Magnetic System of Power Stabilizing Unit of the General Planetary Vehicle

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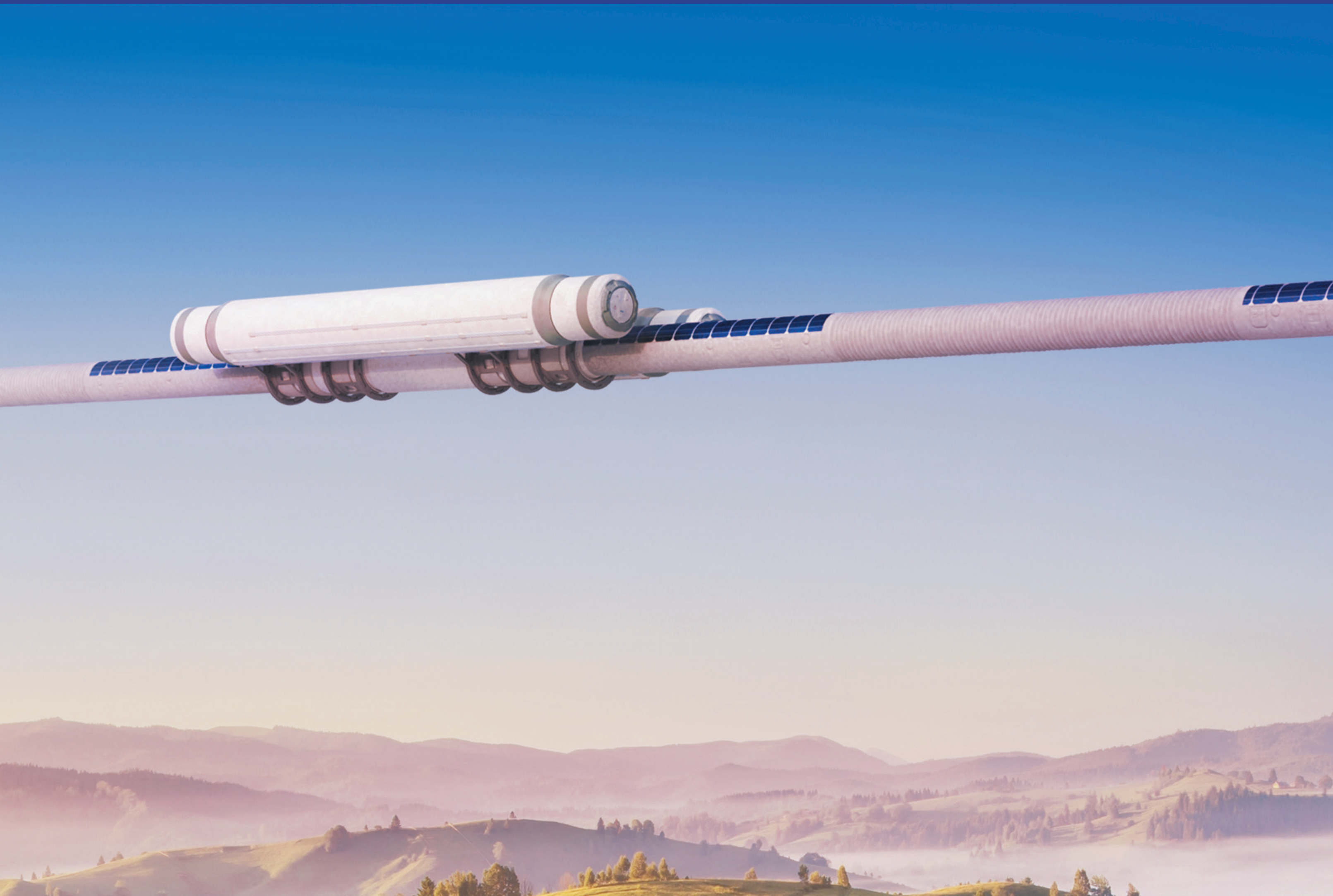
The purpose of this research is to develop the design of a magnetic system of the power stabilizing unit that provides a restriction of five degrees of freedom of the rotor, as well as a theoretical study of its behavior during operation. The solution of the problem of stabilizing the central position of the rotor in the stator channel of the General Planetary Vehicle (GPV) using magnetic field forces of permanent magnets is proposed. The designed system compensates for external forces acting both on the rotor during takeoff preparation and on the stator during ascent. There was modeled a variant when a linear combined motor as part of the GPV performs several tasks: transfer of lifting force from the flywheel to the GPV body; holding the flywheels in vacuum channels for movement, preventing contact with the walls in static and dynamic modes; acceleration of the flywheel, providing it with the required speed; conversion of the kinetic energy of the flywheel into electrical one in the mode of power take-off.

