Small-sized magnetolevitation system of the trestle type for the Arctic

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Abstract. The construction of large technical systems (industrial and transport) poses a threat to the environmental situation in the Arctic. On the other hand, the operation of such systems in harsh Arctic conditions is also unsafe, especially in permafrost conditions. We offer a small-sized maglev system of the trestle type with "movers" and "fellow travelers" type suspension. In this system, the track magnetic field is created by a moving sequence of interacting magnetic field sources –movers in a special control channel (beam, pipe), which also interact with the magnetic field sources of transport modules –fellow travelers. Fellow travelers are suspended in controlled channels due to interaction with permanent sources of magnetic field. The structure is mounted on arc-shaped supports that evenly distribute the load on the supporting surface and protect it from snow drifts and water flows. A model of a two-channel system with the lower location of the controlled channel has been developed. Further improvement of the system involves the use of the "magnetic potential hole" effect and the principles of the planetary model construction.

1 Introduction

According to the type of trestle equipment, most of the implemented transport systems based on magnetic levitation (maglev) can be defined as single-channel - all equipment in one pipeline (pipe) or around one beam [1]. The overpass stator winding is divided into an accelerating winding and a winding which provides lifting or suspension of transport modules. Transport modules move when a moving magnetic field is generated in the accelerating winding.

The greatest progress in the development of maglev transport has been made in the China [2]. Currently, there is a tendency to consider maglev systems as a type of rail transport, namely high-speed trains [3]. In Italy, RFI and Nevomo are planning to combine maglev with the existing rail system [4].

The Hyperloop transportation system was tested, which is a pipeline inside which cargo and passenger capsules move at high speed in a highly rarefied atmosphere [5].

Maglev and Hyperloop train systems are large technical systems. The creation of large technical systems (industrial and transportation) poses threats to the Arctic environment. On the other hand, the operation of such systems in harsh Arctic conditions is also unsafe, especially in permafrost conditions. In addition, as industrial facilities or mineral deposits are completed, the transport routes to them may become redundant. For example, the operation of the Novy Urengoy – Yamburg railway line was discontinued.

In this regard, in the Arctic it may be advisable to use small-sized transport systems with the number of passengers 4-5 people or carrying capacity of 0.5 tons.

We propose to consider small-sized transportation systems, which can be connected to the main maglev and rail transport systems at hubs for subsequent transportation of passengers and cargo to hard-to-reach points [6]. At the same time, such systems will have some similarities with the Hyperloop system.

2 Small-sized maglev system

The proposed system is shown in Figure 1. The circular magnetic field sources are located in two conjugate channels. In the upper channel, the magnetic sources – movers are located. Movers can form an arbitrarily long sequence.

The upper channel will be called the control channel. the control channel has an oval shape in the cross section, which eliminates the overturning of the movers. The movers in the channel have a gap relative to the inner walls, which does not cause difficulties when moving.

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Thus, the control channel is a pipe, inside of which ideal conditions for movement of movers are created, in particular, by analogy with Hyperloop, it can be a very rarefied atmosphere. But we are not trying, unlike Hyperloop, to put the entire transport module (TM) inside the pipe.

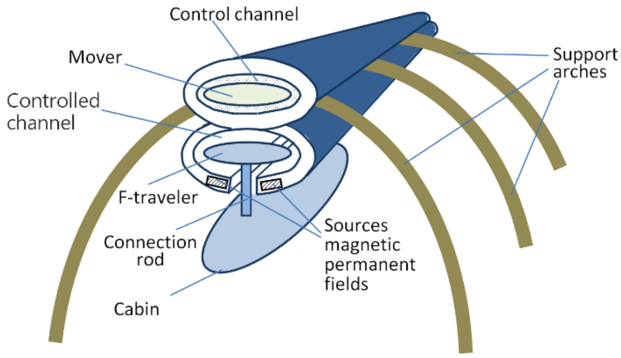

Fig. 1. General view of the small-sized maglev system.

The TM consists of a cabin and several magnetic field sources connected to the cabin, for example, by means of rods. The magnetic field sources of the TM are located in the lower channel (Fig. 1), which we call the controllable channel. In the case of connecting rods, the controlled channel has a notch, in addition, it is equipped with sources of rectangular-shaped magnetic constant fields (magnetic rails) for levitation of the TM.

