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STUDY OF THE INFLUENCE OF THE PASSAGE OF HEAVY TRAINS ON THE THROUGHPUT AND CARRYING CAPACITY OF RAILWAY SECTIONS WITH ELECTRIC TRAIN TRACTION

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The criterion for the effectiveness of the organization of heavy traffic on the sections of the Russian railway network is the presence of large correspondences of bulk goods presented by the consignor for transportation. An obstacle to the development of a promising cargo traffic are areas with limited throughput and carrying capacity, the overcoming of which is the organization of heavy traffic. All countries that have railways, at a certain stage of development, face capacity constraints. Summarizing the world experience, we can conclude that the priority in the development of increasing volumes of "heavy cargo" is increasing the weight norms of freight trains. The problem of passing heavy trains for Russian Railways is urgent, because the capacity of some sections has exhausted itself completely. The very timely appearance of heavy traffic becomes one of the options for solving the problem of increasing the carrying capacity of sections and directions and, as a result, creating a reserve of carrying capacity. In this article, a study of the influence of their movement on the carrying capacity and carrying capacity has been carried out.

Aim. *To consider the effectiveness of the formation and passage of heavy trains. The influence of the organization of the movement of such trains on the throughput and carrying capacity of railway sections.*

Methods. *To solve the problem, graphic and analytical methods of mathematical modeling, scientific methods of collecting and processing statistical data, modern achievements in terms of general principles and methods of risk management was used.*

Results. *The authors have developed a formula for determining the rate of removal of freight trains. The analysis of the influence of the values of the inter-train intervals of freight trains and heavy trains on the removal rate is given.*

Practical relevance. *As the main alternative to increasing the size of traffic on the main cargo-intensive directions, with a shortage of traffic capacity, it is proposed to use the technology of heavy traffic. In modern market conditions, an increase in the weight and length of a freight train is one of the main reserves for increasing throughput and carrying capacity. By passing heavy trains, we get an increase in carrying capacity. In the article, we prove the consistency of these measures. The increase in carrying and carrying capacity is considered in the context of increasing unified weight standards.*

Keywords: *throughput; carrying capacity; removal rate; inter-train interval; freight train; heavy freight train*

ИССЛЕДОВАНИЕ ВЛИЯНИЯ ПРОПУСКА ТЯЖЕЛОВЕСНЫХ ПОЕЗДОВ НА ПРОПУСКНУЮ И ПРОВОЗНУЮ СПОСОБНОСТИ ЖЕЛЕЗНОДОРОЖНЫХ УЧАСТКОВ ПРИ ЭЛЕКТРИЧЕСКОЙ ТЯГЕ

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Критерием эффективности организации тяжеловесного движения на участках сети железных дорог России является наличие крупных корреспонденций массовых грузов, предъявляемых грузоотправителем к перевозке. Препятствием к освоению перспективного грузопотока становятся участки с ограниченной пропускной и провозной способностями, преодолением которого выступает организация тяжеловесного движения. Все страны, которые имеют железные дороги, на определенном этапе развития сталкиваются с ограничениями пропускной способности. Обобщая мировой опыт можно сделать вывод, что приоритетом *в освоении возрастающих объемов «тяжелых грузов» становится повышение весовых норм грузовых поездов. Проблема пропуска тяжеловесных поездов для Российских железных дорог является актуальной, вследствие того, что пропускные способности некоторых участков исчерпали себя полностью. Весьма своевременное появление тяжеловесного движения становится одним из вариантов решения проблемы повышения провозных способностей участков и направлений и, как следствие, создание резерва пропускной способности. В данной статье выполнено исследование влияния их движения на пропускную и провозную способности.*

Ключевые слова: *пропускная способность; провозная способность; коэффициент съема; межпоездной интервал; грузовой поезд; тяжеловесный грузовой поезд*

The organization of heavy traffic on railways is aimed at increasing the carrying capacity of cargo-strained directions, which limit the development of promising volumes of fuel and energy cargo transportation from places of origin to places of consumption [1]. However, is it so? Is it possible to assume that only an increase in the length and mass of trains will be sufficient to achieve the efficiency of freight transportation?

