Ensuring the safety of transport processes based on improving the infrastructure of railway stations

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Abstract. In the process of organizing transportation on the world railway transport, the issues of ensuring a high level of safety of trains and equipment do not lose their relevance. In this scientific article, a mathematical model has been developed for determining the braking distance of wagons after putting on shoes using an automatic stopping device in front of a spontaneously departing rolling stock, taking into account the number of wagons and the state of congestion. As a result, dependencies were obtained indicating the possibility of braking the rolling stock at safety and trapping dead ends.

1 Introduction

Currently, in modern economic conditions, the task of rail transport is to meet the transport needs of freight owners, ensuring timely and safe delivery of goods on the basis of digitization of the transportation process. At the same time, the organization of the transportation process should provide minimal costs, which will contribute to the stable financial condition of the railways.

Solving this problem requires the use of both new and advanced technologies to reduce the share of manual labor through the complex use of new technologies to achieve a high level of mechanization and automation of technological processes.

Also, one of the leading places in the process of organizing transportation in World rail transport is the issue of ensuring a high level of Traffic Safety. In this regard, special attention is paid to the improvement of control devices and systems in order to ensure the safety of movement in rail transport. In particular, a variety of mechanized and automated mechanisms are being created in order to prevent rolling stock from moving on its own on the world's Railways.

Globally, statistics show that there are incidents of car spontaneous movement from Station tracks that cause accidents for train traffic every year on the railway network. In particular, in 2017-2022, an analysis of Traffic Safety disruptions found that while the self-driving phenomenon of rolling stock in JSC "Uzbekistan railways" was 3% of the total, the amount of damage caused was 31%, while the share of such cases in industrial railways was 5%, the damage caused was 14%.

It can be seen from this that while the number of
incidents of rolling stock self-driving at railway stations has been very low, it has been considered that there has been significant economic damage caused by the occurrence of these cases. Despite the development of a number of measures to prevent such incidents in the world, there are still cases of train loss of control and spontaneous movement of rolling stock, and various types of accidents are occurring. This in turn requires that railway stations increase the safety of transport processes by further improving the ways in which rolling stock on station roads is caught without losing in the event of spontaneous movement.

In this case, there is a need to develop special devices (systems) that operate automatically without a human factor at the time of sudden movement of the rolling stock on the station tracks, allowing the possibility of preventing possible spoilage by stopping the rolling stock in a timely manner.

In railway stations, it will be possible to achieve such a system in its automatic way by continuous connection to alarm, centralization and blocking devices so that they work without a human factor. Therefore, by creating such a system on the basis of scientific theory, it assumes the transfer of an expression in laboratory conditions [1,2,13,15-21].

2 A method for determining the braking distance of a rolling stock using a special device that works automatically

![Diagram](image)

Fig. 1. A model for determining the braking distance of a spontaneously departed wagon under the action of a braking device (on the slope of the Station Road).

The kinetic braking energy of such rolling stock is equal to the initial speed of the wagons at the point of installation of the shoe, since it moves when descending from a height, the initial potential energy is generated and the energy of the wind action.

However, at a point at the stopping distance, energies opposite to the final kinetic and potential energies and the braking force are generated, the sum of all their initial energies is equal to the sum of all their final energies. The equation of expression of these processes is presented in the following form:

\[ E_K + E_p + E_w = E_K' + E_p' + E_{br} \]

Considering that the forces of all generated energies acting on the states of the process, depending on the speeds and road slopes of the wagons and the amounts of brake shoes that will damage them to stop, for small angles (less than 5º), \( \sin i \approx 1, \cos i \approx 1 \) along the length of the rail:
The above expression provides an opportunity to determine the distance of the brake path in accordance with the amount of spikes required to stop the moving contents that have moved on their own:

\[ L_{by} = \frac{\sum_{j=1}^{n} Q_j \cdot (V_B^2 - V_F^2)}{g \cdot K_{st} \cdot F_{by} + k_f - i \sum_{j=1}^{n} O_j - F_w} \]

