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ECONOMIC EVALUATION OF BULK CARGO PROCESSING TECHNOLOGY IN BUNKER-TYPE RAILWAY WAREHOUSES

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Abstract

The railway transport complex is of special strategic importance for Russia. It is a connecting link for the unified economic system, providing stable operation of industrial enterprises, timely delivery of vital goods to the most remote corners of the country. Timely delivery of goods largely determines the economic efficiency and competitiveness of Russian railway. With systematic delays of cargo delivery, the railway has a risk to loose clients. Open joint stock company "Russian Railways" conducts systematic work in all areas of its activity, on which this indicator depends in one way or another. To reduce the delivery time, it is necessary to ensure that the duration of technological operations is as minimal as possible, employees of different services perform operations in parallel, and the waiting time for operations (inter-operational downtime) is minimal. To date, no general methodology has been developed for designing and evaluating technical and economic indicators of mechanisms for moving bulk cargo in bunker devices that ensure uninterrupted delivery of materials to vehicles for targeted delivery to consumers of various economic sectors. This article highlights issues of economic evaluation of bulk cargo processing technology in bunker-type warehouses on the railways, taking into account consequences of vaulting. The authors propose a method for calculating energy terms of the operation for the bulk cargo release from bunker devices in transportation tanks. The method allows determining the energy consumption to ensure the specified operation modes of the bunker device, including technological interruptions in their work to eliminate vaulting of bulk cargoes.

Keywords: Economic evaluation, labor productivity, bulk cargo, transport and storage complex.

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1. Introduction

To carry out loading and unloading operations with bulk cargoes, its storage and release into transportation tanks of vehicles on the territory of the Russian Federation, transport and storage complexes of various purposes have been created and have been operating for a long time. The need for warehousing goods is determined by the uneven production and transportation cycles, therefore warehouses play an important role, providing a clear rhythm and work organization of the entire transport and storage complex of Russia and its regions.

It should be noted that the annual processing of goods in the form of bulk materials, temporarily stored in bunker devices for various purposes at industrial enterprises (construction, agro-industrial complex, powder metallurgy and others domestic industries) amounts to 70-100 billion tons. To date, there is no general methodology for designing and evaluating technical and economic indicators of the vaulting mechanisms of bulk cargo in bunker devices, ensuring their uninterrupted loading into transportation vehicles (Varlamov, 2010).

2. Problem Statement

The research problem is the study of formation and transformation processes and mechanisms of prevention and elimination of bulk materials vaulting, as well as additional compensatory influences that determine dynamic properties of bunker devices and allow stabilizing their output parameters by the intensification of adverse external influences on the materials, changing their physical and mechanical properties during storage and release and leading to the emergence of vaultings.

The prevailing reason for the violation of the uninterrupted release of bulk materials from bunker devices to the transport capacities of vehicles is the appearance of bulk materials vaulting in the bunkers, which are eliminated using a wide range of different physical nature arch-destroying mechanisms (mechanical, vibrational effects, aeration devices, etc.) (Varlamov & Muljukin, 2012).

3. Research Questions

In this work, indicators for evaluating design, technological and technical and operational capabilities of arch-destroying mechanisms were considered from an energy and ergonomic point of view. The following tasks are to be solved:

- development of an energy model for the release of bulk materials from the bunker during periodic sampling a fixed mass of bulk materials portions with a mathematical justification of conditions for uninterrupted outflow and conditions for the emergence of bulk materials vaulting;

- development of a methodology for calculating the energy intensity of the of bulk materials release from the bunker in the tanks of transportation vehicles, taking into account stops for technological breaks to eliminate arising vaulting formations.

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4. Purpose of the Study

This study is aimed at theoretical and experimental research and development of practical recommendations on this basis to improve the dynamic quality and functional reliability of mechanisms for preventing and eliminating bulk materials vaulting of a fixed mass in bunker devices. These recommendations determine the rational choice of the force magnitude for the working body of the mechanism for vaulting elimination under the condition of minimizing energy costs for eliminating bulk materials vaulting with specific geometric and dynamic parameters.