Keywords: *General Planetary Vehicle (GPV), high-speed linear motor, magnetic levitation, magnetic suspension.*



Introduction

One of the fundamental components of the program for the non-rocket exploration of near-Earth space is a geocosmic transport system that allows passengers and cargo to be transported to the Industrial Space Necklace "Orbit" (ISN "Orbit"), as well as to descend them to our planet's surface.

Over 40 years ago, engineer A. Unitsky proposed the design of a geocosmic vehicle capable of delivering millions of tons of payload and millions of people to near space in one flight without the use of conventional jet rocket engines [1, 2]. The operation of the General Planetary Vehicle (GPV) designed by the inventor – a self-supporting aircraft encircling the Earth in the equatorial plane, weighing several tens of millions of tons – involves solving a number of complex engineering problems. One of them is the development and creation of a linear combined electric motor with a length of 40,000 km that will be able to lift such a grandiose structure into space. No other mechanism is acceptable due to the high relative speeds of its moving and stationary parts.

The force that draws the GPV into near space is centrifugal. It acts on any body moving along the segment of a circle, and becomes greater with the increase of the mass and velocity of the object and reduction in the radius of the circle along the arc of which the movement takes place [3–5].

The design of the GPV engine contains a rotor – a belt flywheel, which is located inside the body in a vacuum channel. After receiving the command to prepare for take-off, the linear motor begins to accelerate the rotor. Under the action of linear electric motor, the rotor starts to move around the Earth along a circle coinciding with the plane of the equator, or parallel to it. A centrifugal force directed away from the center of the Earth begins to act on the rotor, lifting the flywheel vertically upwards. Thus, the question arises about the interaction of the flywheel rushing at great speed and the stationary GPV body with passengers and cargo.

In this paper, the use of magnetic fields is proposed to solve this problem. It describes the design of the magnetic system of the power stabilizing unit, which provides both the retention of the rotor in the vacuum channel of the stator and the transfer of centrifugal force from the rotor to the GPV body. The system automatically stabilizes the position of the GPV body relatively to the longitudinal axis of the rotor when forces of any nature arise that tend to deflect the GPV body in different directions other than this axis.

Analysis of the Forces Acting in the System of Permanent Magnets of Power Stabilizing Unit

Any system that provides levitation must compensate for the effect of gravity. In world practice, there are two types of such systems: electrodynamic and electromagnetic.

To implement levitation in the magnetic fields of electromagnets, a well-known solution is used. A pair of "ferromagnet – electromagnet" [6, 7] or "conductor – electromagnet" [8–10] with feedback on the position of the moving part is used as interacting components. In these systems, in one form or another, there is the same set of composite functional blocks: an electromagnet, its power supply device, a levitating body position control device and an electromagnet control device based on information received from the sensors of the control device. The principle of operation of the composite blocks of such a levitation system may be different, but the algorithm of operation is always the same. The position sensor tracks the distance to the levitating body. The device for monitoring the current flowing through the electromagnet, based on the signal from the sensor, changes the current of the electromagnet so that the magnetic field of the electromagnet, acting on the levitating body, returns it to a predetermined distance from the sensor. Such a system is called electromagnetic.

Figure 1 shows the forces acting on a levitating body: F_1 – the force with which the electromagnet acts on the body; F_2 – the force of universal gravity from the planet, directed to its center, lying in the plane of the equator. When the body is at a given distance from the sensor, the force F_1 is equal to zero. Under the action of force F_2, the body will start to move. The distance to the sensor will decrease. The force F_1 will automatically begin to increase, striving to return the distance to the predetermined value (Figure 1). The equilibrium position in this case is unstable, so the body will make micro-oscillations, creating the effect of stationary levitation.

Electrodynamic levitation is based on the emergence of eddy currents in conductive materials induced by an alternating electromagnetic field or the field of a moving permanent magnet (Figure 2).