3 Features of the small-sized maglev system

3.1 Advantages of the small-sized maglev system

Ideal conditions for the movement of movers (rarefied atmosphere, low temperature, etc.) can be created in the pipe, which allows not to use a large amount of electric current. The design of the overpass ensures a safe distance of the cabin from magnetic field sources, as well as overcoming hard-to-access terrain. Such transportation system with small passenger and freight flows will pay off faster than trains on magnetic suspension.

3.2 Features of the small-sized maglev system limiting its application

Tests of the transportation system model revealed several features that may limit its use. Specifically:

a) The box for f-travelers is made with a cutout, which weakens the strength of the structure.

b) The use of more than two connecting rods per cabin makes it difficult for the modules to move in roundabouts.

c) The connecting rods do not provide absolutely contactless movement of the transport modules, so at some points they will touch the edges the box cutout.

4 Possible solutions to problems

The next step in the development of such transportation systems could be the non-contact coupling of movers and f-travelers using the “magnetic potential hole” effect and superconducting magnetic field sources.

The “magnetic potential hole” effect in the interaction of ideal conducting ring structures was discovered by V.V. Kozoriz [7]. Dimensions of rings and distances between them are determined from relations (1) and (2):

$$\Psi_1 \Psi_2^{-1} \neq 1; \qquad (1)$$

$$a_1 R^{-1}, a_2 R^{-1} \leq \frac{1}{2}, \qquad (2)$$

where Ψ1 and Ψ2 are magnetic flows; a1 is the radius of a smaller ring; a2 is the radius of a bigger ring; R is the distance between the rings.

Let us also refer turn to the organization of movement in the universe [8]. Cosmic bodies with magnetic fields move in elliptical orbits relative to more massive bodies, so planets move relative to stars, and rotate around their axes.

This principle can be the basis for the functioning of multi-channel maglev systems (Figure 2).

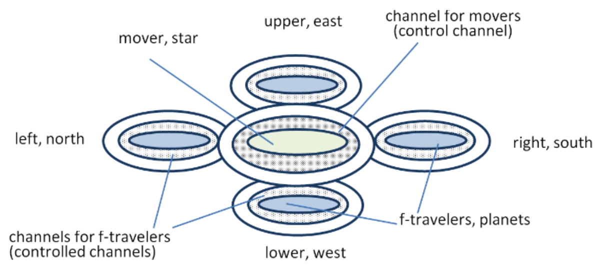

Fig. 2. Planetary model of maglev-system.

In the center of the system there is a control channel, inside of which movers (stars) move. The control channel is connected to the controlled channels, the number of which can reach four in accordance with the number of parts of the world: upper (east), right (south), lower (west), left (north). Together with the movers, satellites (planets) located in controlled channels move. In the planetary model with four controlled channels, the “magnetic potential hole” effect appears both when the magnetic sources are located in one plane (north – center – south) and when they are located in parallel planes (east; center; west).

Other researchers also consider magnet-interacting systems based on planetary models [9].

A possible implementation of a multi-channel maglev system based on a planetary model is shown in Figure 3, where denoted: 1 – cabins of transport modules; 2 – magnetic sources of transport modules; 3 – f-travelers; 4 – controlled channels; 5 – mover; 6 –

control channel; 7 – linear motor; 8 – trestle rack; 9 – supporting surface.

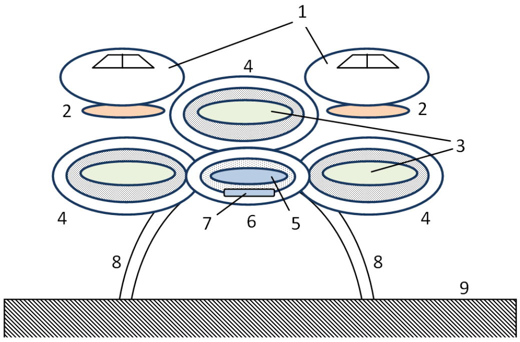

Fig. 3. One of the implementations of a multi-channel maglev system

The location of the magnetic sources in the longitudinal planes (top view) is shown in Figure 4.

To meet conditions (1) and (2), the rings of larger and smaller sizes must alternate with each other both in the sequence of movers and in sets of f-travelers and magnetic sources of transport modules.

controlled channels 4 in the form of a pipe may are physically absent. movers 5, when interacting with f-travelers 3, must form a stable structure (nest).

