Providing mechanisation of loading and unloading operations in hopper rail stores

Alexander Varlamov¹, Nelly Varlamova¹, and Natalya Mazko¹*

¹Samara State Transport University, 443066 Samara, Russia

Abstract. Grain and fertiliser transportation are the fastest growing segments of the transportation services market, including railway transportation. Presidential Decree No. 204 of 7 May 2018 “On the national goals and strategic objectives for the development of the Russian Federation for the period until 2024” tasked the Russian government with developing a programme of measures to increase the productivity of economic sectors, including the agroindustrial complex. The increase in the productivity of the latter should entail the development of both domestic consumption and the export component, which places an additional burden on rail transport. The aim of the research is to improve loading and unloading operations in bunker-type railway yards by using auxiliary constructions to speed up and facilitate the loading and unloading of rolling stock by bulk cargo. The research is based on the principles of the system approach using methods of mathematical modelling of technical systems, numerical methods of problem solution and rheology engineering methods. The results of the research are resource-saving ways of bulk cargo loading and unloading from containers of various purposes, allowing to increase the degree of their uniform distribution in the container, and to ensure smooth release of material.

1 Introduction

Bulk goods (grain, mixed feed, mineral fertilisers, etc.) are used in various industrial and agricultural applications and are transported in multipurpose or in combination. Are used in a wide variety of industrial and agricultural applications. These types of cargo (for rail shipments) are most commonly stored in bunker-type rail warehouses (for bulk and bulk cargo).

In the current situation of the transport services market, the most preferred method of transportation and storage of bulk cargo is bulk storage, where bulk cargo is stored in storage containers of different purposes (specialised containers, silos, and bunkers). These storage tanks are widely used in various sectors of chemical, industrial and agricultural production, as their use allows to ensure the stable functioning of the entire technological complex.

* Corresponding author: natalya2323@mail.ru
2 Materials and methods

In this work the authors consider the processes of piling up in hoppers for various purposes and ways of implementing additional compensating influences on bulk material stored in them in order to optimise the technical parameters of these devices, allowing to stabilise their output parameters.

In research a system method was applied. The subject of the research is the bulk solids stored (transported) in containers of different geometry, which have a complex particle-size composition characterized by a combination of different sizes and shapes of particles with their disordered location inside the cavity of the container. In addition, bulk solids have properties of both solids (the particle of bulk material is a solid body) and liquids (a set of particles of bulk material has the ability to move as a liquid). But in general, the properties of bulk solids are quite different from both solids and liquids. In addition, bulk solids are characterised by discreteness, which is a major factor in phenomena such as vaulting.

Therefore, the physical-mechanical and chemical-biological properties of bulk solids must be taken into account in the design of bunkers with puddling equipment.

3 Results

In a number of cases when bulk goods are loaded from hoppers into rolling stock or unloaded by gravity (under its own weight) from the latter, the problem of slowing down the flow or stopping it completely arises. The reasons for this research are as follows:
- the friction coefficient between the walls of the storage or conveying vessel and the bulk material particles changes upwards;
- high adhesion of the bulk solids to the walls of the storage or conveying vessels due to the high adhesion of the bulk solids contained therein;
- high absorption of bulk solids, resulting in a non-linear increase in adhesion, which causes the solids to stick to the walls of the storage or transport container or to freeze to the walls during the cold season as well as the formation of large pieces of material consisting of coagulated (frozen) particles of bulk solids
- the formation of bulk material arches as a result of "tracking" during storage of the material being handled, fully or partially blocking the flow of the latter during unloading or reloading.

The storage of bulk materials in containers is directly related to the frequent problems with their unloading, which in turn leads to a reduction in the usable volume of the latter. This is a consequence of the above-disclosed phenomenon of puddling, the extent of which is largely dependent on the factors listed below:
- the design of the storage or transport tank;
- the capacity of the storage or conveying tank;
- fractional composition, moisture content of the bulk cargo, etc;
- time period (duration) of storage;
- technology of transport and warehousing operations with the goods in the storage or transport tanks.

Solving the problem of storage and unloading of bulk cargo will solve the following tasks:
- it will create conditions for quality operation of equipment for storage and transportation of these cargoes;
- it will reduce the percentage of substandard cargo during storage or transportation;
- it will increase occupational safety and reduce the physical stress of operating personnel;
- it will increase the service life of bulk storage and transportation tanks.
The use of stationary and mobile vault breakers equipped with a swivelling working body, which cleans the inside of the tanks, allows to prevent the formation of vaults, and thus to maintain constant readiness of the tank for work, regardless of the characteristics of the cargo. The installation of a stationary cleaner should be carried out in those parts of the tank (bunker, silo) where the formation of vaults is most frequent or permanent.