The numbers 1 and 2 (Figure 2) indicate two ring coils nested in each other. A disk of conductive material is placed on top of them. The disk is affected by the force of universal gravity F_2. When an alternating voltage is applied to the coils, an alternating current will flow into them, which will create an alternating electromagnetic field around them, inducing eddy currents in the conductive disk lying on the coils.

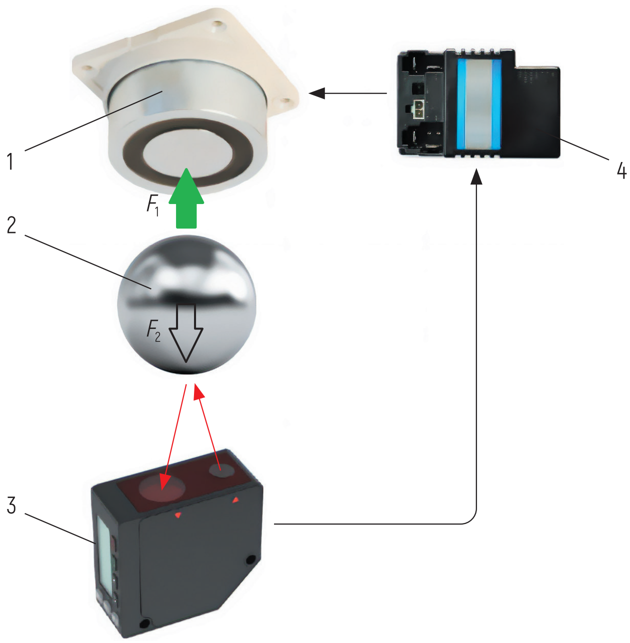


Figure 1 – Electromagnetic levitation:
1 – electromagnet; 2 – levitating body; 3 – distance sensor;
4 – control unit

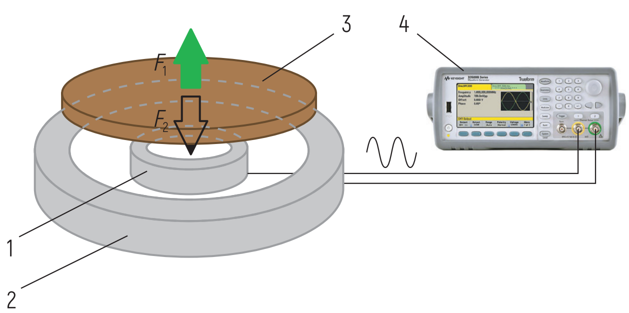


Figure 2 – Electromagnetic levitation:
1 – inner coil; 2 – outer coil; 3 – disk made of conductive material;
4 – alternating voltage generator

The currents will create an alternating electromagnetic field around the disk, which will interact with the field of the coils. The coils and the disc will push off from each other. There will appear the force F_1 (the mass of the disk and the parameters of the coils are chosen so that the force F_1 is greater than the force F_2). The disk will start moving upwards. As the disc moves away from the coils, the force F_1 will decrease. At a certain distance of the disk from the coils, the forces F_1 and F_2 will get equal, the disk will take its equilibrium position in space and begin to levitate.

Both systems considered require constant power supply and uninterruptible power supply of control devices, as well as feedback sensors. In addition, duplication of units is required for security reasons.

The third system used is a "magnet – superconductor" [11, 12]. The method is based on the repulsion of a diamagnet (superconductor) and a ferromagnet (permanent magnet) (Figure 3).

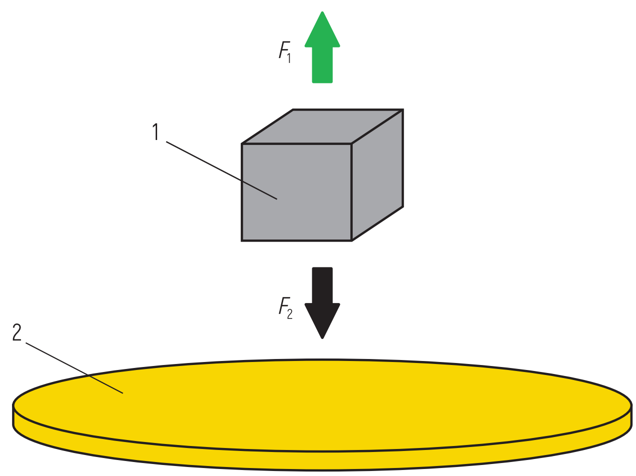


Figure 3 – Levitation over a superconductor:
1 – permanent magnet $Nd_2Fe_{14}B$; 2 – ceramic disc $YBa_2Cu_3O_7$

