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# Potential Development of Vehicle Traction Levitation Systems with Magnetic Suspension

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**ABSTRACT**

Below is given the brief analysis of development trend for vehicle traction levitation systems with magnetic suspension. It is presented the assessment of potential development of traction levitation systems in terms of their simplicity. The examples are considered of technical solutions focused on reducing the complexity of transport systems. It is proposed the forecast of their further development.



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## 1. INTRODUCTION

Nowadays in Russia due to increase of transport problems the interest in transport technologies based on contactless movement of objects has renewed. The development programs of magnetic-levitation transport providing realization of a number of difficult and expensive projects on design of passenger transport for megalopolises, high-speed transport of distant following, freight transport and systems of conveyor movement based on design of new technology "MagTranCity" have been worked out [1].

Basic components "MagTranCity" are combined use in magnetic levitation poles, lateral stabilization and traction permanent magnets and bulk high-temperature superconductors (flight) of racetrack modules of composite low-temperature superconductors, and the combination of travel levitation tracks as "winding Gram" shorted coils and discrete T-shaped squirrel cells. In world practice the magnetic-levitation transport is not still widely used due to the high cost of construction and insufficiently intensive passenger flow. All range of its transport system's commercial operation based on «Transrapid» technology is limited by the line 30km long connecting Shanghai with international airport Pudong.

At the same time the long-felt need for development of transport systems, having the isolated track with trestle laying of route for transportation of steady passenger traffic, generates a problem for searching of technical solutions allowing us to lower the cost for design and operation of magnetic-levitation transport system.

## 2. DEVELOPMENT DIRECTIONS OF TRACTION LEVITATION SYSTEMS

From the very beginning of magnetic-levitation transport systems' development it was proposed several various principles of levitation and traction and within each principle there are a lot of variants and modifications. But none of them has become preferable, due to this fact the problem of selection the best variants are still actual [2]. In the objective context the selection criteria is the technical solutions allowing us to reduce the cost for system's development.

From the history of engineering it is known that the only variant having low complexity of new technical system is implemented, survived and selected. The simplicity and related survivability, reliability are reached during development of a new technical object. This regularity is distinctly traced in the development direction of traction levitation systems. Let's give some examples. As is well known the operation of magnetic levitation vehicle generally requires generating the force systems in vertical and horizontal planes. One of them realizes the magnetic suspension of the vehicle in the vertical plane, the other one is a guiding force and the third one ensures the movement in the horizontal plane. In the first development works for creation of each force system rather self-contained units were used. The mechanical configuration of three-functional levitation system, lateral stabilization and traction, presented at figure 1, can be a typical example. At the vehicle bogie frame 1 it is installed the following: suspension electromagnets 2, lateral stabilization magnets 3, stator of linear traction motor 4. П-shaped ferromagnetic rails 6 and 7, and the lines of passive rotor 8 of linear motor are located through the track trestle 5. The attractive forces of electromagnet 2 to ferrorail 6 are used to generate the levitation, in the same way by means of electromagnets 3 and ferrorail 7 the system of guiding forces, preventing the shift of vehicle in the lateral direction, are created. The movement along the track is realized due to interaction forces of linear motor stator 4, installed at the bogie frame of the vehicle, with a passive rotor 8 located at the track. Such mechanical configuration was found to be material-intensive and bulky.

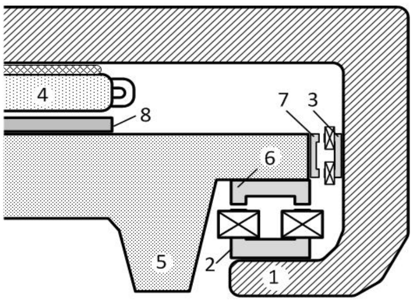


Figure 1. Three-functional mechanical configuration of Traction levitation system

The further development of system was related with attempts to combine the structural elements in the way to merge various functions. The most common merged functions are magnetic suspension and guidance. The example can be the scheme given at Figure 2. At the bogie frame of the vehicle 1 it is installed the Traction levitation module, contained the inductor of linear traction motor 2, electromagnets 3, 4 with L-shaped magnetic conductors used for interaction with track П-shaped ferromagnetic guide rail 5 fixed at the track 6. Between the guide rail branches the inductor of linear traction motor 2 is set. When power supplying at electromagnets 3, 4 the magnetic flux is isolated by means of L-shaped magnetic conductors of electromagnets and magnetic conductors of guide rail 5 that generates lifting and lateral effort of stabilization and in case of supplying the inductor 2 of linear motor, the vehicle starts moving.