The development of heavy-weight traffic with the participation of professionals of various fields on the problems of the wheel, rail and their interaction, which are fundamental for railway transport operating under conditions of high axial loads, train masses and load stress is presented in the research of William J. Harris (The USA), James Lundgren (The USA), Harry Tournay (RSA), Willem Ebersöhn (RSA) [2].

The problem of organizing a heavyweight movement was studied by Martins. R., S. Costa R. J., Roney M, Zhixiu Geng [3; 4; 5].

Therefore, according to DR. Abhyuday, heavy traffic means the organization of work of freight trains with a large axial load, weight and length. [6]

Many pluses, advantages, progressive components of the heavyweight movement can be found in Russian literature.

The rules of technical operation of the railways of the Russian Federation determine that a heavy train is a freight train whose mass exceeds the mass norm established by the train schedule for the corresponding series of train locomotives by 100 tons or more [7], i.e.

$$Q_h \succ Q_n + 100. \tag{1}$$

Considering the movement of heavy trains on the traffic schedule, it should note that when they skipped, freight trains of the established mass and length norms removed. This is primarily due to the different size of the inter-train intervals with which freight trains and heavy trains follow (Fig. 1 and 2).

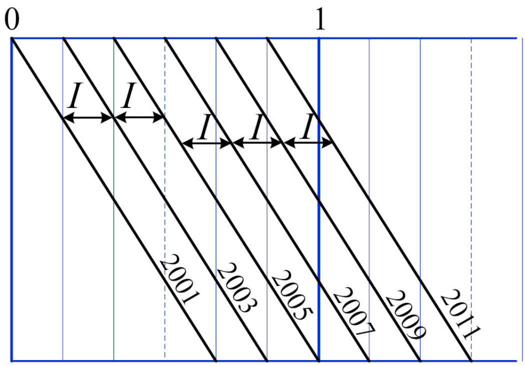


Fig. 1. The passage of freight trains of the established mass on the site in the absence of heaviness

Figure 2 shows that when heavy trains pass at different intervals, the number of missed freight trains of the specified mass also changes. If the intervals are equal (10 min), the total number of freight trains does not change – Fig.2 (a), but a heavy replaced by the freight train. At an interval of 12 minutes (Fig.2.b) 1.2 trains are removed from the schedule, at an interval of 15 minutes – 2 trains (Fig.2.c), 20 minutes - 3 trains(Fig.2.d).

In other words, the greater the difference between the intervals, the more freight trains removed from the schedule. Thus, we can say that when heavy trains skipped, there is a removal of freight trains. It is regulate by the removal coefficient, the value of which can be determined by the formula proposed by the authors: $\varepsilon_h = \frac{2L_h}{I} - 1$, but not less than one, where L_h is the inter-train interval for heavy trains, min; "*I*" is the calculated inter-train interval for the remaining freight trains.

