Optimization of lengths of maglev trains.

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ABSTRACT: At the moment, when development of maglev transport has approached to a stage of practical realization, the researches, directed on optimization of its key parameters, become especially actual. This paper is devoted to a solution of some problem of such kind.

1 INTRODUCTION

Our previous researches [1,2] have shown the advantage of application of the transport maglev system “Transmag” with superconducting magnets as a high speed ground transport (HSGT) in the territory of Ukraine, provided that the route is a ring line, passing through the basic regional centers of the country and concentrating the main passenger traffic on the line However, realization of such solution requires huge capital investments of which the economy of Ukraine does not presume now. In works [3,4] a complex technique for optimization of maglev systems and the length of maglev trains have been developed.

2 PROBLEM STATEMENT

With the purpose of further reduction in expenses for construction of a line of the “Transmag” system, in this work advantage of such system is estimated under complex optimization of its parameters, namely:

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

3 MATHEMATICAL MODEL

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

It is set that the total amount of passenger and freight transportations is reduced to a volume of passenger traffic. The last is determined by the expression

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

where

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

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

where

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

m_p is the carrying capacity of the car [ton].

In this case the reduced volume of passenger- and freight transportations for the last year of settlement term of operation of Transmag system is determined from the expression

$$P_p^m = P_{p_1} * (1+q_p)^{(m-1)} + P_{p_1}^a * (1+q_G)^{(m-1)} \qquad (3)$$

[Passenger/year]

where

m is the last year of settlement term of operation of the line;

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

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

q_p is an average gain of the volume of passenger traffic for a year;

q_G is an average gain of freight traffic for a year.

Since the Transmag system of passenger and freight transportations contains sections which can be used either for transportation of passengers (44 persons) or cargoes (5 т. Net), calculations were conducted for the reduced volume of the passengers. .

At forecasting volumes of passenger traffic, an additional volume due to transit on the direction Center - South (Moscow - Crimea, Moscow - Sochi), accepted according to data of the Institute of Complex Transport Problems of the Ministry of Economics and Development of the Russian Federation, has been taken into account. Thus, the maximal passenger traffic of 200 million passengers for a year on the line has been accepted. Moreover, updating of the mathematical model, allowing to take into account overlapping the main and suburban transportations on the line.has been carried out.

For determination of the carrying capacity and type of a line at introduction of the joint operation of main and suburban trains on one line, the algorithm for calculation of so-called factor of main trains allowing to estimate an opportunity of operation of suburban trains on the same line has been advanced by calculation of the resulted volume of passenger HSGT traffic.

According to [5], this factor is determined by the ratio

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

where

t_{nc} is the duration of motion of a suburban train (pair trains) between some stations;

t_{mc} is the corresponding duration of motion of a main train (pair trains).

The durations depend on the distance, motion speed and the value of the mean bias of the line that is taken into account under determination of the motion speed.

This mathematical model enables one to execute a change of a train length and to evaluate an advantage of such change. Thus, the optimum length of a train is determined from the condition of the minimal size of the specific tariff for transportation of passengers and cargoes, under condition of an invariance of the volume of passenger traffic and the length of a line.

The minimum values of the specific transportation tariff were determined from the condition that the recoupment term of the line should not exceed the normative one (t_n), equal 10 years, according to a discount 0,1 accepted in transport construction ($E_{нп}$). Thus, the specific transportation tariff is determined from the expression:

$$T_p^s = \frac{G_k^n * 10^6}{\sum_1^n P_p^t * L_S} \text{ [\$US /1км*passenger]} \qquad (5)$$

where

P_p^t is the total reduced volume of passenger traffic for the current year [passenger/year];

G_k^n is the total reduced charges to normative term of operation of a line of Transmag system [million $US];

1 is the first year of operation of the line;

n is a normative year of recoupment of the line;

L_S is the general length of the line in a single-line calculation.