5. Research Methods

All research stages were carried out on the basis of systematic approach principles. On the theoretical stage, the authors used methods of parametric and mathematical modeling of technical systems, numerical methods and methods of engineering rheology. The experimental stage was carried out in laboratory and production conditions with analysis and processing of obtained data with mathematical and statistical methods using modern measuring equipment and computer technology.

The efficiency of the technological operation for the release of bulk materials from the bunker devices into tanks of transportation vehicles is characterized by the amount of accumulated energy in this operation, and poor-flowing materials have the greatest energy absorption (Vargunin, Goryushinsky, Varlamov, & Varlamova, 2007).

In general terms, the energy intensity Q_{mjip} of this operation for an uninterruptedly functioning of a bunker device (without the occurrence of vaulting formation) is representable as a sum of energy terms, which are usually functions of production and regulatory parameters, volumetric and mass characteristics of the bunker device with bulk materials, the distance and the time the vehicle was involved in the transportation of bulk materials from the loading place to the consumer (Varlamov, 2011):

$$Q_{mjip} = q_{mj} + q_{mi} + q_{pj}. \qquad (1)$$

Below is a series of relations for calculating the energy terms of the expression (1):

1. The material and energy costs q_{mj} for a bunker with its mechanisms and devices can be determined from the ratio:

$$q_{mj} = \frac{1}{W_j} \cdot \sum_{\ell} M_{Bi} \frac{(\alpha_\ell + r_\ell)}{100 \cdot T_{H\ell}}, \qquad (2)$$

where W_j is a productivity of the j^{th} bunker device (tons/hour); M_{Bi} - a mass of the unloaded bunker with its mechanisms and devices (tons); α_ℓ, r_ℓ - accordingly, the annual normative deductions for the constituent parts of the bunker device for renovation and repair (%); $T_{H\ell}$ - annual normative loading of the bunker device (hours).

2. The costs q_{mi} of vehicles transporting bulk materials from the loading place to the consumer can be calculated by the formula:

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$$q_{mi} = \frac{h_j \cdot L_j \cdot M_{Bj}}{G_j \cdot \beta_j} \cdot \sum_{\ell} M_{Gj} \frac{\left(\alpha'_\ell + r'_\ell\right)}{100}, \quad (3)$$

where h_j is the leverage of the cargo or the ratio of the maximum movement of the transportation vehicle to the maximum mass of the loaded bulk materials when the vehicle moves without refueling, km/t; L_j - the vehicle mileage from the loading place to the consumer, km; M_{Bj} - the mass of bulk materials in a fully loaded bunker device, t; G_j - the mass of cargo (bulk materials) carried by the vehicle for one trip, t; β_j - the coefficient of mileage usage; M_{Gj} - the mass of the unloaded vehicle with its mechanisms and devices, t; and α'_ℓ and r'_ℓ are respectively the annual normative deductions for renovation and repair of the vehicle components, %.

3. The calculation of living labor costs q_{pj} can be carried out according to the dependence:

$$q_{pj} = \sum_t \frac{N_{tj} \cdot W_{tj}}{W_j}, \quad (4)$$

where N_{tj} is a number of employees engaged in the *t*-category of works;

W_{tj} – productivity of an individual worker on each of the *t*-category of works, t/h.