If a magnet is placed on a ceramic disc at room temperature, an electric current will arise in the disc material, which will excite a magnetic field. This field, interacting with the field of the magnet, will repel it. Since the resistance of the disk material is very high, the current will be negligible, as well as the magnetic field of the disk. If the disk material starts cooling, its specific resistance will decrease, and the current will begin to grow according to Ohm's law. Upon reaching the critical temperature (for $YBa_2Cu_3O_7$ – 90 K) the material of the disk will pass into a state of superconductivity. Now the induced eddy current will be undamped and the excited field will displace the magnetic field of the permanent magnet from the volume of the disk material. There will appear a lifting force F_1. When the force F_1 compensates for the force of gravity F_2, the magnet will begin to levitate, which will continue until the temperature of the disk is below critical. This system, in addition to power supply and control devices, requires a dual-circuit helium-hydrogen cryostat that provides the operating temperature of superconductors and needs electricity to function.

For non-rocket near space exploration, it is necessary to create a magnetic suspension system that does not need a huge amount of electricity to operate. The system should have an exceptionally high efficiency and be relatively economical.

The proposed design has only permanent magnets in its composition and does not require continuous power supply, control mechanisms and adjustment of the rotor position. Let us consider the operation of such a system.

If the direction of the destabilizing force does not coincide with the longitudinal axis of motion of the rotor and the plane perpendicular to it, this force is decomposed into a force acting along the axis of motion of the rotor (for example, the thrust (braking) force of a linear electric motor accelerating (or slowing down) the rotor), and a force perpendicular to the axis of motion of the rotor, which is balanced by the forces of a system of permanent magnets (Figure 4).

a system of permanent magnets that provide levitation of a solid body without the impact of forces other than magnetic ones on it, since the Earnshaw's theorem [13] (formulated by an English physicist in 1842) is violated. In technology, certain limitations on solving engineering problems are associated with this theorem, in particular, the tasks of developing a stable suspension of a body with the help of permanent magnet fields, i.e., without a direct contact with solid retaining structures. However, the proposed system does not violate the Earnshaw's theorem. The rotor segments, both adjacent and remote, rigidly interconnected, exert the same external influence on each other, making levitation possible.

Magnetic System of Power Stabilizing Unit

Figure 5 schematically shows the design of a magnetic system consisting of identical clusters.

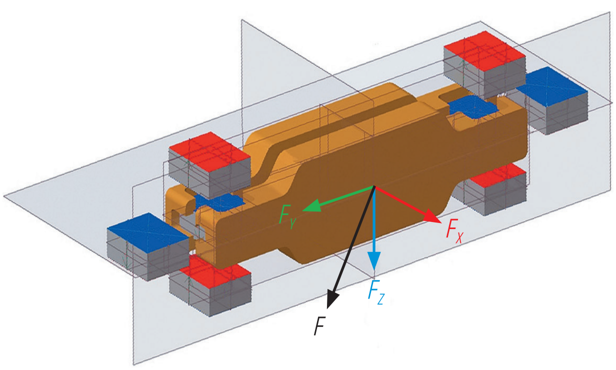


Figure 4 – Decomposition of the destabilizing force

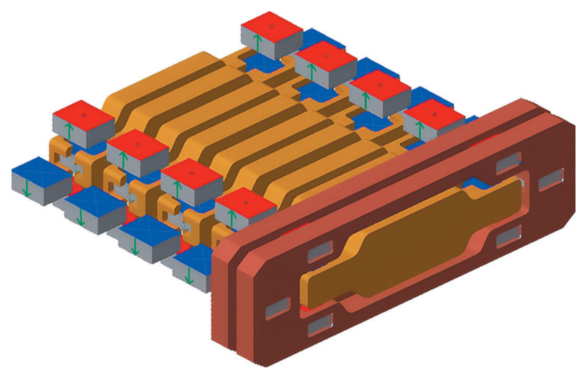


Figure 5 – Magnetic system structure

At the stages of the rotor acceleration, the separation of the GPV from the takeoff and landing overpass and the climb to 100 km, destabilizing forces oriented in any direction may occur. Figure 4 shows in black the destabilizing force F (chosen randomly) directed into the volume of the first octant. Let us consider its decomposition into three components. The forces F_Y and F_Z will be compensated by the magnetic field of the stator's magnetic system, and F_X will tend to move the rotor in a useful direction.

