Complex optimization of parameters of Maglev systems is a basic condition of their implementation

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ABSTRACT: Now development of Maglev transport is in a stage of its practical implementation. So, the most important problem is finding an area of its effective operation The main task of this work is finding favorable conditions for operation and optimum technical parameters of Maglev systems at which their application would be effective.

1 INTRODUCTION

The previous researches by the authors have shown advantage of application of Maglev transport system on aer - oelectrodynamic suspension with superconducting magnets - Transmag[*)] as high-speed ground transport (HSGT) in the territory of Ukraine under condition of construction of the ring line which passes through the basic regional centers of the country, and allowing artificialy concentrate volumes of passenger traffic on line HSGT [2]. However, realization of such project demands huge capital investments of which the economy of Ukraine is not capable now.

In work [3] a complex technique for optimization of Maglev systems has been developed. In a work [4] an efficiency of optimization of the length of a Transmag train has been evaluated.

[*)] System Трансмаг it is developed in Institute of Transport systems and Technologies of the National Academy of sciences of Ukraine [1]

2 STATEMENT OF THE PROBLEM

With the purpose of the further reduction of expenses in construction of a line of Transmag system, in the present work an advantage of application of such system is estimated under complex optimization of its parameters, namely:

- overlapping of cargo and passenger transportations in one structure of a train;
- overlapping the main and suburban transportations on one line;
- optimization of train lengths depending on a volume of passenger traffic and length of a line.

3 MATHEMATICAL MODEL

For this purpose updating of the mathematical model has been carried out, allowing to calculate the resulted volume of passenger traffic which takes into account overlapping cargo and passenger transportations in one structure of a train.

The total amount of passenger and freight transportations is reduced to a volume of passenger traffic. According to this, for recalculation of the volume of a freight traffic into a volume of passenger one, the resulted volume of passenger traffic is defined from expression:

$$P_p^a = G * K_G \text{ [passenger/year]} \qquad (1)$$

where

G is total amount of an annual freight traffic [t/year];

$$K_G = \frac{n_p}{m_p} \qquad (2)$$

where

n_p - is a quantity of passengers which can be placed in one car, i.e. passengers capacity of the car;

m_p - is a carrying capacity of the car [t].

In this case the resulted volume of passenger and freight transportations for the final year of calculated term of operation of Transmag system is defined from the expression:

$$P_p^m = P_{p_1} * (1+q_p)^{(m-1)} + P_{p_1}^a * (1+q_G)^{(m-1)} \text{ [passenger/year]} \qquad (3)$$

where

m - is the last year of a calculated term of operation of the line;

P_{p_1} - is the annual volume of passenger traffic in the both directions for the first year of operation of the system [passenger/year];

$P_{p_1}^a$ - is the annual resulted volume of passenger traffic in the both directions for the first year of operation of the system, which replaces the total freight traffic [passenger/year];

q_p - is a mid-annual factor of a volume of passenger traffic;

q_G - mid-annual factor of a freight traffic.

At research of probable streams of cargoes for the Transmag system, the statistical data on transportations of perishable cargoes (fish, meat, vegetables, fruit, express mail, etc.) on the Pridneprovskaya railway have been processed. In result, it has been determined that the daily average volume of such cargoes is equal 500 t. net, and the annual volume is 0,183 mln.t.

Having accepted that the volume of transportations of perishable cargoes on roads of Ukraine is approximately identical, we shall receive, that the total volume of transportations of such cargoes on the roads of Ukraine is equal 1,1 mln.t. net/year.

Taking into account that the freight traffic transported by the Ukraine railways makes ≈55 % of the total freight traffic, and also occurrences of new kinds of high-speed cargoes with the advent of the Transmag system, it can be expected that by 2010 the volume of transportation of high-speed cargoes will reach 2,5 mln.t. net / year.

As on Transmag system passenger and freight transportations are provided, at which cars of the same carrying capacity can be used both for transportation of passengers (44 passengers), and for cargoes (5 t. Net), calculations were conducted for the equivalent volume of passenger traffic.

At forecasting volumes of passenger traffic the additional volume of passenger traffic has been taken into account due to transit on a direction the Center - south (Moscow - Crimea, Moscow - Sochi), accepted according to the data provided by the Institute of Complex Transport Problems of the Ministry of Economics and Development of the Russian Federation. Thus, the maximal volume of passenger traffic on the line HSGT has been accepted as 250 million passengers per one year.