Taking into account ratios (2), (3) and (4), ratio (1) will take the form:

$$Q_{mjip} = \frac{1}{W_j} \cdot \sum_{\ell} M_{Bi} \cdot \frac{(\alpha_\ell + r_\ell)}{100 \cdot T_{H\ell}} + \frac{h_j \cdot L_j \cdot M_{Bj}}{G_j \cdot \beta_j} \cdot \sum_{\ell} M_{Gj} \frac{\left(\alpha'_\ell + r'_\ell\right)}{100} + \sum_t \frac{N_{tj} \cdot W_{tj}}{W_j}. \quad (5)$$

When making episodic stops of the bunker device within the considered technological process for the period of time necessary for the destruction of formed vaulting, the formulas (2), (3), (4) and (5), respectively, are transformed into a system of expressions (6), (7), (8) and (9):

$$q_{mj} = \frac{1}{W_j\left(1 - \frac{\tau_P}{\tau}\right)} \cdot \sum_{\ell} M_{Bi} \cdot \frac{(\alpha_\ell + r_\ell)}{100 \cdot T_{H\ell}}, \quad (6)$$

where τ is the normative time of uninterrupted release of CM bulk materials from the bunker, tons; τ_p – idle time of the bunker device from the moment of occurrence to the moment of elimination of vaulting, h.

$$\left.\begin{aligned} q_{mi} &= \frac{h_j \cdot L_j \cdot \left(M_{Bj} + \Delta M^P_{Bj}\right)}{G_j \cdot \beta_j} \cdot \sum_{\ell} M_{Gj} \frac{\left(\alpha'_\ell + r'_\ell\right)}{100} \\ \Delta M^P_{Bj} &= W_j \cdot \tau_p \end{aligned}\right\}, \quad (7)$$

where ΔM^P_{Bj} – conditional increment of the bulk materials mass in the bunker (lost production capacity of the bunker device) during its idle time τ_P.

$$q_{pj} = \sum_{t+t_P} \frac{\left(N_{tj} \cdot W_{tj} + N_{tPP} \cdot W_{tPP}\right)}{W_j}, \qquad (8)$$

where t, N_{tj} are respectively the categories of works and the normative number of workers by the uninterrupted operation of the bunker device with their planned productivity W_{tj} at the normative value of the parameter ; W_j, t_P, N_{tPP} - respectively additional required categories of work and the number of workers with the projected productivity of labor W_{tPP} required during the idle time τ_P of the bunker device to eliminate the arisen vaulting in it and renewal of its uninterrupted work.

$$Q_{mjip} = \frac{1}{W_j\left(1 - \dfrac{\tau_p}{\tau}\right)} \cdot \sum_{\ell} M_{Bi} \cdot \frac{(\alpha_\ell + r_\ell)}{100 \cdot T_{H\ell}} + \frac{h_j \cdot L_j \cdot \left(M_{Bi} + W_j \cdot \tau_P\right)}{G_j \cdot \beta_j} \cdot \sum_{\ell} M_{Gj} \frac{\left(\alpha'_\ell + r'_\ell\right)}{100} + \sum_{t+t_P} \frac{\left(N_{tj} \cdot W_{tj} + N_{tPP} \cdot W_{tPP}\right)}{W_j}. \quad (9)$$

6. Findings

The described relations allow to give an economic evaluation of a technology for processing bulk cargoes in warehouses of bunker type on the railways of the Russian Federation taking into account the delivery of cargoes to consumers by the maintenance of set functioning modes of bunker devices, including technological breaks in their work for elimination of the arisen vaults of bulk materials with specific physical and mechanical properties (Varlamov, Moulyukin, & Ushakov, 2009).

The research results can be used in further research and development works to improve the performance and increase the functional reliability of mechanisms to prevent and eliminate vaulting in storage and release bunkers of bulk materials.

7. Conclusion

The authors proposed evaluation indicators for design, technological, technical and operational capabilities of arch-destroying devices from the energy and ergonomic points of view. These indicators form the basis of the developed:

- energy model of bulk materials release from the bunker by periodic sampling a fixed mass of bulk materials portions with a mathematical justification of conditions for uninterrupted outflow and emergence of bulk materials vaulting;

- methodology for calculating the energy intensity of the of bulk materials release from the bunker in the tanks of transportation vehicles, taking into account stops for technological breaks to eliminate arising vaulting formations.

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