The main advantage of this solution is a complete autonomy, no need for power, control systems in static and dynamic modes of operation. The disadvantage is the need to cool the magnetic system in a dynamic mode [4].

The study of literary sources shows that many researchers of magnetic levitation say that it is impossible to create

Clusters are assembled separately and mounted together, creating a magnetic system. Each cluster (Figure 6) consists of two blocks (stator and rotor) holding permanent magnets in a certain position. The stator is rigidly connected to the GPV body, and the rotor levitates in the magnetic field.

The forces of magnetic interaction block the degrees of freedom of linear movement of the rotor along the *X* and *Z* axes, as well as the degree of freedom of rotation around the *Y* axis.

The mechanical interaction of magnetic clusters together with the interaction of magnetic fields limit the degree of freedom of rotation around the *X* and *Z* axes. The degree of freedom of linear movement along the *Y* axis remains unblocked (Figure 7).

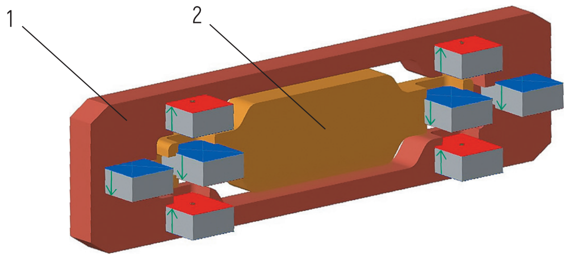


Figure 6 – Magnetic cluster: 1 – stator; 2 – rotor

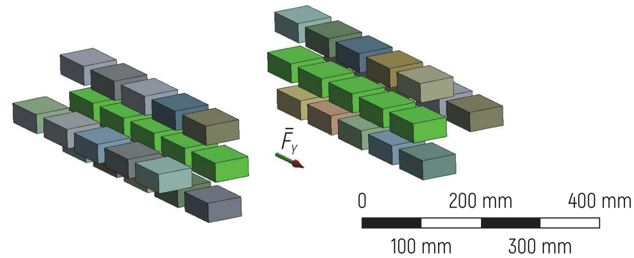


Figure 8 – Force acting in the Y axis direction

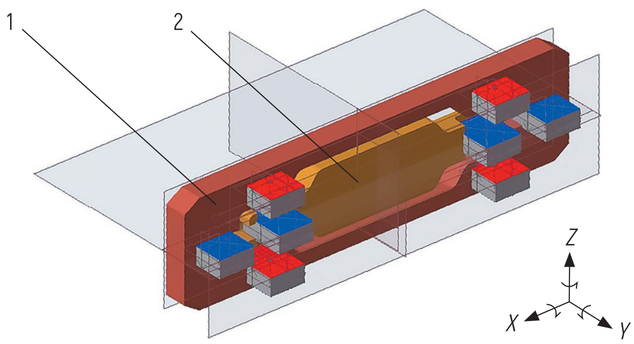


Figure 7 – Rotor freedom degrees: 1 – stator; 2 – rotor

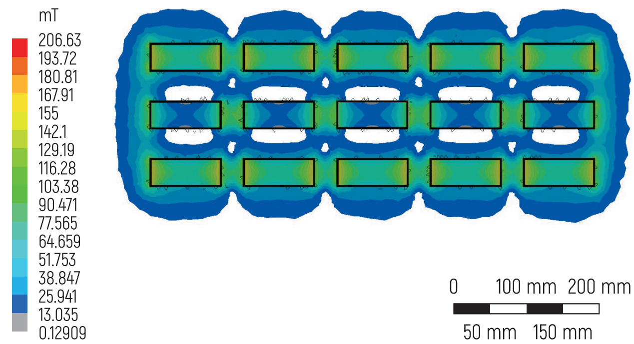


Figure 9 – Magnetic induction lines of the system (view in the X axis direction based on Figure 7)

Simulation

In order to obtain information about the stability of the system under development, let us carry out mathematical modeling of the force interaction of groups of stator and rotor magnets on the principle of superposition. The system is placed under gravity conditions at sea level in a static position.

The force acting in the direction of the rotor movement (along the Y axis), shown in Figures 7 and 8, is equal to zero, since this is the resultant force acting on the rotor magnets (green in Figure 8) from the side of the stator magnets. The power lines of the rotor magnets are locked onto the stator magnets (Figure 9).