Updating of the mathematical model, allowing to take into account overlapping the main and suburban transportations on one line, has been carried out/

For definition of the throughput and type of the line at introduction of the joint operation of main and suburban trains on the same line, the calculation algorithm was remade. So-called train removal factor for a main traffic was calculated to estimate the possibility of the passing suburban trains on the same line by calculation of resulted volume of the passengers.

According to [6] the train removal factor of the main traffic is the relation of durations of motion of trains of various categories:

$$\varepsilon = \frac{t_{nc}}{t_{mc}} \qquad (4)$$

where

t_{nc} - is the time of a course of a train/pair of trains*) of the suburban traffic over stage;

t_{mc} - is the time of a course of a train/pair of trains of the main traffic over stage;

Time of a course of a train on a site depends on length of the site, speed of train movement and size of a bias of a line that is taken into account at definition of the train speed.

*) For a single-line line with travels time of a course of two trains of both directions is taken into account. For a two-acceptable line time of a course of one train is taken into account.

Besides, this mathematical model enables us to change the length of trains and to estimate an advantage of such change. Thus, the optimum length of a train is defined from the condition of the minimal tariff for transportation of passengers and cargoes, under condition of an invariance of the volume of the passenger traffic and length of the line.

The minimal sizes of tariffs were defined from condition of term of self-support of a line in time, not exceeding a normative time of recovery of outlay **(t_n)**, equal 10 years, according to the present discount ($E_{нп}$) in transport construction, equal 0,1.

Thus, the size of the specific transportation tariff is defined from expression:

$$T^s_p = \frac{G^n_k * 10^6}{\sum_1^n P^t_p * L_S} \text{ [US \$/1км*passenger]} \quad (5)$$

where

- P^t_p - is the general volume of passenger traffic for calculated current year [passenger/year];
- G^n_k - is the total resulted charges to normative term of operation of a Transmag system line [million US $];
- 1 - is the first year of operation of the line;
- n - is a normative year of self-support of the line.

The total resulted charges in the case of construction of a Transmag system line instead of an existing traditional railway line are defined from expression:

$$G^{mr}_k = \sum_0^{mr} I^t_k * \eta^r_t + \sum_{p+1}^{mr} B^t_k * \eta^r_t \text{ [mln. US \$]} \quad (6)$$

where

- mr - is the last year of calculated term of operation of a Transmag system line taking into account the term for its construction [years];
- 0 - is the zero year. In this case it is the year of the beginning of construction of the line
- p - is the year of the completion of construction of the line and the beginning of its commissioning;
- η^r_t - is the factor which takes into account an estrangement of expenses in time at replacement of the working line on new, is defined from the expression:

$$\eta^r_t = \frac{1}{(1+E_n)^t}, \quad (7)$$

where

- E_n - is the normative factor of reduction of occurring at different times expenses at replacement of a working line on new, is defined from expression:

$$E_n = \frac{1}{t_n}, \quad (8)$$

4 INITIAL DATA

At calculation the following initial data have been accepted:

- the allowable size of acceleration for trains of the suburban transportations makes 1 m/s^2 (such acceleration is allowed in the railway transportation and is considered safe for passengers); the allowable value of the acceleration for trains of the main transportations is 2 m/s^2 (in local trains travel of standing passengers is possible whereas in trains of the main transportations all places are sedentary and at dispersal and braking, people should sit in an armchair);
- the factor of growth of a volume of passenger traffic for trains of the main transportation for a year was accepted 0,1. Thus, the effect of double growth of a volume of passenger traffic was admitted, as on line Sinkansen., due to occurrence of additional working trips (in this case people have an opportunity to live and work in different cities);
- the average bias of a line was accepted 10 ‰ that corresponds to the average bias of a line on directions of its possible passage;
- the maximal bias of a line was accepted 100 ‰ from the condition that at the speed of 600 km/h the train will manage to overcome it;
- the general share of viaduct was accepted 93 % from the condition that 7 % of the length of a line will be occupied with stations for which embankments are planned;
- the length of the stage for trains of the main traffic was accepted 100 km, as average distance between regional cities in Ukraine;
- the length of the stage for trains of the suburban traffic was accepted 10 km as average distance between large railway stations, whence passengers can reach destinations by traditional transport of the suburban traffic.

The volume of suburban passenger traffic has been accepted equal 1 or 2 million passengers in a year. Besides, the cost of a car of a suburban train has been accepted twice smaller, than the main train car that corresponds to the existing conditions.