The total reduced charges in case of construction of a Transmag line instead of an existing line of a conventional type are determined from the expression:

$$G_k^{mr} = \sum_0^{mr} I_k^t * \eta_t^r + \sum_{p+1}^{mr} B_k^t * \eta_t^r \text{ [million \$US]} \quad (6)$$

where

mr is the last planned year of operation of the line with the account of the construction time;

0 is the zero year (the year of the beginning of the line construction);

P is the year of the termination of construction of the line and the beginning of its commissioning;

η_t^r is the factor taking into account a change of expenses in time at replacement of a working line by new one; it is determined from the expression:

$$\eta_t^r = \frac{1}{(1+E_n)^t} \quad (7)$$

where

E_n is a normative factor of reduction of expenses, occurring at different times under replacement of a working line by new one, determined from the expression:

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

4 THE INITIAL DATA

At calculation the following initial data have been accepted:

- the allowable size of acceleration for main trains is 2 м/s^2 under condition that all places are sedentary, and at dispersal and braking, people should sit in armchairs;
- the factor of growth of the passenger traffic of main trains for a year equals 0,1. Thus the growth of approximately 2 times (as on the line SHINKANSEN) takes into account that, due to occurrence of additional working trips, people have an opportunity to live in one and work in the other city;
- the average bias of a line is 10 ‰;
- the maximal bias of a line is 100 ‰ (it is assumed that the train will manage to overcome it at a speed in 600 km/h;
- the general length trestles is 93 % of the total length (it is accepted that 7 % of the line will be occupied with embankments in the stations area);
- the length between cities (span) of 100 km was accepted as an average distance between Ukrainian regional cities.

The initial data for calculations are resulted in table 1.

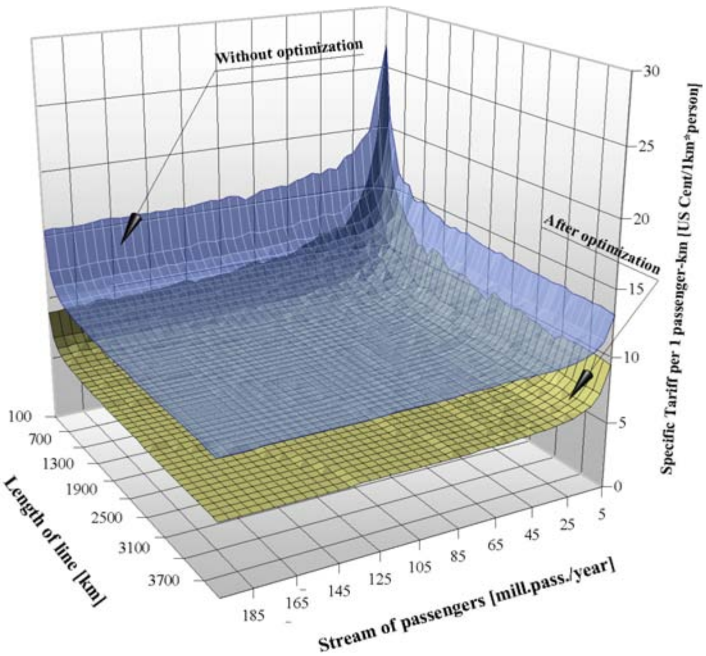
Parameters	Unit of measu-rements	1-st variant	2-nd variant
Duration of boarding / landing	minutes.	5	5
The factor of a year growth of traffic	-	0.1	0.1
Allowable acceleration value	m/s^2	2	2
Initial length of a line	km	100	100
Final length of a line	km	4000	4000
Step of change of line length	km	100	100
Initial volume of passenger traffic	mill.pass./ year	5	5
Final volume of passenger traffic	mill.pass./ year	200	200
Step of change of a volume of passenger traffic	mill.pass./ year	5	5
Initial amount of train sections	section	1	13
Final amount of train sections	section	60	14
Step of change of amount of train sections	section	1	1
Span	km	100	100
Average bias of a line	‰	10	10
Maximal bias of a line	‰	100	100