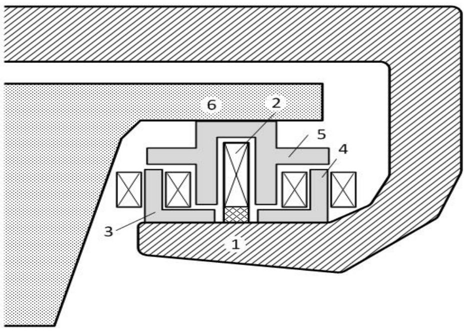


Figure 2. Combined scheme of traction levitation system

The further search of possible increasing of mass-dimensional and power indicators led the designers to the idea of integration the different functions within a single power element. The integration principle was practically realized in the system designed on the basis of three-functional Linear Synchronous Motor (LSM) [3]. LSM design, presented at figure 3, contains the yoke 1; drive winding 2; winding of transverse stabilization 3; traction winding 4; track element 5; anchor tooth 6; track structure 7.

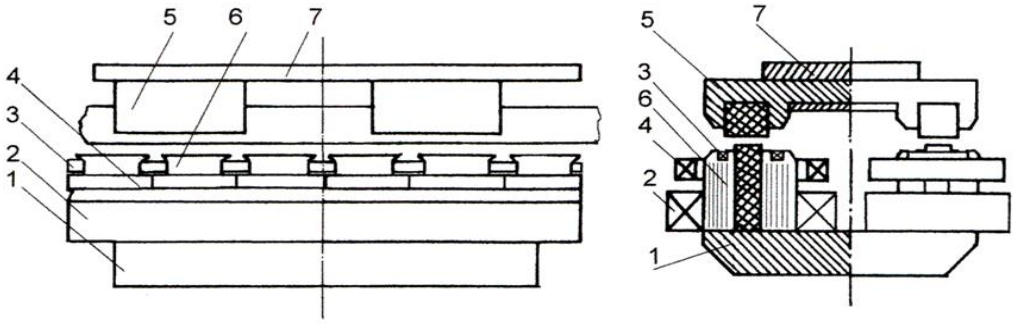


Figure 3. LSM design

The motor inductor consists of U-shaped magnetic conductor in the form of two cores 6 connected by yoke 1. The cores of inductor 6 are divided in longitudinal direction into teeth with three-phase traction winding 4 inside. There is a transverse stabilization winding 3 inside longitudinal slots of the teeth. Coils 2 of drive winding are installed at the inductor's cores; when current supply these coils generate the magnetic flux going through yoke 1, teeth 6 and closing through air gaps at ferromagnetic package of track element 5 fixed at the track structure 7. Three-phase AC current is supplied to the anchor winding 4 generated magnetic field. Ferromagnetic packages of track element 5, actuated by excitation flux, interact with the field of traction winding, therefore it causes to traction effort. Magnetic attraction of the inductor to the track elements 5 creates the lifting effort. In case of transverse (lateral) deviation of the inductor under the effect of magnetic flux it is created the reaction transverse force, increasing in emergency operation modes when current supplying to the winding 3 of transverse stabilization of controlled DC.

For investigation the system with integral traction-levitation module it was manufactured the real prototype of vehicle bogie weighting 10 tons equipped with 10 LSM of 40 kW each [4].

In spite of the fact that it was succeeded to integrate functions of suspension and traction as well as the guidance system inside the single power element, as a whole the system is rather complicated, since each subsystem of traction, suspension and stabilization require the power supply and control systems.

Unfortunately, at this stage of traction levitation system development the research in Russia has been frozen. Renewed interest to magnetic levitation transport technologies causes to actuality of assessment of traction levitation systems' development potential in the context of their simplification.

