Periodic tunnelling reloaders improvement

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Abstract. The investigated object - periodic action tunnelling bunker-loaders. It is proposed to increase the mining operations efficiency by introducing an intermediate loading and transport element in a periodic action bunker-reloader form into the tunnelling machine - main transport technological chain, which ensures mining machine continuous operation while implementing the minimum time for loading a vehicle. It has been established that there is an experience in the bunker designs - loaders use with a traction-transporting body reciprocating movement: the transporting elements wedge-shaped or with variable geometry. To eliminate the identified shortcomings, fundamentally new technical solutions are proposed, based on a forward-acting hydraulic drive and transported elements use that provide material single movement in large volumes, at their movement low speeds. A proposed design detailed description protected by RF patents is given. The methodology general provisions for conducting experimental studies on a model setup are considered.

1. Introduction and problem setting
Scientific developments' analysis in the loading and unloading operations' mechanization field when carrying out mine workings\cite{1-5} allows to conclude that, as bunker - reloaders, along with the well-known structures produced by leading machine-building plants, there is an experience in the structures used with a traction-transporting body return - translational movement: the transporting elements wedge-shaped or with variable geometry. Such structures have advantages in a number, including the ability to transport hard rocks; drive stars lack, gear groups in the loading area; significant power implementation with the drive relatively small dimensions, etc. However, was identified and a defects number.

So, for example, questions arise about the reloaders use effectiveness, which working elements make active reciprocating movements inside a highly abrasive transported material, in their wear and tear and durability terms. In this regard, fundamentally new technical solutions were proposed, based on a forward-acting hydraulic drive use and transported elements that provide the material single movement large volumes, at their movement low speeds\cite{6}.
The present research is aimed at improving the periodic action bunker-loaders, to increase their loading efficiency with tunnelling machines, carrying out the tunnelling face continuous development.

2. Methods for solving the problem

The improving the designs' purpose is to increase the reloader productivity by changing its length during the loading process and increasing the reloader chute useful volume.

This goal is achieved by the fact that in a reloader containing a stand, a chute connected to the stand pivotally, with its inclination angle changing possibility relative to the working surface during operation by a power cylinder means for lifting the chute and a transporting element, the chute is made of several kinematically interconnected sections, with the ability to move relative to each other, and the sections one is pivotally connected to the lifting cylinder, which, in turn, is fixedly fixed on the stave. Such a constructive solution makes it possible to change the reloader chute length during its loading with the transported material upward, which, in general, leads to an increase in productivity.

The technical solution essence is illustrated by drawings (figure 1).

![Figure 1. Inclined bunker-reloader with variable chute volume.](image)

The unloader for transporting bulk and lumpy materials consists of a fixed stave 1, a chute 2, made of several (in this case, two), kinematically interconnected sections 3 and 4, which one is hinged connected to the stave 1, and the other is hinged connected to the power cylinder for lifting the chute 5, fixed on the stave 1, the transporting element 6, driven by the power cylinder 7 and the tailgate 8. The reloader operates as follows. Before starting work, the power cylinders 5 and 7 are in the extreme retracted position, while the loading chute 2 is located at an angle relative to the working surface, and the tailgate 8 is in a vertical position, preventing the submerged material movement along the chute 2. Chute section 3 is partially located inside section chute 4. When the mining machine is operating, the transported material enters the reloader 2 chutes and, under the gravity action, moves along the chute towards the tailgate 6. As the reloader 2 chutes are filled with the transported bulk material, the power cylinder 5 rods extends, the reloader 2 chutes turns relative to the stationary rod 1. Chute section 4 moves together with the actuating cylinder 5 rods relative to section 3 (figure 1). At the same time, the chute 2 total useful volume increases in comparison with the initial value corresponding to the reloader loading beginning. The reloader unloading is carried out by
pushing out the material by the conveying element 6 using the power cylinder 7 with the tailgate 8 in a horizontal position. After the conveyor chute 2 complete unloading, the latter is lowered to its original position using cylinder 5. In this case, chute section 3 takes a position inside chute section 4. In the future, the process is repeated.