Here:
- \( V_B \) - speed of the wagon at the time of installation of the shoe in front of the wagon, km/h;
- \( V_F \) - final speed of the wagon, km/h;
- \( F_{by} \) - braking force of the brake shoe to the rim of the wagon wheel, kN;
- \( Q \) - wagon weight (\( Q_{04} \) is the gravity of a four-axle wagon, \( Q_{08} \) is the gravity of an eight-axle wagon), kN;
- \( g \) - free fall acceleration, \( m/s^2 \) (\( g = 9.8 \, m/s^2 \));
- \( i \) - slope of the corresponding station track, ‰;
- \( F_w \) - wind power, kN;
- \( K_{st} \) - braking distance for wagons;
- \( k_f \) - coefficient of friction between the wagon wheel and the rail;
- \( Q_{st} \) - the number of brake spikes with damage to stop the wagons.

\[ F_{b/sh} = q_w \mu_f \beta N \]

Here:
- \( q_w \) - load on the brake shoe of a single wagon wheel;
- \( \mu_f \) - coefficient of friction between the brake shoe and the rail, wheel and brake shoe block.

**Fig. 2.** A model for determining the braking distance of a spontaneously departed wagon under the action of a braking device (berk in cases opposite to the slope of roads).
The expression of the car moving on its own opposite the slope of the road will look like this:

\[ E_K^B - E_P^B + E_w = E_K^V + E_P^V + E_{br} \]

\[
\sum_{j=1}^{n} Q_j \cdot V_B^2 + \sum_{i=1}^{n} Q_i \cdot L_{br} \cdot F_{br} + F_0 \cdot L_{br} = \sum_{j=1}^{n} Q_j \cdot V_Y^2 - k_j \cdot \sum_{i=1}^{n} Q_i \cdot L_{br} \cdot F_{br} + K_n \cdot F_{br} \cdot L_{br}
\]

3 Results

[Graph showing braking distance vs speed]
Fig. 4. A graph of two 4-axle empty wagons brake track in relation to the quantity and speeds of the braking shoes of the rolling stock.

Case 3 in the case of single-loading and single-empty four-axle wagons being self-propelled:

Fig. 5. A graph of a 4-axis single-load single-empty carriage brake track in relation to the quantity and speeds of the rolling stock braking shoes.

Case 4: one four-axle, one eight-axle freight wagon in a self-propelled state:

Fig. 6. A graph of a single 4, single 8-axle freight wagon brake track in relation to the quantity and speeds of the rolling stock braking shoes.
Case 5: the wagons are in a single four-axle and one eight-axle empty position with self-propelled:

Fig. 7. A graph of a single 4- and single 8-axle empty carriage brake track in relation to the quantity and speeds of the rolling stock braking shoes.

Case 6: one four-axle load, one eight-axle empty wagons in the case of self-derailment:

Fig. 8. A graph of a single 4-axle load, single 8-axle empty carriage brake track in relation to the quantity and speeds of the rolling stock braking shoes.
Fig. 9. A graph of a single 4-axle empty and one 8-axle freight wagon brake track in relation to the quantity and speeds of the rolling stock braking shoes.

4 Discussion

From the results obtained on the basis of a mathematical model for determining the stopping distance of spontaneously departing rolling stock, it can be seen that in relation to empty wagons, it was found that they register loaded ones, as well as values at which the braking distance increases as their speed increases. This method automatically made it possible to choose the most optimal option for the installation site of the spike installer device on the station tracks. In addition, taking into account the places of placement of this device, its marginal capabilities were determined.

5 Conclusion

The current state of use of Stop Systems has been researched in cases where rolling stock has left on its spontaneous in rail transport. The results showed that spontaneous departures of rolling stock in the Republic of Uzbekistan accounted for 4.2% of the share of total traffic safety violations and accounted for 19.9% of the damage caused.

In order to prevent these phenomena, a mathematical model was developed for determining the braking distance after installing shoes through an automatic stopping device on a spontaneously departing rolling stock, taking into account the number of wagons, speed and their state of occupancy. As a result, dependencies were obtained indicating the possibility of stopping rolling stock at protected and trapping dead ends.

References


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