The cabins 1 of the transport modules with their magnetic sources 2 sort of to "sit" in this nest. When the sequence of movers 5 in the channel 6 moves, the nest together with cabins 1 also moves in a predetermined direction (in this case forward or backward).

We have not yet defined a specific method for setting the motion sequence of the movers. This can be a linear motor, pressure drop, liquid flow, and many other things.

To describe the processes, the development of Dr. G.A. Vitkov [10] may be useful in case of using liquid flow. In particular, he proposed models for the occurrence of resistance. These models can be used to calculate hydrodynamic, heat and mass exchange processes in any systems and conditions of force fields.

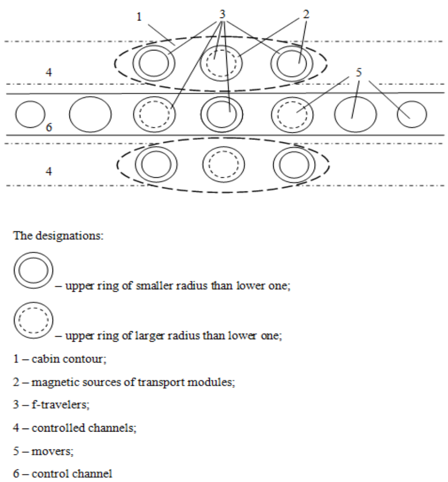

Fig. 4. The location of magnetic sources in longitudinal planes (top view).

5 Our mock-up studies

We discovered the resistance of the movers to each other when we tried to investigate the mock-up model. A mock-up made by 3D printing a three-channel system was tested (Figure 5).

Fig. 5. The mock-up of the three-channel system

Niobium magnets with a diameter of 30 mm with countersink were used as movers. The control channel is a closed pipe of 160 cm length with an oval section and a slot in the upper part for observation of the movers. The controlled channel is a straight pipe with oval section and a cutout in the lower part for connecting rods of the transport module model. It was assumed that the sequence of movers in the control channel would move from one or more sources of rotational motion. When the movers interact with the f-travelers of the transport module model, it would have to move linearly. However, the action of the resistance forces manifested themselves.

To overcome this resistance, we have developed magnetic transmission (Figure 6).

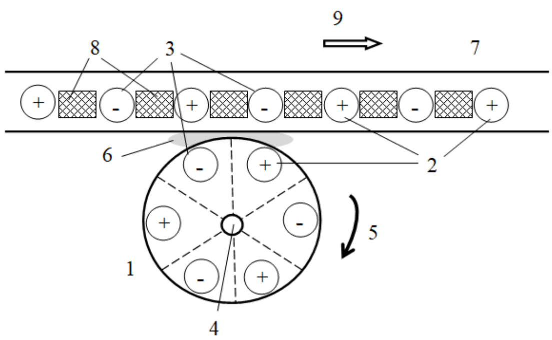

Fig. 6. Magnetic transmission

Fig. 6 shows: 1 – rotor; 2 – magnetic sources of positive polarity; 3 – magnetic sources of negative polarity; 4 – rotation axis; 5 – rotation direction; 6 – interaction sector; 7 - guiding beam; 8 – "soft" buffers; 9 – direction of TM movement. Magnetic sources 2 and 3, located in beam 7 and separated by buffers 8, form a sequence of movers.

Such magnetic transmission allows for recovery. Let us suppose that the unloaded movers move linearly, for example, with a linear stepper motor. By overcoming the interaction sector, they will force the rotor rotate. As a result, energy can be generated and accumulated. When the movers do useful work in the suspended transport modules, the rotors rotate due to the stored energy. This

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ensures the linear movement of the sequence of movers and the associated transport modules.

The long control channel can be multi-cascade. A system with a three-cascade control channel is shown in Figure 7. The controlled channels can be called working ones, since they provide motion of f-travelers and transport modules. The source of rotational motion can be called the accelerator of the movers.

