THE CREATIVE SOLUTION TO IMPROVE THE LOCOMOTIVE TRACTION AND EFFICIENCY

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КРЕАТИВНЕ РІШЕННЯ З ПІДВИЩЕННЯ ТЯГОВО-ЕКОНОМІЧНИХ ЯКОСТЕЙ ЛОКОМОТИВА

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The interaction of wheel and rail is the physical basis of train movement on the railroad. It largely determines the safety, speed and level of operating costs. At the same time, the requirements for indicators of interaction between wheels and rails in different contact zones are contradictory. On the one hand, the traction of wheels and rails should be such that low train resistance is ensured. On the other hand - to realize the necessary traction force it is necessary to ensure a high and stable level of traction of locomotive wheels with the rail surface.

The work set a goal – to research methods of improving the traction and braking qualities of the locomotive, and to identify the most effective of them. To develop a design which allows increasing traction and braking qualities of a locomotive and providing increasing of ecological safety with application of energy- and resource-saving technologies. As a result an analysis of scientific and technical information sources was carried out which testifies to the existence of different methods of increasing traction and braking qualities of locomotives: structural and operational.

On the basis of the performed analysis of designs of sand systems used it is established that manual and pneumatic systems were used in the process of locomotives operation, their significant disadvantages and advantages are studied.

In order to achieve the optimum sand flow rate, preliminary studies on electrostatic and tribostatic sand electrification were carried out, which gave positive results. Both methods are approximately equal in scale of application, the advantages and disadvantages of each of them were studied in detail.

On the basis of the carried out theoretical and preliminary experimental works a creative solution to improve the design of the resource-saving sand system of the locomotive, modernized on the basis of the tribostatic method of sand charging is developed.

The developed design allows for the supply of sand directly to the wheel raceway along the rail, which will significantly reduce its consumption, reduce the adverse impact of ground sand on the environment and increase the traction force of the locomotive, by increasing the coefficient of adhesion of the wheel to the rail, which contributes to the improvement of technical and economic indicators locomotive as a whole.

Keywords: railway transport, coupling qualities, sand, electrification, wheel, rail.

Introduction. One of the most important conditions for social and economic development of a country is the improvement of environmental safety and application of energy and resource-saving technologies in different industries. In the context of increasing scopes and rate of the transportation process the application of these technologies in railway transport is of high priority.

Goal setting. Improving the locomotive traction and braking performance is the core task in designing a new rolling stock and upgrading the existing one. The analysis of the research papers showed that traction and dynamic performance, as well as the efficiency of a rolling stock [1, 2] depend significantly, in general, on processes occurring when contact surfaces of wheels touch rails. The increasing power load of wheel to rail contact causes unavoidably losses in mechanical energy in the system, which is consumed for irreversible changes in thin surface layers and heat generation. In practice, this leads to considerable operating costs because of wheel slippage and aquaplaning, considerable failure of rails because of contact fatigue defects, large losses of bandage material in very short supply, natural and process wear, underutilization of power unit capacity, and overconsumption of fuel, sand, and lubricants [1, 3].

Work objective. Studying the methods for improving traction and braking performance, and detecting the most efficient ones. Developing the design that allows improving the traction-coupling and braking performance of the locomotive and ensures the higher environmental safety, with the use of energy and resource-saving technologies.
Data for the research. As the analysis of the scientific and engineering data shows there are different methods for improving the traction-coupling and braking performance of locomotives (Fig. 1): design and operating [3, 4].

The improved friction behaviour of the «wheel-rail» tribological system due to design factors promotes the creation of potentially high friction behaviour of the system, but is not a guarantee of traction forces without wheel slippage and aquaplaning during operation. This is explained by the dominant impact of climatic and weather conditions under which a locomotive is operated on the friction behaviour of the «wheel-rail» system. The most efficient way to mitigate this impact is to use sand in the «wheel-rail» contact zone. This is mainly dictated by sand availability, as well as its effect making 5% to 30% in relation to the cohesion factor increase [1]. A short-term increase in the cohesion factor to its maximum value shall be performed provided that the minimum possible quantity of sand is supplied to the wheel to rail contact zone. The researches [4] showed that the maximum quantity of sand supplied to the wheel to rail contact zone must be 0,6-1 kg/min for efficient cohesion (the value is less for diesel locomotives and more for electric locomotives). The sand flow rate shall not exceed 1,5-1,6 kg/min for electric locomotives and 50% of this quantity for diesel locomotives, taking into account inevitable sand losses due to different factors (traffic speed, side wind, rail vibration, sand system nozzle kinematics, etc.). If the locomotive traffic speed increases to 6-20 km/h, the quantity of sand should be increased by 20-30%. The best effect of the traction force increase is reached by using sand with the grain size of 0,1-0,3 mm [4].