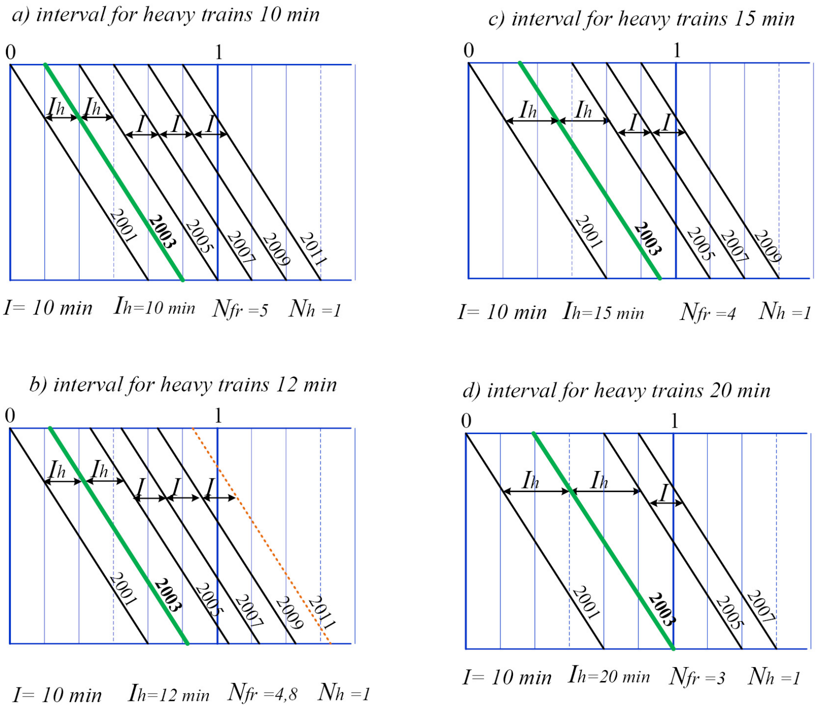


Fig. 2. Passage of heavy freight trains along the section

To see how the carrying capacity will change, you can perform a simple calculation using Figures 1 and 2 and the accepted estimated train weights of 6300 and 8300 tons. The ratio of net and gross weight is 0.75.

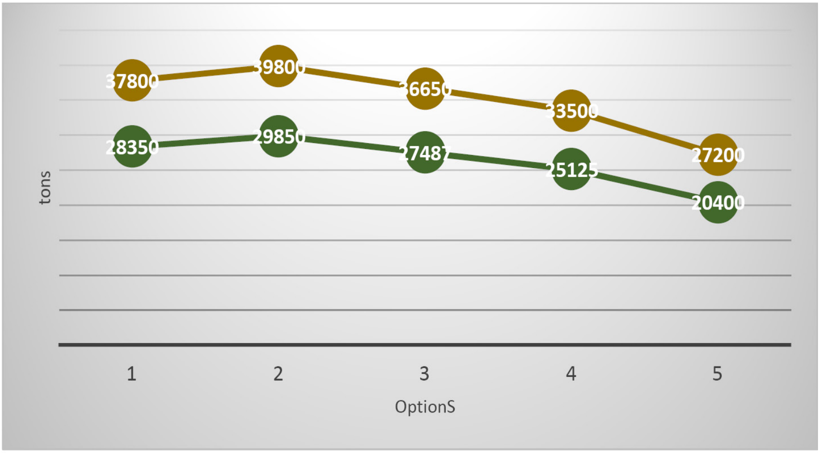
Table 1.

Calculation of transported tons of cargo depending on the interval

Option	Number of freight trains	Number of heavy trains	6300	8300	Gross tons transported	Tons of cargo transported
1	6	0	37800	0	37800	28350
2	5	1	31500	8300	39800	29850

End of a table

3	4,8	1	28350	8300	36650	27487
4	4	1	25200	8300	33500	25125
5	3	1	18900	8300	27200	20400



- tons of cargo transported - gross tons transported

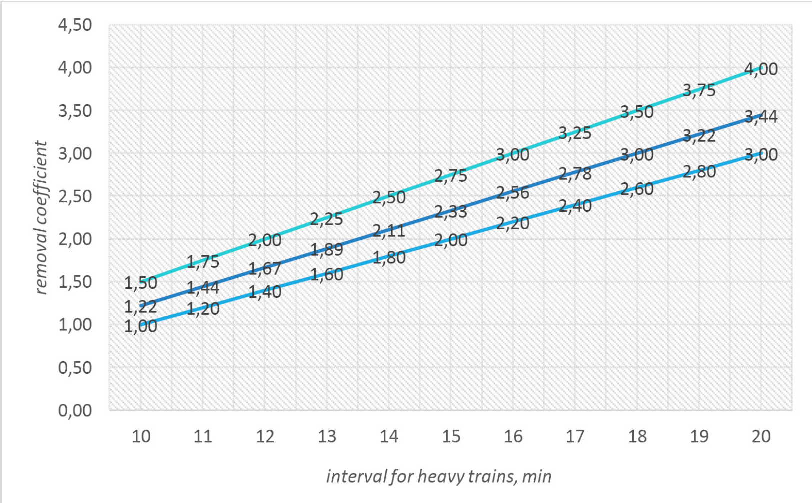
Fig. 3. Graph of the dependence of transported tons of cargo on the inter-train intervals of heavy trains

Thus, with a slight difference in intervals (10 and 12 minutes), an increase in the volume of transported cargo is observed, but with an increase in the gap between the inter-train intervals (10 and 15, 10 and 20) for the same period, the number of gross and net tons transported decreases.

Considering the influence of the values of the inter-train intervals of freight trains and heavy trains on the removal coefficient, the following dependence can observed (Fig. 4). When the interval between freight trains decreases, the value of the removal coefficient increases.