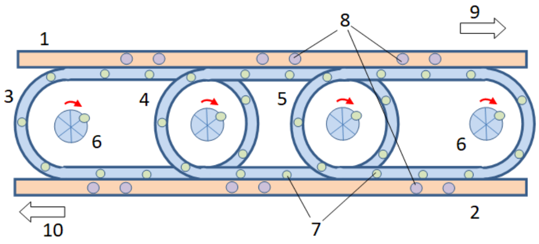

Fig. 7. The system with three-cascade control channel

In Fig. 7, 7 is marked as follows: 1 – working channel 1; 2 – working channel 2; 3 – first control channel cascade; 4 – second control channel cascade; 5 – third control channel cascade; 6 – rotors; 7 – movers; 8 – f-travelers; 9 – direction of f-travelers movement in working channel 1; 10 – direction of f-travelers in working channel 2.

Thus, taking into account the direction of the transport modules, each control channel cascade covers two accelerators: an initial and a final. The final accelerator of one cascade is initial for the next.

For example, accelerator 6 is the initial one for stage 3 of the control channel. It sets the acceleration of nearby movers 7. Under the action of this acceleration, movers 7 reach the interaction zone with the final accelerator of cascade 3, which is the initial accelerator of cascade 4. The process is then repeated for cascades 4 and 5. The movers 7 interact magnetically with the f-travelers 8 which are located in working channels 1 and 2. As a result, the transport modules move in directions 9 and 10.

6 Features of the multi-channel systems

1. The movers must be powerful magnetic field sources and have a circular shape. It is desirable that they are magnets on superconductors.

2. The fellow travelers (f-travelers) are constant magnetic field sources, which are part of the transport module, and also has a circular shape.

3. magnetic field sources are placed in channels. The movers are placed in the control channel. F-travelers are placed in controlled channels.

4. arc-shaped trestle allows for compact placement of the control channel and the controlled channels, to ensure their interaction.

5. ideal interaction of movers with f-travelers can be ensured through the “magnetic potential hole” effect.

6. In the planetary model of the maglev system, the electromagnet can be replaced by the motion of movers along an elliptical trajectory in the control channel. The movers will pull or push f-travelers in the working channels. The transport modules will also move along with the f-travelers.

7. Small-sized maglev systems of the trestle type can be used to create messages-bindings of remote industrial facilities with the reference nodes of the transport network of the Arctic zone of the Russian Federation.

In particular, in the Arctic, maglev systems can be used to connect remote facilities to backbone transportation systems, fill gaps in the supporting systems, connect remote marine terminals to the coastal infrastructure [11, 12], transport of hydrocarbons in mini tanks [13], etc.

A study of the weather parameters of the proposed maglev systems has not yet been carried out. However, there is reason to believe that they will be similar to the characteristics of the Yunitsky string transport systems [14].

It should be noted that when using superconducting magnets as movers, their operability is cheaper to ensure in climatic zones with prevailing low temperatures than in southern territories.

Installation of piles in permafrost conditions is a significant problem [15]. The trestle supports will essentially be piles whose bases rest deep into the permafrost, so that the seasonal thawing of its upper layer does not affect the stability of the structure. The gaps between the column supports do not prevent the free circulation of air under them, which minimizes the additional heat effect.

The method of pile installation is determined on the basis of physical and mechanical parameters of permafrost soils, the average annual soil temperature, the climatic area of construction, the time of the year and the requirements for the degree of accuracy of pile immersion into the permafrost. The average annual temperature of permafrost soils is determined at a depth of 10-15 m, where the change of seasons causes almost no change in the level of the average soil temperature. Given this indicator, frozen soils are divided into low-temperature (from -1.5°C) and high-temperature (0°C, not lower than -1.5°C) soil layers. Based on this, a certain method of installing piles is chosen.

In addition to the technical component, an important advantage of trestle maglev systems is the fact that they do not interfere with the free movement of local fauna under the highway. Thus, the negative effect of the inclusion of extraneous organisms in the ecosystem is minimized. The transport modules of the maglev systems themselves are capable of driving in almost any weather.

7 Conclusion

The events associated with the spread of coronavirus infection have led to a drop in production in many countries, accordingly affecting the development of new modes of transport around the world. There is growing skepticism towards high-speed transport projects due to significant investments in construction and long payback periods, their feasibility and economic efficiency are questioned. However, according to the authors [16], the main recommendation for creating the most sustainable multimodal transportation system (as a whole) is to change thinking, identify and evaluate approaches to the organization of transportation, especially for evaluating new concepts of transportation facilities with real potential for solving problems.

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