The initial data for calculations are submitted in table 1.

5 CALCULATION RESULTS

Multiple calculations have been executed at a wide range of a volume of the passenger traffic and length of a line.

The bounds for a sphere of effective application of Transmag system under the considered conditions similarly [4-5] were defined by comparison of the tariff for the Transmag system with that for the existing types of transport, depending on the volume of transportations and length of a line.

Results of comparison of tariffs for Transmag system with that for conventional types of transport are resulted in table 2.

When the volumes of passenger traffic are higher than the volumes specified in table 1, the cost of the tariff for transportation of passengers for the Transmag system becomes less than that for indicated types of transport.

Table 1: Calculation data

Parameters	Initial data	
	The suburban transportation	The main transportation
Time of boarding/ landings of passengers [min]	1	5
Factor of growth of a volume of passenger traffic	-	0,1
The admitted size of outstanding acceleration [m/s^2]	1	2
Initial line length [km]	250	250
Final line length [km]	4500	4500
Step of change of length of a line [km]	250	250
Initial size of an annual volume of passenger traffic [million passenger/year]	1	25
Final size of an annual volume of passenger traffic [million passenger/year]	2	250
Step of change of an annual volume of passenger traffic [million passenger/year]	1	25
Length of a stage [km]	10	100
Part of viaduct on a way at its height 10 m	0,2	0,2
Part of viaduct on a way at its height 15 m	0,6	0,6
Part of viaduct on a way at its height 25 m	0,13	0,13
Average gradient of a line [‰]	10	10
The maximal gradient of a line [‰]	100	100
Station interval of crossing of trains [minutes]	2	2

In more detail results of the carried out calculations are submitted in figure 1.

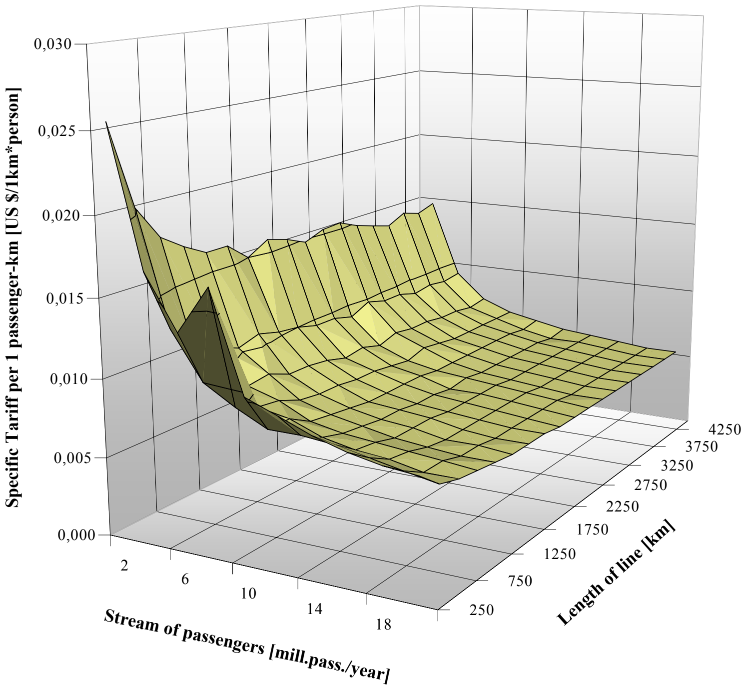

Figure 1: The schedule of definition of spheres of effective application of Transmag system in comparison with types of transport which are listed in table 2

Table 2: Rational spheres of application of Transmag system

Type of transport	Size of the average specific tariff [US $/ 1km*person]	Conditions at which the tariff of Transmag system is equalized with the tariff of traditional types of transport on a range:	
		Volume of transport-tations [million passengers /year]	Length of the line [km]
Buses	0,014	2 ÷6	250÷2750
General car in a passenger train	0,008	8 ÷16	250÷1000
Car with reserved seats in a passenger train	0,012	4 ÷8	250÷600
Compartment car in a passenger train	0,020	2 ÷3	250÷500
Car with reserved seats in a fast train	0,013	4 ÷7	250÷500
Compartment car in a fast train	0,022	2	350

6 CONCLUSIONS

It proves out that the developed actions allow to expand essentially the spheres of effective application of Transmag system in Ukraine. Thus, it is now economical to introduce the Transmag system on existing transport directions.

The offered technique of researches can be used also at designing Maglev lines in other countries of the world community [7].

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