The problem of the difficulty of flowing loose materials from containers with different geometries and the formation of vaults in loose media, grain and fertilizer transportation issues have been addressed by many researchers: Deijs W (Deijs, 2001), Arnold P (Arnold, 2003), Matchett A (Matchett, 2006), Fadeyibi A (Fadeyibi et al, 2014), Mehos G, Eggleston (Mehos et al., 2018), Sment J, Albrecht K (Sment et al., 2019), Bulgakov V (Bulgakov et al., 2021), (Bulgakov et al., 2023) (Bulgakov et al., 2018), (Bulgakov et al., 2017), Hevko R (Hevko et al., 2015), (Hevko et al., 2016), Lyashuk O (Lyashuk et al., 2015), Nukeshev S (Nukeshev et al., 2018), Meng Q (Meng et al., 1997) [1-15]. They give theoretical conclusions and practical recommendations on the "cure" of this problem. However, this problem has not yet been completely solved, as it is influenced by a huge number of inherently different factors.

Theoretical and practical aspects in this area are also the authors of this article, which proposes a constructive scheme of devices that can help to solve the problem of vaulting in the bunker-type warehouses on the railroad.

The constructive and technological scheme of the bunker device with knives-water cutters for storing and releasing dusty and fine-grained bulk cargoes developed in SamGUPS is offered.

The hopper device (Fig. 1) consists of a vertically arranged hollow body with the upper cylindrical part 1, the middle conical part 2 and the lower cylindrical part 3 made together with it, a screw with blades 4, rigidly connected to a rotating shaft 5 on which knives-water cutters 6 are fixed. The swath breakers are switched on periodically during formation of swaths in the hopper.

The proposed technical solution due to the organization of reciprocating movement of knives-water breakers reduces the energy consumption for the destruction of dusty or fine-grained bulk cargo vaults and, accordingly, reduces the cost of operational maintenance of bunker dispensers of bulk cargo. This device is suitable for use in the technological chain of storage and release of the aforementioned cargoes into rolling stock in rail warehouses.

To clean bulk cargo tanks (hoppers) in hard-to-reach places, there is a constructive engineering diagram of a vault destroyer-cleaner, developed by SamGUPS. The swell-destroyer-cleaner (Fig. 2) consists of a driving mechanism 1, a directing branch pipe 2, a hollow driving shaft 3, a running sleeve 4, a transition branch pipe 5, a ring 6, spherical plain bearings 7, transverse rollers 8, links of a working device 9, the working device 10, joints 11, limiters 12.

Charging device (Fig. 3) consists of corrugated pipe 1, cylindrical body 2, fixing devices 3, 8, axis 4, cylinder 5, spring 6, blades 7, 9, cone 10. Due to inflow from the tank, the loose matter paddles 7 having a helical profile start rotating, and the cylinder 5 goes down and makes the paddles 9 rotate. Due to the rotation of the blades 9 the bulk cargo is scattered over the whole cross-sectional area of the vehicle body. This device can be used successfully in elevators for grain loading of hopper cars, which will increase the static load of the car due to its uniform load.

In the feed industry, bunkers of relatively small volumes are used to store ingredients such as salt, meat and bone meal and premixes. For elimination of pile formation in them, it is possible to use a design of the spring and piston mechanism shown in Fig. 4, consisting of: housing 1, connection for supplying the control gas pressure 2, sealed differential piston 3, spring 4, threaded shell 5, gate valve 6.
The operation of this vaulting mechanism is achieved by the reciprocating movement of the sealed differential piston 3 under the influence of the spring 4, which is compressed by gas pressure. By providing a pulsating supply of control gas pressure, this creates an oscillating movement of the spring.
For elimination of formation of puddles in storage hoppers for coarse bulk solids (crushed stone, coal, etc.) it is possible to apply a "finger arching depredator" design (Figure 5). It is possible to apply a "finger-like" arching depredator structure (Figure 5) which consists of feed and outlet flanges 1, 4, hopper body 2, welded-on pneumatic actuator cylinders 3, 9, bottom 5 with outlet openings 8, crosshead 6, bearing 7, a set of finger-like vault breakers 10, removable lock rings 11, 18, spherical lugs of pneumatic actuator piston 12, 17, seals 13, 16. The operating principle of the device is based on alternate supply of compressed air. This results in turning the crosshead 6 clockwise or anti-clockwise. The vaults are broken by the fingers 10 attached to the crosspiece 6, which repeat its movement.
4 Conclusions

Construction of auxiliary equipment presented in this article for their use in bunker-type railway warehouses as vaults, dozers, loading and distributing devices will allow providing storage, loading and unloading of any bulk cargo with minimum energy consumption in compliance with all sanitary and epidemiological requirements and labour protection requirements.

The designs presented in the article will allow:
- to increase the static load of the wagons;
- to reduce demurrage of wagons during loading-unloading operations;
- to reduce energy consumption during loading of wagons;
- to increase the safety of loading and unloading work;
- to improve sanitary and epidemiological conditions and working conditions of employees.

References

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