## 3. DEVELOPMENT POTENTIAL ASSESSMENTS OF TRACTION LEVITATION SYSTEMS

The further simplification of traction levitation system can be related with application of linear switched reluctance motor. The possibility to apply this type of electric machines is defined by the great value of normal force component between stator and rotor which can be used for generation of levitation and insurance of guidance system. Such kind of electric machine obtains the passive rotor consisted of ferromagnetic elements located along track structure. Rotors elements have great mechanical strength, which eliminates restrictions for transmission of mechanical traction force and suspension and gives the possibility to create the passive discrete track structure with reduced materials consumption, and at the same time the design of stator winding with concentrated coils is extremely simple.

In the range of switched reluctance machines there are two types which differ in direction of flux closure generated by motor's phase: with longitudinal flux design (Figure 4) coincided with moving direction, and with traverse design, vertical to moving direction (Figure 5).

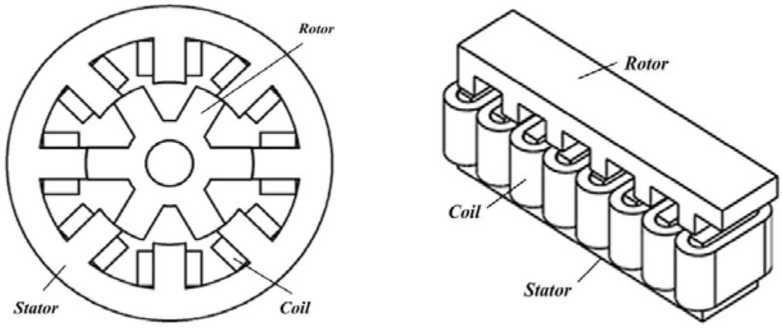


Figure 4. Switched reluctance motor with longitudinal flux design

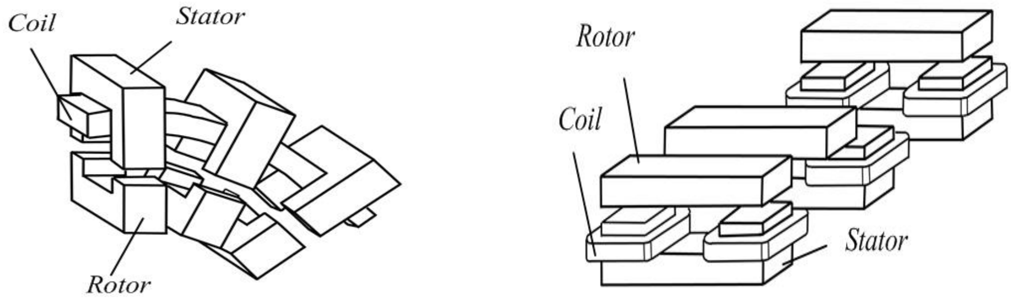


Figure 5. Switched reluctance motor with transverse flux design

These two linear configurations are the analogue of rotating machines and can be achieved as the result of stator and rotor turning about. These machines are simple, technologically efficient, mechanically enduring and have low loss; their power supply systems have simple circuits.

It is known the application of switched reluctance machines with longitudinal flux design in the traction levitation system of industrial conveyors [5].

The design of traction levitation system is proposed where one group of linear machines ensures levitation and traction, the second one ensures traction and guidance system. Therefore, the necessity to develop the separate traction, suspension and stabilization systems eliminates. The proposed concept provides the transition from three different systems to two single-type systems where each of them is involved in traction setting and as a whole it leads to cost reduction.

Mechanical configuration of vehicle traction levitation system developed by this concept can be presented at Figure 6. Rotors 3 and 5 of linear switched reluctance motor with longitudinal flux design are installed at the track structure 1 in its lower horizontal and side edges; motor's stator 4 and 6 are installed horizontally and vertically at the vehicle bogie frame. Horizontally installed motors generate traction and lifting effort, and vertically installed motors in addition to traction effort in running direction generate the force in the horizontal plane, vertical to running direction. The guidance system is provided by adjusting the ratio of forces values of the left and right vehicle sides.