The force acting in the direction perpendicular to the movement of the rotor and the force of gravity is the course stabilizing force, and it also equals to zero, since according to the simulation conditions there are no forces tending to shift the rotor in the X axis direction (Figures 7, 10).

Magnets A_1, A_2, A_3 (Figure 11) push out magnet B in the direction of magnet C_2 with force F_1. In their turn, magnets C_1, C_2, C_3 push out magnet D in the direction of magnet A_2 with force F_2. If the rotor is at equal distances from magnets A_2 and C_2, forces F_1 and F_2 are equal in modulus and opposite in direction, and their sum is equal to zero.

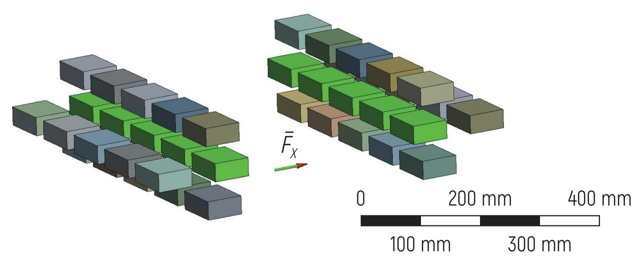


Figure 10 – Force acting in the X axis direction

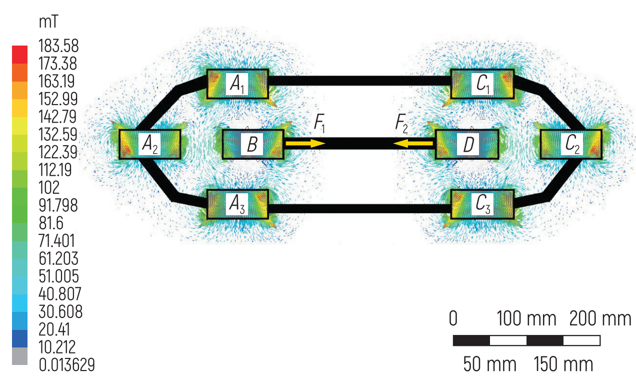


Figure 11 – Forces acting in the X axis direction from the stator side

The force acting in the Z axis direction (Figure 7) is a lifting force equal to 2,475 N/m, since, according to the simulation conditions, the gravity force acts on the rotor, tending to shift the rotor in the Z axis direction, i.e., to the center of the Earth (Figures 7, 12).

The force of universal gravity acting on the rotor tends to reduce the distance between rows of magnets 2 and 3 (Figure 13), as well as increase the distance between rows 1 and 2.

If the equality of distances from row 2 (rotor row) to rows 1 and 3 (stator rows) is violated, there appears a difference in the interaction forces between the rows, which tends to reduce the difference in distances to zero.

Analyzing Figures 14 and 15, one can notice the reaction of the magnetic field to the destabilizing force applied to the rotor. The magnetic field density was redistributed in such a way that the resulting strength of all the fields of individual magnets would compensate the external disturbance.

The specific load capacity of the magnetic unit is 18,825 N/m, or 1,920 kgf/m. Minus the weight of the hull and equipment, and also taking into account the curvilinearity of the takeoff and landing overpass, the actual load capacity of the GPV will be 350 kg/m.

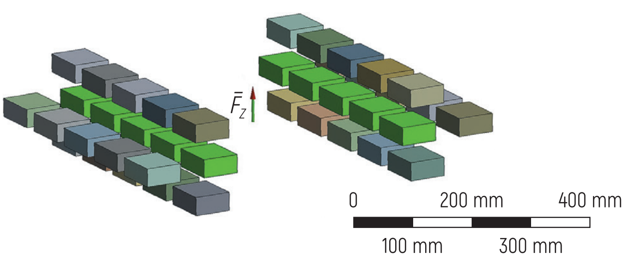


Figure 12 – Force acting in the Z axis direction from the stator side

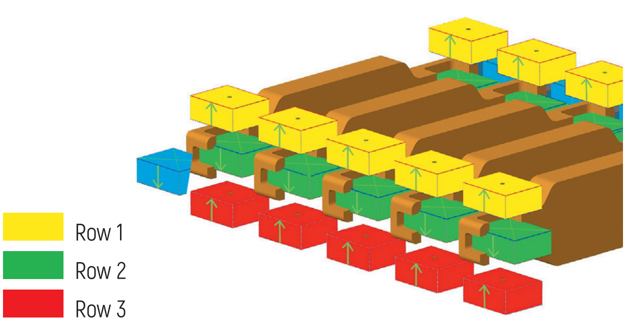


Figure 13 – Rows of rotor magnets (row 2) and stator magnets (rows 1 and 3)

