EXPERIMENTAL STUDIES OF A DYNAMIC LATERAL STABILIZATION SYSTEM

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ABSTRACT

The purpose of the ongoing experimental research of a dynamic lateral stabilization system is to identify permanent magnets-based design solutions that provide lateral stability of a magnetic levitation (maglev) vehicle. The obtained results are useful in designing an energy independent system, i.e. one that uses no electromagnets or superconductors thanks to which a reduction in the mass and dimensions of the system can be achieved. The practical significance of this study consists in the possibility of applying the researched principles in the design of magnetic levitation transport systems.

Keywords: *magnetic levitation transport, experimental test facility, lateral stabilization, magnetic pole, Halbach array.*

Background. *Magnetically levitated transport vehicles that rely on permanent magnets [15] are a fundamental novelty in transportation technology. The novelty is constituted by the contactless method of the transportation vehicle's suspension, guidance and propulsion, with the interaction between the vehicle and the guideway effected by means of magnetic fields.*

As can be seen from the history of maglev transportation development, researchers [8] focused on different problems at different stages, which makes the task of providing a complete list of such problems rather difficult. However, according to V. A. Dzenzersky [3], three groups of problems can be distinguished that, when solved, defined the path of progress of this whole transportation technology.

The first group comprises problems associated with a set of computational and experimental studies that aimed to select the optimal, most efficient concept and parameters of the levitation and propulsion unit [4].

The second group has to do with the design of magnetic systems that can be used in transportation. Magnetic modules, to a large extent, drive the selection of the propulsion, suspension, and lateral stabilization systems [9], as well as their efficiency and reliability.

The third group includes problems that are related to the need of physically modeling, in laboratory conditions, of various processes that take place both in the levitation system as a whole and in individual units and devices used in such systems.

The problems listed above are quite visible at all stages of maglev transportation development, since the invention and design of a new method of transportation relying on a completely new principle is unthinkable without experiments, both exploratory and confirmatory, that involve physical modeling. Furthermore, various data must be collected and organized into a database, such as data obtained at experimental test facilities, data on the use of diagnostic devices and test methods used to test individual structures, units, and components.

Objective. *This article presents the results of studies performed by a team of young researchers from the Laboratories of Magnetoelectric Transportation Systems who were led by A. A. Zaytsev, member of the Joint Academic Council of OAO RZD Open Joint Stock Company. The primary goal of these studies was to address the problem of lateral stabilization using permanent magnets. A monograph dedicated to issues of magnetic levitation transportation technologies [1] points out that a levitation system based on permanent magnets or electromagnets lacks, according to Earnshaw's theorem, internal stability, which lack is inherent to magnetic and electromagnetic systems. As a result of our research, we were able to achieve a lateral stabilization effect with permanent magnets, wherein lies the scientific novelty of our findings.*

Methods. *The authors use general scientific and engineering methods, mathematical calculation, comparative analysis, graph construction.*

Results.

1. Description of the experimental test unit

Our research was conducted on a magnetic levitation experimental test unit whose general view is provided in Figure 1.

The test unit consists of a rotating disk 3 m in diameter upon which a track module made of a 10 mm thick solid aluminum sheet is attached. Rotation is provided by a 3.5 kW motor installed beneath the disk.

A test sample of the magnetic pole assembly is positioned immediately over the track module. The speed of disk rotation is controlled with a frequency converter. The test unit's instrumentation included force sensors that were used to measure the forces applied to the tested magnetic pole assembly as dynamic stabilization emerged.

2. Dynamic lateral stabilization system

In global practice, several primary types of lateral stabilization system are known (Figure 2): systems relying on side stabilization wheels; systems using electromagnets; systems with high-temperature superconductors (HTS), etc. [7, 2, 6, 13, 14]. All systems have both advantages and drawbacks, the primary drawback being the complexity of such systems.

Based on the results obtained in the course of numerous experiments, the authors developed a design of a magnetic pole consisting of elementary

Figure 1. General view of an experimental test unit set up in the Magnetoelectric Transportation Systems Laboratory.

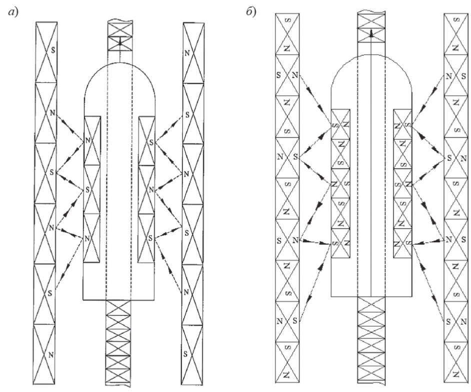


Figure 2. Levitation, lateral stabilization, and propulsion diagram: a – system developed by the Railway Technical Research Institute (RTRI), Tokyo, Japan; b – Inductrack system with a Halbach array of permanent magnets [5].