5 CALCULATION RESULTS

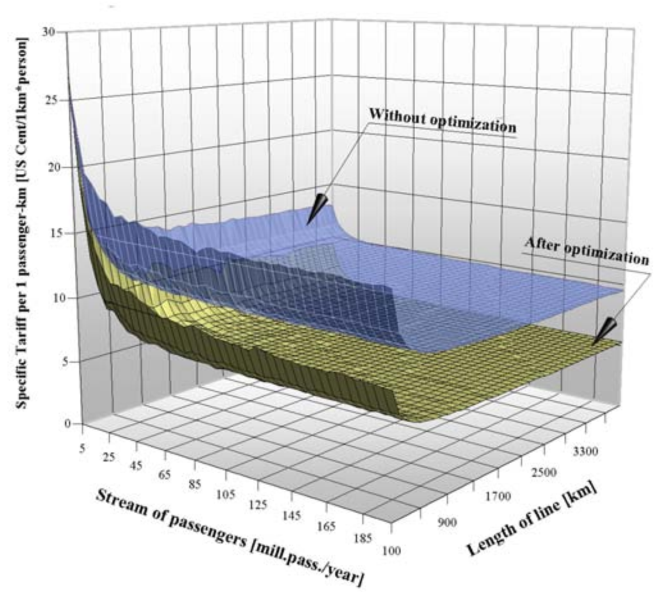
Using the above model, multiple calculations have been executed. The length of a line varied from 100 up to 4000 km and the reduced volume of passenger traffic from 5 up to 200 million passengers per year.

For the first variant, calculations were carried for trains of optimum length, while for the second variant trains of standard length were considered; all other parameters are identical.

The calculation results show that optimization of lengths of trains of Transmag system allows to reduce essentially the specific tariffs for transportation of passengers and cargoes. For presentation the corresponding results are shown in Figure 1 in two kinds. As is seen, optimization of a train length reduces operation costs approximately in 1,5 times, while the capital expenses, practically, do not depend on the length



a) right-side view



b) left-side view

Figure 1. Dependence of specific transportation tariff on length of a line and annual volume of transportations.

6 CONCLUSIONS

The above analysis of algorithm of calculation has shown, that the length of structures can affect the resistance to train motion and, thereby, on the expenditure of the electric current. The corresponding calculations, executed for a volume of passenger traffic, changing from 5 up to 200 million passengers per year, have shown, that, under the use of trains of optimum length, expenditure of the electric current decrease by 1,7 - 2,0 times.

As a result, the optimization of the lengths of maglev trains allows to cut down essentially (approximately in 1,5 times) the total operation expenses. This will allow to substantially expand the areas of effective operation of maglev systems.

7 REFERENCES

1. Prykhodko O. A., Polevoy O. B., Menddriy A. V., “On the calculation of aerodynamic characteristics of high-speed ground vehicles on the base of three-dimensional navier-stokes equations”, 18th International Conference on Magnetically Levitated Systems and Linear Drivers, Shanghai, China, p.575-583, 26-28 October, 2004.
2. Umanov M. I., Taturjevich A. L., Lascher A. N., “Definition of sphere of effective application Maglev-transport in a national economy of Ukraine”, 2. Internationale Konferenz – Elektrische Bahnsysteme, Berlin, Germany, p.383-387, 23. und 24. Marz 1999.
3. Lascher Arkadij, Umanov Mark, Prishedko Helen, “Complex Method of Optimization of Magnet Levitation Transport Systems and Determinations of Spheres of their effective Applications”, 18th International Conference on Magnetically Levitated Systems and Linear Drivers, Shanghai, China, p.235-247, 26-28 October, 2004.
4. Umanov Mark, Frishman Evgeni, Lascher Arkadij, Prishedko Helen, “Optimization of parameters of the Maglev-systems as the principal way of the pise of their efficiency”, 8-th International Symposium on Magnetic Suspension Technology, Dresden, Germany, p.34-38, 26-28 September, 2005,.
5. Galaburda V. G., “Uniform transport system”, Publishing house Transport, Moscow, Russia, 2001.
6. Gurol S., Baldi B., Post R.F., “Overview of the General Atomics Low Speed Urban Maglev Technology Development Program”, 17th International Conference on Magnetically Levitated Systems and Linear Drives, Lausanne, Switzerland, September 4-8, 2002.