cdot l_2$, (5)

*from which*

$$R = \frac{P \cdot l_1}{2 l_2}, \quad (6)$$

*where R is reaction force of mounting of a brake shoe on a wheel;*

*$l_1$ is arm of the force P;*

*$l_2$ is arm of the force k.*

*Considered forces that adversely affect the brake system of bogies, inclining brake shoes to mounting on wheel treads, are caused by the weight of components, which in the brake system are connected by cylindrical joints with relatively large gaps (1–10 mm). And since they are placed in unsprung part of the bogie, the forced vibrations of parts during the movement of the car contribute to movements of the shock nature in pin-connected joints. As a result, the force P is greatly increased by a dynamic component $P_{din}$ of the hard-shock nature. This explains the fact that the applied and a large number of newly developed devices that keep the brake shoes from inclining and mounting of the upper edge in wheels, under operating conditions show a small resource and are usually ineffective.*

**Conclusions.** *The conducted studies provided the theoretical justification of a vector of practical solution of the problem, which would give the opportunity to overcome the identified deficiencies and create new technical prerequisites for upgrading the brake system for freight car bogies (Patent UA № 87764 from 10.08.2008).*

*The department of railroad cars of Ukrainian State Academy of Railway Transport jointly with Krukovsk Car-building plant have conducted extended operational tests of upgraded brake system of bogies of 18–100 model on one car of hopper-dosing unit train for four years (mileage of more than 80 thousand km) and ten gondola cars for more than two years (mileage of about 200 thousand km). Periodic inspection of brake systems of these cars and accumulated statistical data prove their stable performance.*

*The guarantee of high efficiency of theoretically grounded modernization of the brake system of bogies is that by changing the nature of gravitational forces the latter do not incline the brake shoes to mount on wheels, and developed design of the guide device provides a strictly uniform keeping of brake shoes relative to the forming wheel tread. Improved reliability is achieved by simplicity of design and the neutralization of destructive force moment.*

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