Improvement of friction units limiting the durability of mechanical systems

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Abstract. The efficiency and competitiveness of transport, other things being equal, directly depends on improving the safety of the transportation process, which in turn depends on the actual technical condition and durability of the rolling stock. To solve problems of this type, it is proposed a set of solutions is proposed that increases the durability of especially critical friction units that affect the safety of operation of technical systems used in loading and unloading and transport processes. The proposed solutions are characterized by manufacturability, low resource consumption and versatility.

1. Introduction
The transport system is of strategic importance for Russia, as it is the main one connecting all its regions, and its effective work largely determines the state of the country’s economy [1]. Ways to improve this efficiency have a wide range of technical solutions [2-21]. Efficiency and competitiveness of transport directly depends on reducing production costs, transportation, on increasing speeds and volumes of cargo transportation, as well as on the safety of the transportation process. Traffic safety, in turn, largely depends on the actual technical condition and durability of the rolling stock.

An analysis of the current state of the transport system of Russia and the railway in particular shows that in recent years, the main source of financing investments of the JSC «Russian Railways» are depreciation charges, which depend on tariffs. Raising railway tariffs in Russia may lead to a loss of competitiveness of the country’s economy. So, for example, railway tariffs in Russia are one and a half times higher than in the USA and Canada, which are similar to Russia in the industrial structure of transportation [1].

Thus, in order to ensure the competitiveness of the transport system of Russia, as well as to increase the efficiency of the transportation process under the prevailing conditions of a tough market of transport services, it is necessary to introduce technologies that increase the real durability and safety of operation of railway transport facilities [15-21].

2. Analysis and solution of the problem
Among the parameters for the selection of priority innovative technologies, among other things, the following aspects should be distinguished [1]:

• high commercial potential;
• the prospect of mass implementation of the results;
• realistic timelines for achieving the target parameters.
In the current economic conditions, a promising solution may be the formation of the introduction of new technologies that increase the safety of the transport process. Within the framework of this approach, the article describes designs that allow solving a number of industry problems that arise during the operation of rolling stock, both on the main line and at loading and unloading terminals, which include:

- slip regulator in the wheel-rail system,
- anti-crash stop,
- undercarriage support bearing,
- system for reducing wear of wheel flanges of rail industrial vehicles.

3. The slip regulator in the wheel-rail system

One of the important problems of the railway industry is the formation of thermo-mechanical damage to wheels during logistic processes of rolling stock on non-mechanized marshalling yards. To solve this problem, a slip controller has been developed, which eliminates the formation of thermo-mechanical damage on wheelset.

The controller is an ordered system of devices (working modules) located on the neck of the rail thread within each brake position from the side of the brake shoe in the specified order with an interval of not more than seven meters [15].

When wagon moving in a brake shoe, the wheel of a wheelset with a comb is run onto the wedge-shaped element of each working module (figure 1), lifted (figure 2) and rotated by a certain angle, thereby the contact area another wheel with the rail changes before the wheel is damaged. After passing the module, the wheel is again fixed on the brake shoe and the wheelset continue to sliding.

A system of this type [15, 16] has been in continuous commercial operation on the non-mechanized sorting slide of the Voronezh park of the Likhaya station of the North Caucasus Railway since 2005.

![Figure 1. The working module of the anti-slider system at station Likhaya](image)

1 – wedge element, 2 – counter rail, 3 – rail, 4 – brake shoe
As practice has shown, the formation of sliders is completely excluded, and the service life of the wedge element in contact with the wheels is at least 15 months.

The average sectoral economic effect from the exclusion of brake damage of the wheels and the downtime of the vehicles will be at least 5.1 billion rubles per year, with a payback period not exceeding twelve months. The technical documentation was approved by the Vice President of JSC «Russian Railways» on 11/23/2006.

4. Anti-crash stop

Another example of solutions that increases the safety of loading and unloading and transport systems is the active stop (figure 3) designed to ensure the safety of wagons, goods, and rail cranes from damage during uncontrolled movement at the end sections of station tracks and loading and unloading terminals, respectively.

The proposed design of the active stop [17,18,19] uses the principle of the servo effect, which, in contrast to existing braking methods (catching a dead end, resetting shoe, etc.) provides a smooth increase in braking power, which allows you to stop a braking object without damage.