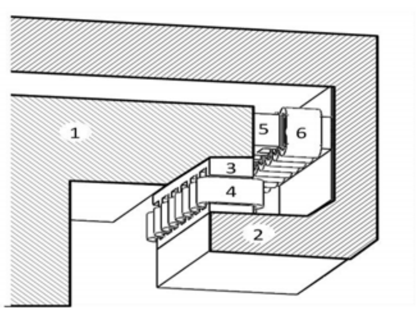


Figure 6. Concept scheme of traction levitation system

Simpler traction levitation system is possible to implement on the basis of linear switched reluctance motor with longitudinal flux. It can be used in two structural schemes. In the first scheme (Figure 7) the magnetic conductor of stator 1 with phase windings 2 are installed at the horizontal plane of bogie frame and the magnetic conductor of stator 4 is mounted at the track structure 5. U-shaped configuration of motor's magnetic conductor ensures the self- guidance system of the vehicle; the control is provided by two coordinates of traction and suspension. The disadvantage of this configuration is the mutual influence of traction and suspension as well as the weak passive guidance system which makes difficult guiding the vehicle in curves.

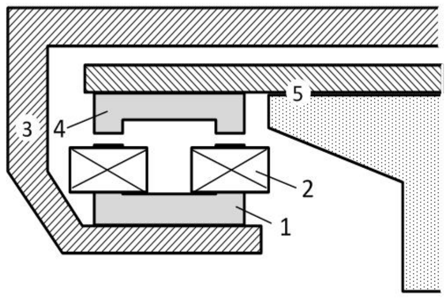


Figure 7. Mechanical configuration of traction levitation system

In the second scheme (Figure 8) U-shaped track is used. On its side edges discretely located passive elements of rotor 2 are mounted; magnetic conductors of stator 4 with phase windings 5 are installed on the sidewalls of a bogie frame 3.

The lifting force is generated when there is current supply in the phase windings and there is a displacement of teeth axles of magnetic conductors of stator 4 and rotor 2 relative to each other in the vertical plane. The width of vehicle vertical lifting can be the half of width of motor's tooth equaled to 25-50 mm. The change of phase current value of the motor does not have a great impact on levitation. Guidance system is provided by adjusting the ratio of total forces generated in horizontal planes by motors of each bogie side. In considered configuration the traction windings merge the functions of traction setting, levitation and guidance system; they are powered by a single converter which greatly simplifies the system and improves its energy indicators.

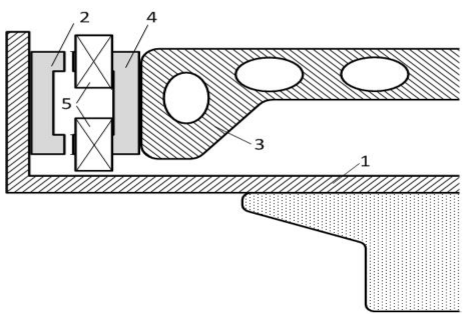


Figure 8. Mechanical configuration of traction levitation system

## 4. THE FORECAST OF TRACTION LEVITATION SYSTEMS DEVELOPMENT

The most important focus area in technology improvement is to forecast its development allowing us to formulate the directions for further research. In the context of the topic it can be assumed that having reached the limit of simplicity, the traction levitation system with the switched reluctance motor will predetermine the beginning of a new round of its sophistication, associated with natural tendency to reduce the working clearance of electric machine, and it will cause to requirements for improvement the dynamic properties of the system and to necessity to apply new magnetic materials.

## 5. CONCLUSION

1) During development of traction levitation system of vehicle with magnetic suspension there is a tendency to simplify the mechanical configuration. The tangible embodiment was received by idea to integrate different functions of traction levitation and lateral stabilization in a single power element designed on the basis of linear reluctance motor.
2) Development potential of traction levitation systems in terms of their simplification relates with application of linear switched reluctance motor with longitudinal flux. The system simplification can be reached by merging the functions of levitation, traction and guidance system in the single power element as well as by management through the one current channel of stator winding.
3) It is possible to predict the possibility of development the simple traction levitation system for high-speed vehicles with magnetic suspension and the possibility to apply during development well studied technical means, which significantly reduce the cost for its creation and contribute to its wide implementation in commercial operation.

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