When calculating the cash carrying capacity of double-track sections equipped with automatic locking, it can be equivocally stated that when heavy trains pass, it increases.

To see the effect of the number of heavy trains passed, let us turn to the formula for calculating the carrying capacity (C). [1].



The removal coefficient for the inter-train interval of freight trains 10 min

The removal coefficient for the inter-train interval of freight trains 9 min

The removal coefficient for the inter-train interval of freight trains 8 min

Fig. 4. Dependence of the removal coefficient of heavy trains on inter-train intervals

$$C = \frac{365 \cdot Q_{gr} \cdot \varphi}{10^6} \cdot \left[\frac{(1440 - t_{tech} \cdot \alpha_{r/a}}{I} - N_r^{pass} - N_r^{acc} - N_r^{comb} - N_r^{h} \right], \quad (3)$$

where: t_{tech} – technological “window”, min; α_r – reliability coefficient, taking into account failures of technical means; I – inter-train interval (schedule period), min. Q_{gr} – the mass of the train composition gross, t; φ – the ratio of the mass of the train composition net and gross, $N_r^{pass}, N_r^{fast}, N_r^{acc}, N_r^{comb}, N_r^{h}$ – the total number of freight trains removed from the schedule of passenger, fast, accelerated freight, combined and heavy trains.

Number of freight trains to be removing is determined by:

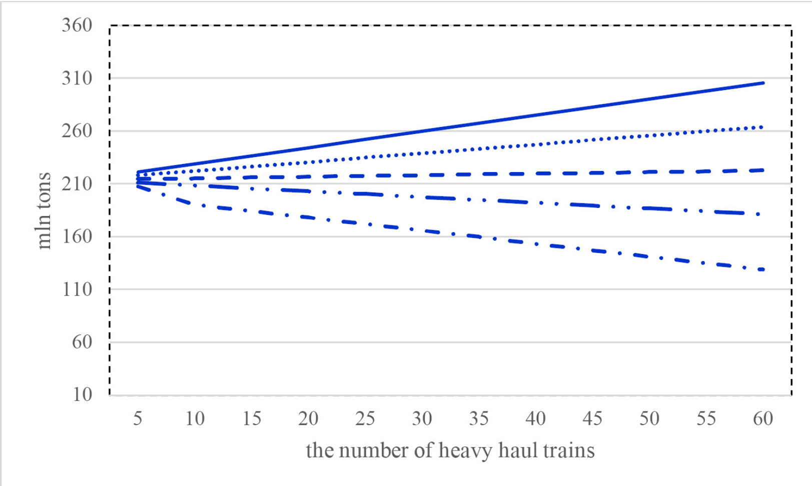
$$N_r^{pass(fast)} = \varepsilon_{pass(fast)} \cdot N_{pass(fast)}, \quad (4)$$

$$N_r^{comb(acc)} = (\varepsilon_{comb(acc)} - 1) \cdot N_{comb(acc)}, \quad (5)$$

$$N_r^{h} = (\varepsilon_h - 1) \cdot N_h. \quad (6)$$

Where $\varepsilon_{pass(fast)}$, $\varepsilon_{comb(acc)}$, ε_h –are the coefficients of removal by passenger (fast of passengers); combined (accelerated freight); heavy trains; $N_{pass(fast)}$, $N_{comb(acc)}$, N_h – the amount of passenger (fast), combined (accelerated), heavy trains.

The graph of the dependence of the available carrying capacity on the amount of heavy trains passed shown in Fig. 5.



__ 12 min; ... 14 min; ----- 16 min; _ . . 18 min; - . - 20 min

Fig. 5. Schedule of changes in the available carrying capacity depending on the number of heavy trains and the inter-train interval between them

From the presented graph, it can be concluded that:

1. With a slight gap between intervals (0-3 min) and an increase in the number of heavy trains, there is an increase in the available carrying capacity.

2. With the difference between the intervals of 4-5 minutes and an increase in the number of heavy trains, there is no significant change in the carrying capacity.

3. With a significant gap in inter-train intervals (6 minutes or more) for heavy and freight trains, there is a decrease in carrying capacity.

If connected trains with intervals of movement are considered as heavy trains, as for heavy trains, then the results will change (Table 2).