Thus, in this technical solution, an increase in the reloader performance is achieved, due to a change in its length during operation and an increase in the useful volume of the chute, which leads to the set goal achievement.

The considered technical solutions provide for the spatial location in the mine, i.e. require certain dimensions to accommodate such structures. In the restrictions' presence on height, the proposed bunker-reloaders placement in the working will look very problematic. In this regard, the authors have developed the reloader a schematic diagram, taking into account the indicated disadvantages.

The development purpose is to increase the bulk and lump materials transportation productivity and efficiency by reducing the dump truck body unloading the conveyor and ensuring uniform loading time, with the reloader positioning possibility in limited mining conditions.

This goal is achieved by the fact that in the loader containing longitudinal sides, a bottom and a drive, the bottom is sectional and consists of several moving elements in the plates form, kinematically connected with the longitudinal sides, with each other and with a drive, with the reciprocating motion possibility by drive relative to each other and longitudinal sides.

This technical solution makes it possible to ensure conveyor chute uniform loading with material coming from the mining machine, increase the bulk and lumpy materials' transportation productivity and efficiency, by reducing the time for unloading the conveyor and the dump truck body ensuring uniform loading.

The development essence is illustrated by a drawing, where figure 2 shows the proposed loader a basic kinematic diagram.

![Figure 2. Bunker-reloader with sectional bottom.](image)

The loader for transporting bulk and lumpy materials includes longitudinal sides 1, rigidly connected, a bottom 2, consisting of several movable elements in the form of plates 3 and a drive 4. Plates 3 are kinematically connected to the longitudinal sides 1, with each other and with a drive 4, with the reciprocating
movement possibility relative to each other and the longitudinal sides. The reloader operates as follows. Before starting work, the bottom movable elements in the plates 3 forms are located in the transported material loading area from the miner, located one above the other. When the material arrives from a mining machine, plates 3, under a drive 4 action, made, for example, in the one or more power cylinders form, are extended, starting from the bottom, carrying with it a transported rock mass and the subsequent plate portion. At the plates' extension end, the reloader is filled with the submerged material. At the next stage, the dump truck drives up to its loading area, completely under the conveyor. Under the drive 4 action, plates 3 begin to move relative to the sides 1 in the opposite direction. In this case, the rock mass, under its weight influence, falls into the dump truck body. The process continues until the loader is completely unloaded, and the dump truck body is filled without additional shunting operations. In this case, the movable plates 3 are brought to their original position for the material next loading from the mining machine.

Thus, in this technical solution, there is no transporting element, and during the reloader operation, the dump truck body uniform loading is ensured, which leads to the set goal achievement.

When mining equipment designing or choosing sets, their constituent elements main technical parameters must be coordinated with each other. So, for example, a mining shearer loading device must provide a technical performance that exceeds the executive body productivity, which is realized when the face is destroyed; the reloader performance is at a level not lower than the harvester conveyor performance while ensuring the main vehicle loading from one installation. To fulfil the listed restrictions, it is necessary to possess optimal parameters calculating and choosing scientifically grounded methods for the tunnelling system elements each. It should be noted that after determining the equipment structural and kinematic schemes, for example, loading and transport, it is advisable to conduct operational studies in a complex to obtain an optimal technical solution. Following this concept, the considered hopper loaders design involves determining the structural, kinematic and energy parameters optimal combination.

3. Results and discussion

As an optimality criterion, the authors propose an objective function use that provides for the main vehicle filling (dump truck body, self-propelled car, etc.) in one cycle. At the same time, it is necessary to fulfil a restrictions' system, first - restrictions on the transporting elements' movement permissible speed, providing for a 0.1 - 0.2 m/s value in the range [7].

The main design limitation is the reloader permissible length, which is determined on the cargo flow ensuring the continuity basis. Proposed, substantiated and experimentally confirmed a model for the freight traffic formation.