The seat condition in the wheel to rail contact zone changes considerably when sand is filled in. It can be believed that the sand presence results in destructing colloidal films in the contact zone and increasing the wheel to rail cohesion force due to the presence of solid abrasive particles that contact with the surface of contacting bodies [5].

Today all locomotives are equipped with pneumatic sand systems. Based on the studied designs of sand systems and the literature they found a considerable above-norm sand consumption, which impairs the cost effectiveness and efficiency of the locomotive in general [5, 6, 7, 8]. It should be noted that the higher the speed, the more above-norm sand is consumed in geometric progression.

The use of quartz sand leads to the “catastrophic” contamination of the top layer of the track and impairment of track drain properties behaviour and ballast performance in terms of moisture removal. Sand has the negative friction performance resulting in the wheel squeak and corrugated wear of rails with short vertical irregularities. In case of excess sand supply, its destruction results in the generation of a huge number of fine particles that are capable of staying in the suspended state in the atmosphere for a long period of time, thus deteriorating the environmental situation near railway roads.
In addition, in case of excess sand supply a major part remains on rails after passing locomotive wheels and this increases the train traffic resistance by 12-20% [1] and fuel and electric power overconsumption, respectively. So, the main issue of designing the sand system is to ensure the minimum allowable sand consumption.

The analysis of sand system designs [5-10] proves that manual and pneumatic systems were used in the process of locomotive operation. Manual sand systems have two significant weaknesses; hence they are almost out of use now:

1. Low effectiveness of using sand, which is caused by the fact that the sand spilled by gravity from a pipeline with nozzle onto rails goes beyond the shroud-rolling circle, out of the rail, and is blown by wind and vortexes generated at a high traffic speed. In accordance with the US data it is expedient to use less than 1% supplied by manual sand systems [5].

2. A large consumption of sand necessitated by the sufficient increase in the cohesion factor in the absence of sand supply control.

Pneumatic sand systems of two types are mainly used in up-to-date locomotives: systems operated on the blow-off principle – sand pushing by the air jet to sand pipes and systems operated on the vortex principle – blowing off top layers of sand in a special nozzle (Fig. 2).

By comparing sand flow rates in different sand systems one may state that the maximum control limits are produced by vortex sand boxes – from 0 to 6,5 kg/min per each sand pipe; blow-off type sand systems change their flow rate from 5,25 to 7,25 kg/min, which causes their inefficient operation at low traffic speeds. The sand flow rate in manual sand systems is yet higher [5].

To reach the optimal flow rate of sand, preliminary researches of sand electrification were conducted by electrostatic and tribostatic methods, which had the positive result [11, 12].

The analysis of scientific and technical literature showed that particles must be exposed to preliminary electrification of particles for uniform distribution of some particles over the metallic surface. Different methods could be used for particle application on the surface; however, the methods for particles conversion into aerosol by means of spraying or fluidization and its maintenance on the surface due to particles electrification prevail. The aerosolized state is provided to loosen the sand compacted in the sand system bin. The electrostatic application of particles is based on the principle of aerosolized particles electrification.

There are two ways of particles application in the electrical field – electrostatic (with the charging of the crown discharge field) and tribostatic (with the charging due to triboeffect). Both methods are almost equivalent in terms of employment level and each of them have its own advantages and disadvantages (Fig. 3).

**Results of the researches.** Based on the completed theoretical and preliminary experiments a creative solution was developed to improve the design of the locomotive’s sand box (Fig. 4) [13].

The operating principle of the improved sand system of the locomotive is as follows.