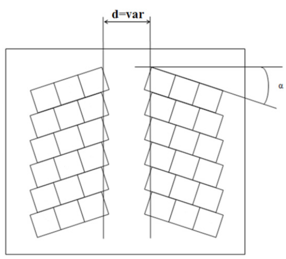


Figure 3. Magnet assembly diagram.

Halbach arrays [10, 12]. A diagram showing the positioning of magnets and the distribution of the magnetic field is provided in Figure 3, and the general view of the assembly and the distribution of the magnetic field lines are shown in Figure 4. The magnetic pole was made of NdFeB 21x21x21 mm magnets placed in tubes of stainless steel. The magnet assemblies were positioned at an angle to the magnetic pole's axis of movement.

The objective of the research was to determine the distance d at which the drag is of a negligible value and the forces impeding the transverse shift are the greatest at a given value of angle α.

3. Determining the system's stabilization force at various values of d

Based on the processed data obtained as a result of the experiments, dependency graphs were drawn for the values of the stabilization force at various linear movement speeds, with d equal to 180 mm and 140 mm (Figures 5–6).

The experiments at d = 120 mm were conditioned on the center of the assembly running over the edge of the track module as shown in Figure 7.

Based on the processed experimental data, dependency graphs were drawn for the values of the stabilization force at various linear movement speeds, as shown in Figure 8.

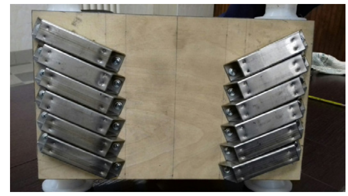
The data obtained in the course of the experimental research, and the results of their processing and analysis lead to the following conclusions:

1. The optimal distance d for the device under study is 140 mm, since at linear velocity of over 11.5 m/s a significant rise of the lateral stabilization forces was observed.

2. The extremum of the magnetic field must coincide with the edge of the track module (the edge of the active track structure). With this condition fulfilled, the maximal values of the lateral stabilization force are achieved.

3. At the distance d = 120 mm and 140 mm, the lateral stabilization forces emerge even at small speeds of movement, whereas at the distance d = 180 mm the emergence of such effect is only possible at speeds of movement above 3 m/s.

Conclusion. The results of the completed experimental studies confirmed the possibility of developing such a design of a permanent magnet-based lateral stabilization system that would in time allow to abandon the currently used designs of magnetic levitation transportation vehicles that are required to wrap the guideway or be wrapped by it.



a)

b)

Figure 4. General view of a magnet assembly: a) magnetic pole; b) the assembly's magnetic field distribution.

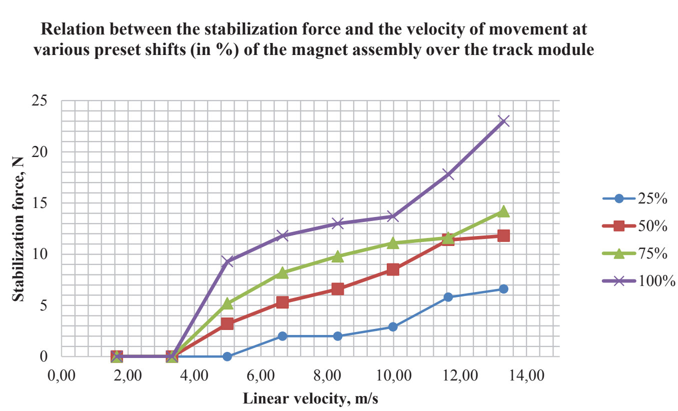


Figure 5. Experimental results at d = 180 mm.

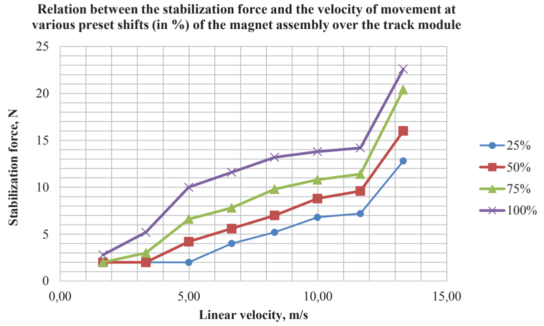


Figure 6. Experimental results at d = 140 mm.

Figure 7. Conditions of the experiment.

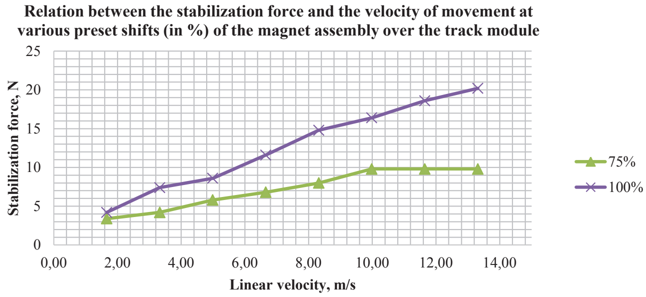


Figure 8. Research results at d = 120 mm.

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