Table 2.

Calculation of transported tons of cargo depending on the interval

Option	Number of freight trains	Number of heavy trains	6300	12600	Gross tons transported	Cargo tons transported
1	6	0	37800	0	37800	28350
2	5	1	31500	12600	44100	33075
3	4,5	1	28350	12600	40950	30712
4	4	1	25200	12600	37800	28350
5	3	1	18900	12600	31500	23625

Considering the dependence graph (Figure 6), a similar picture is observed: the greater the difference between the intervals, the lower the carrying capacity. However, for connected trains, the difference should be more than 5 minutes.

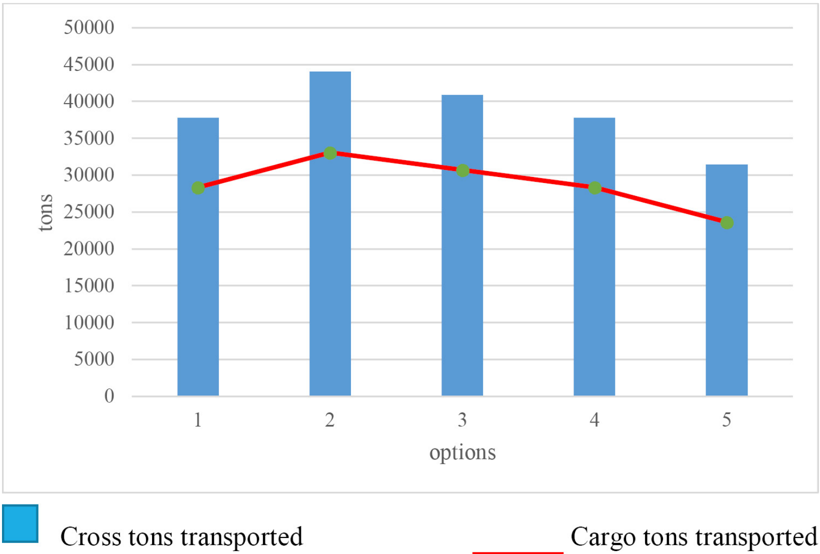


Fig. 6. Dependence of the carrying capacity on the interval value for connected trains

Increasing the mass of trains is not only one of the most effective measures to increase the carrying capacity of railways, but also an important means of improving the operational performance of their work and reducing the cost of transportation. The mass of the train determines the requirements for the technical equipment of railways, primarily for the power of locomotives, the length of station tracks, power supply devices for electric traction, shunting facilities, etc.

Thus, the establishment of a rational mass of trains on railways is an important and complex technical and economic problem, closely related to the increase in the carrying capacity of railways, but affecting a much wider range of issues related to their work. Its choice can be considered for a given type and power of the locomotive or for cases when the power of the locomotive is unknown, i.e. it must be set simultaneously with the determination of the mass of the train.

The development of heavy traffic is one of the tools that will increase the carrying capacity of the direction, create a reserve of capacity on the network of JSC "Russian Railways".

Conclusion

1. To increase the carrying capacity, it is necessary to reduce the difference between the inter-train intervals of freight and heavy trains

2. With a significant difference between the intervals, the number of heavy trains should not be more than 10-15 per day

3. To reduce the removal coefficient, it is necessary to reduce the difference between the intervals

Undoubtedly, the development of heavy traffic will strengthen the capacity of the Russian railway network [8, 9]. In the conditions of increasing the volume of transshipment, it is possible to increase the number of heavy trains with the appropriate infrastructure. Thus, only with the introduction of 25% of heavy trains, excluding capital investments, the annual additional income increases by 15%. Therefore, it can be argued that such an organization of train traffic is economically profitable and justified. The additional volume of traffic received at the same time will reduce the cost of train-km, and train stops. The studies presented by the authors confirm the validity of this statement. At the same time, in connection with the organization of the constant circulation of trains of increased weight and length, there are issues that need to be resolved [10]. The analysis of the Russian literature shows that there are both supporters and opponents of the heavyweight movement [11]. But as practice shows, the increase in the efficiency of the transportation process, including "by increasing the weight and length of freight trains, provides an increase in the carrying capacity of the railway network in conditions of limited investment resources in the medium term" [12] .

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