The active stop works as follows. After the wheel 1 of the lifting-transport device or rolling stock is hit by the support block 2, their joint movement begins as a single system leading to compression of the spring 3. The braking power of this spring $F_{n1}$ supplements the friction forces arising in the contact of the wheel with the block and the block with the rail $F_{тр1}$, $F_{тр2}$. Further, in the direction of travel, spring 4 begins to compress, providing an increase in braking power $F_{n2}$.

With further movement of the braked object, the slider 5 rests against the cone 6, revealing a split cylinder 7, the horizontal movement of which inside the housing 8 compresses the spring 9. Friction forces $F_{т4}$ occur in the contact between the housing and the outer surface of the cylinder, leading to a maximum increase in braking power due to the implementation of the surf effect.

Such a cascade increase in braking power provides a safe stop for a variety of lifting and transport vehicles, including rolling stock. The ability to adapt such a system to almost any load-speed characteristics is limited only by the strength and overall parameters of the stop elements, which greatly expands its scope.

The average annual losses in the Russian Railways from the collision of wagons with serial deadlock systems are about 320 million rubles. The design cost of one emphasis in mass production will be about 100 thousand rubles. Thus, with the money saved from eliminating damage to wagons,
about 3200 of such systems can be manufactured, which is enough to equip all dangerous end sections of tracks. The payback period is 1 year.

Figure 3. Kinematic scheme of active dead end stop with servo effect

5. Undercarriage support bearing
In addition, in accordance with the program of scientific and technical development of Russian Railways, adaptive undercarriage support bearing for freight car are proposed. The first development is associated with the adaptive principle of supplying lubricant to the friction zone as the surface wears. The adaptive node of the freight cars allows you to increase the turnaround cycle of the entire pivot node by 1.5–2 times.

A design feature is that blind holes 3 with depth not exceeding the allowable wear level (figure 4) and filled with composite lubricant are provided on supporting 1 and persistent 2 surfaces of the heel and thrust bearing [20].

As the working surfaces of the heel and heel wear out from the blind holes, a composite lubricant containing film-forming components (for example, fluoroplast or graphite) will cover the friction surfaces, reduce the wear rate and stabilize the coefficient of friction.

Figure 4. Surface scheme of the adaptive undercarriage support bearing
This design can be used in bogies of freight cars of any type, since it does not require a fundamental change in design and retains the standard assembly technology, as well as in slewing rings of construction and road equipment.

The expected effect only from saving material and energy resources with an increase in the overhaul cycle of the pivot node will be at least 14 million rubles in the industry in year.

Given the decrease in the resistance of the trolley, when inscribing into the curved sections of the path, which in turn will reduce the wear rate of the flanges of the wheels and the likelihood of the trolley coming off the rails, the economic effect will increase significantly.

System for reducing wear of wheel flanges of rail industrial vehicles.

A similar principle of adaptive lubricant supply is based on the solution of another problem of reducing the increased wear of the flanges of wheels of rail hoisting vehicles [21].

A recess is provided in the flange of the wheel (figure 5) around its entire perimeter, into which a solid film-forming lubricant is introduced. Deepening can be performed in the form of a single annular groove or several annular grooves of a smaller diameter, the edges of which are in contact with the side surface of the rail.

During operation, the lubricant will enter the friction zone as it wears, covering the working surface of the flanges and the side surface of the rail head, reducing the wear rate, while eliminating the ingress of grease onto the rolling surface.

![Figure 5](image_url)

**Figure 5.** Surface of the hoisting-transport equipment wheel
1 - skating surface, 2 - flange, 3 - groove, 4 - rail

Tests of the described construction on the example of an overhead crane showed that by reducing the wear rate, the wheel resource more than doubled.

The proposed design of the wheels is promising for bridge, tower, and gantry cranes on the rail, which are widely used at the loading and unloading terminal.

The total economic effect from the implementation of the presented systems can reaches at least 6 billion rubles per year, which, for example, in 2010 prices amounted to 7% of the net annual profit of Russian Railways (70 billion rubles).

### 6. Conclusions

Thus, several projects are presented that allow saving significant resources for the sectors of the national economy, at low financial and technological costs.
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