A bulk material (sand) is supplied from the bin 1 to the nozzle 2. When air is supplied from the air draft pipe 6 to the nozzle 2, a mixture of bulk material with air is formed and supplied through the pipeline 3 to the accelerator 5 where the air jet from the air draft pipe 6 increases the mixture discharge rate and then enters the nozzle 4.
Methods for settling particles in the electric field

<table>
<thead>
<tr>
<th>Electrostatic</th>
<th>Tribostatic</th>
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<td><strong>Advantages</strong></td>
<td><strong>Advantages</strong></td>
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<tr>
<td>possibility of settling any particles</td>
<td>good deposition of particles in areas with blind holes and recesses</td>
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<tr>
<td>high productivity</td>
<td>uniformity of settling of particles on the protruding and concave areas</td>
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<tr>
<td>high degree of particles settling</td>
<td>lack of reverse ionization</td>
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<td>resistance to influence of the humidity of the surrounding air</td>
<td>low cost of installations</td>
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<td>increased cost of installations due to availability high-voltage equipment</td>
<td>the need for air preparation (air conditioning)</td>
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<tr>
<td>requirement in a power supply</td>
<td>low degree of electrification</td>
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<tr>
<td>the difficulty of settling of particles on products with blind holes and recesses</td>
<td>reduced productivity</td>
</tr>
</tbody>
</table>

Disadvantages

The pipeline 3 and nozzle 4 are lined inside with the material that ensures the effective charging of mixture particles, has high resistance to wear, particle adhesion when exposed to impact (such material can be polytetrafluorethylene which is one of the best acceptor in the triboelectric series). In addition, such material shall easily donate electrons (donors) and accept electrons (acceptors). When mixture particles go through the pipeline 3, the number and force of collisions between particles and charging material 7 of the inner surface of the pipeline 3 increase in the air pipe due to the forced supply of the mixture. These multiple collisions between the surface 7 and particles result in transferring the electrical charge. Charged and polarized particles of the bulk material fall onto the earthed wheel 8 of the locomotive and are maintained there by the charge forces resulting from friction on the inner surface 7 of the pipeline 3 and nozzle 4. The particle charge also results in attracting particles that failed to enter directly to the wheel to rail contact zone when they leave the nozzle 4. The tribostatic method ensures high-quality settling of mixture particles on the wheel.

If this sand system is installed in the locomotive, one should take into account that the nozzle to rail surface distance is to be about 200–250 mm, in which case the mixture particle settling effectiveness is the highest. The material 7 is expected to be replaced with new one as it wears.
Conclusion. The completed systematic set of researches allowed developing a resource-saving sand system of the locomotive which was improved by tribostatic method of sand charging. This design enables the sand supply to the wheel raceway on rails, thus reducing considerably its consumption, reducing the adverse effect of ground sand on the environment and increasing the locomotive traction force due to the increased wheel to rail cohesion factor, this will improve technical and economic indicators of the locomotive in general.

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Kovesa T.M. Kreativne rizhennia z pidvishennia t'jagov-opymochnykh koz'estv lokomotiva

У роботі постає задача — проведення досліджень методів підвищення якості та гальмівних якостей локомотива виявлення його ефективного використання. Розробити конструкцію, яка дозволяє підвищити якісні показники локомотива. На підставі аналізу досліджень встановлено, що процеси експлуатації використовувалися ручні та пневматичні системи, винені їх суттєві недоліки та переваги.

Для досягнення оптимальної втрати піскі були проведені попередні дослідження з електризованої піскі електромагнітними та прибічними способами, що дає позитивний результат. Обидва способи приблизно рівноправні за масштабами застосування, детально вивчено їх рівень та недоліки кожного з них.

На основі проведених теоретичних та попередніх експериментальних робіт розроблено креативне рішення щодо удосконалення конструкції ресурсобезпеченої п'єжкової системи локомотива, модернізованої на основі застосування прибічного методу зарядження піскі.

Розроблена конструкція дозволяє забезпечити подачу піскі безпосередньо на дорожню поверхню коліс по рейці, що значно зменшить його витрати, знизити несправність одиних з них, а також підвищити силу тяги локомотива, за рахунок збільшення коефіцієнта зчеплення піскі.

Ключові слова: гальмівний, піск, експлуатація, колес, рейка.

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