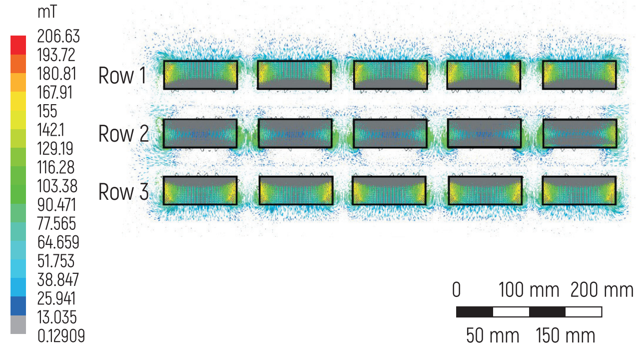


Figure 14 – Distribution of the magnetic field density of the system under microgravity conditions (view in the X axis direction based on Figure 7)

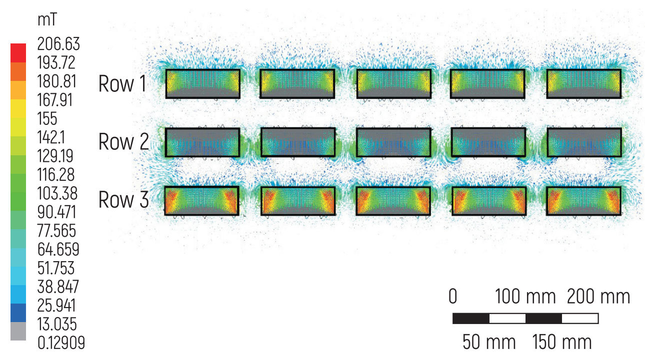


Figure 15 – Change in the distribution of the magnetic field density of the system when the gravity force of the Earth at its surface acts on the rotor (view in the X axis direction based on Figure 7)

Conclusions and Future Work

As a result of the conducted research and calculations, the configuration of the magnetic system was determined. It provides stabilization of the rotor relatively to the GPV body at the stage of preparation for takeoff, as well as stabilization in the horizontal plane of the GPV body relatively to the rotor at the takeoff and landing stages.

The shape of the takeoff and landing overpass in the plane of the equator will differ from the ideal circle due to the terrain of the Earth's surface (Figure 16). The magnetic system stabilizes the position of the rotor relatively to the GPV body in the vertical plane during the preparation for takeoff.

At the takeoff and landing stages of the GPV, the magnetic system stabilizes the position of the GPV body in the vertical plane relatively to the rotor, and also removes the rotation of the rotor inside the channel and excludes the possibility

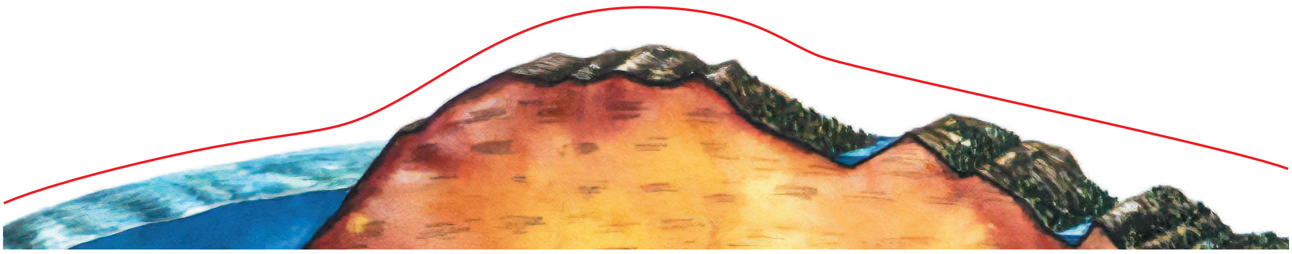


Figure 16 – Layout of the GPV overpass in the equator plane

of a contact of the rotor with the walls of the vacuum channels at all phases of the operational cycle. In addition, the described system does not interfere with the movement of rotor along the channels.