Developed and implemented a technique for experimenting to study the variable factors influence on the desired functions, followed by the mathematical models’ adequacy confirmation to the real loading process. In particular, the batch-type hopper-loader permissible length depends \( L \) on the material layer height \( H_l \), the pushing element height \( h \), material friction coefficient along the chute \( \mu_h \), \( \mu_v \). As evidenced by the research carried out by the authors, the transported material granulometric composition, characterized by the piece average diameter, has a significant effect on the deformation zones formation and, as a consequence, on the periodic action bunker-loader permissible length. This parameter influence is taken into account by the soil type coefficient \( k_{s} \), obtained as an experimental studies result. Then the expression for the batch hopper loader permissible length takes the form.

\[
Q = f \left( B_3, H_3, v \right);
\]

\[
L = f \left( \mu_h, \mu_v, B_3, h, H_l, \rho, \phi_0 \right);
\]

\[
R = f \left( \mu_h, \mu_v, B_3, h, H_l, \rho, \phi_0 \right).
\]
The functional dependence that is requested can be taken as a basis when determining the power hydraulic cylinder automatic control parameters lifting the loader chute.

Let's consider the change limits in values of $\beta_i$ and $m_i$. It is obvious that the overloader angle to the product surface, before loading, should exceed the immersed material friction angle value on the overloader bottom $\beta_b \geq \mu_t$. After the full loading is completed, the pipeline chute takes a horizontal position. The changing area in the material volume (mass) $m_i$ is between zero and $m_{\text{max}} = L \cdot B_n \cdot H_i$.

Experimental studies for this dependence are planned to be carried out on a model installation (figure 3) on a scale of 1:10 relative to the average piece transported, according to the program given in table 1.

**Figure 3.** The loader bunker experimental model.

| Indicator name          | Designation | Value in the $i$-th experiments series |
|-------------------------|-------------|----------------------------------------|
| The reloader inclination angle | $\beta_i$   | $\beta_1$  | $\beta_2$  | $\beta_3$  | $\beta_4$  | $\beta_5$  |
| Material weight (volume) in the gutter | $m_i$       | $m_1$     | $m_2$     | $m_3$     | $m_4$     | $m_5$     |

The experiment program provides for the bulk material actual volume determination accumulated in the reloader chute at its inclination fixed angle to the horizontal surface. As a result, it is planned to obtain the data necessary and sufficient to determine the chute initial optimal angle.

4. Conclusion

The following conclusions have been drawn as the studies a result.

It is proposed to increase the mining operations efficiency by introducing an intermediate loading and transport element in a periodic action bunker-reloader form into the tunnelling machine - main transport technological chain, which ensures mining machine continuous operation while implementing the minimum time for loading a vehicle.
The loading and transport modules with hydraulic drive conducted theoretical studies allowed us to establish the transporting and raking elements maximum permissible speeds values in the range of 0.1-0.2 m/s, and to use them to justify the functions-restrictions in modelling the periodic action designed hopper-reloaders operation.

Patents have been developed and protected, and the loader bunker technical solutions provide a mountain mass maximum single volume sufficient to fill the vehicle, at allowable transporting speeds of between 0.1 and 0.2 m/s.

The deformation zones formation graph analytic studies when moving a large-bit loose material layer have established the main patterns inherent in this process, in the permissible loader length dependence form on the granulometric composition, all other things being equal $L \leq k_{s,t} \cdot H_t / \mu_0$.

The load type proposed coefficient mathematical interpretation $k_{s,t}$, which establishes the deformation zones formation dependence on the granulometric composition $k_{s,t} = 1 + (d_{90} / H_t)$, is obtained as experimental studies a result conducted on a model reloader installation performed on a scale of 1:10, which confirmed the theoretical calculations' adequacy to the work real process. The maximum discrepancy between calculated and experimental data does not exceed 12%, and the error in determining the average experienced values is no more than 20% at a confidence probability of 0.9.

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