The next stage of research and simulation is the creation of a rotor and stator construct based on the concept of interaction of magnets proposed in this paper. In addition, an urgent task should be considered to solve the problem of the efficiency of shielding the fields of permanent magnets that affect the redistribution of the power lines of the GPV magnets.

References

1. *Unitsky, A. Peresadochnaya, kosmicheskaya, kol'tsevaya [Interchange, Cosmic, Circular] / A. Unitsky // Izobretatel' i ratsionalizator. – 1982. – No. 4. – P. 28–29.*
2. *Unitsky, A. V kosmos… na kolese [Into Space… by Wheel] / A. Unitsky // Tekhnika – molodozhi. – 1982. – No. 6. – P. 34–36.*
3. *Non-Rocket Space Industrialization: Problems, Ideas, Projects: Collection of Articles of the II International Scientific and Technical Conference, Maryina Gorka, Jun. 21, 2019 / Astroengineering Technologies LLC; ed. A. Unitsky. – Minsk: Paradox, 2019. – 240 p.*
4. *Bezraketnaya industrializatsiya blizhnego kosmosa: problemy, idei, proyekty [Non-Rocket Near Space Industrialization: Problems, Ideas, Projects]: Collection of Articles of the III International Scientific and Technical Conference, Maryina Gorka, Sep. 12, 2020 / Astroengineering Technologies LLC, Unitsky String Technologies Inc.; ed. A.E. Unitsky. – Minsk: StroyMediaProyekt, 2021. – 516 p.*
5. *Unitsky, A.E. Strunnyye transportnyye sistemy: na Zemle i v Kosmose [String Transport Systems: On Earth and in Space] / A.E. Unitsky. – Gomel: Infotribo, 1995. – 337 p.: il.*
6. *Lineynyy dvigatel' [Linear Motor]: Patent RU 2,370,874 C1 / G.V. Nikitenko, V.A. Grinchenko. – Published 20.10.2009.*
7. *Sarapulov, F.N. Issledovaniye tyagovogo lineynogo asinkhronnogo dvigatelya konveyyernogo poyezda [Research on a Traction Linear Asynchronous Motor in a Conveyor Train] / F.N. Sarapulov, I.A. Smol'yanov, I.Ye. Rodionov // Elektrotekhnika. – 2018. – Vol. 5, No. 1. – P. 34–37.*
8. *Abdullayev, M. Primeneniye lineynykh dvigateley v elektroprivodakh [Application of Linear Motors in Electric Drives] / M. Abdullayev, M. Matkasimov, D. Karimzhonov // Universum: tekhnicheskiye nauki. – 2020. – No. 11 (80). – P. 12–14.*
9. *Sinyuk, K.V. Primeneniye nechotkoy logiki dlya sistem upravleniya lineynym sinkhronnym dvigatelem s postoyannymi magnitami [Application of Indistinct Logic for Control Systems of a Linear Synchronous Motor with Permanent Magnets] / K.V. Sinyuk, V.A. Anchutin // Simvol nauki. – 2018. – No. 3. – P. 21–24.*
10. *Akhatov, S.T. Issledovaniye sistemy sinkhronnoy tyagi s lineynymi dvigatelyami [Research of Synchronous Traction System with Linear Motors] / S.T. Akhatov, V.G. Solonenko, N.M. Makhmetova // Vestnik KazATK. – 2021. – Vol. 116, No. 1. – P. 89–95.*
11. *Kim, K.K. Sistemy elektrodvizheniya s ispol'zovaniyem magnitnogo podvesa i sverkhprovodimosti [Electric Propulsion Systems Using Magnetic Suspension and Superconductivity]: Monograph / K.K. Kim. – Saratov: IPR Media, 2019. – 351 p.*
12. *Penkin, V.T. Sinkhronnyye elektricheskiye mashiny s kompozitnymi i ob"yomnymi sverkhprovodnikami v rotore dlya transportnykh sistem [Synchronous Electric Machines with Composite and Bulk Superconductors in the Rotor for Transport Systems] / V.T. Penkin, K.L. Kovalov. – Moscow: MAI, 2018. – 216 p.*
13. *Martynenko, Yu.G. O problemakh levitatsii tel v silovykh polyakh [On the Problems of Bodies Levitation in Force Fields] / Yu.G. Martynenko // Sorosovskiy obrazovatel'nyy zhurnal. – 1996. – No. 3. – P. 82–86.*