Volume 17, Number 1, 2024. pp. 87-95

Jordan Journal of Physics

ARTICLE

The Principle of Operation of an Engine That Draws Energy from the Electrogravitational Vacuum

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Doi: **https://doi.org/10.47011/17.1.8**

Received on: 03/06/2022; *Accepted on: 22/09/2022*

Abstract: The principle of operation of a fuel-free electromagnetic engine is presented, in which the relativistic charged particles of the electrogravitational vacuum serve as a driving force. The crossed electric and magnetic fields in the engine's working chamber lead to the Lorentz force, which results in asymmetric fluxes of charged vacuum particles in this chamber. The subsequent interaction of these particle fluxes with the charged matter of the chamber walls leads to the appearance of the resultant thrust force. The parameters of the charged particles of the electrogravitational vacuum can be determined using the theory of the infinite hierarchical nesting of matter and the theory of similarity. Taking this into account, the motion trajectories of the charged particles in the working chamber and the forces created by the particles are determined. When the engine is running, the laws of conservation of energy and momentum are fully satisfied; in particular, the engine increases its momentum due to the change in the total momentum of the fluxes of the vacuum's charged particles.

Keywords: Fuel-free engine, Force field, Electromagnetic interaction, Electrogravitational vacuum.

1. Introduction

At present, several projects have explored fuel-free electromagnetic engines generating thrust even in empty cosmic space or in vacuum. Shawyer presented an engine named EmDrive, comprising a conical microwave resonator supplied with electromagnetic radiation from a magnetron [1]. This engine generates a thrust force, resulting in an acceleration of up to 6 m/s^2. The appearance of thrust in such a device is associated with the fact that electromagnetic radiation exerts a greater pressure force on one side of the resonator along the direction of the cone axis compared to the opposite side.

According to [2], the thrust force of an engine of the EmDrive type could be increased if a Fabry–Perot laser resonator was used instead of a microwave resonator. This proposal stems from the conclusions outlined in [3], where the appearance of thrust is hypothesized based on the Unruh radiation and modified inertia model. This approach was tested experimentally in [4], which showed the absence of an effect and the probable inapplicability of the modified inertia theory.

An overview of theories attempting to explain the operation of engines of the EmDrive type was provided in [5]. In [6], the authors referred to zero-point fields of the quantum vacuum state, the interaction of which involves microwave radiation in a conical resonator, taking into account the crossed electric and magnetic fields in standing waves, which could lead to thrust.

In [7, 8], a quantum engine with high thrust was described; this engine is more than 100 times more cost-effective than liquid-propeller rocket engines. The developers of this engine explain its operation by the fact that the space vacuum is considered a quantized structure consisting of quantons, which can be repelled by means of crossed electric and magnetic fields in

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the engine workspace. It is assumed that quantons, as spacetime quanta, are carriers of superstrong electromagnetic interactions and that they form a net that binds the entire universe. According to the general theory of relativity, the gravitational force emerges when the spacetime is curved by a gravitating mass. Similarly, the repulsion of the engine from the net of quantons can be considered a consequence of the elastic curvature of this net due to the electric and magnetic fields in the engine.

Unfortunately, the vacuum models presented above are limited in their ability to explain exactly how electromagnetic engines can work and what physical principles are involved. Nevertheless, such engines could become the basis of future power plants, including both transport vehicles and spacecraft, as well as power generation units. In this regard, we assume that the theoretical basis for creating a fundamentally new electromagnetic engine could be the theory of the infinite hierarchical nesting of matter [9]. According to this theory, the electrogravitational vacuum is filled with graviton particles and tiny charged particles [10], with masses and sizes significantly smaller than those of all known elementary particles.

It is assumed that each object of the universe can be attributed to one or another basic level of matter, among which we know the metagalactic, stellar, nucleon, praon, and graon levels of matter. Each of these matter levels has its own most stable main carriers that have the highest concentration of mass and energy and possess strong gravitational and electromagnetic fields. Neutron stars represent the most stable main carriers at the level of stars, while nucleons fulfill this role at the nucleon level of matter, comprising the observed matter in the universe in various forms and phases.

For the main carriers, the principle of matter nesting lies in the fact that each such carrier consists of the main carriers of the lower levels of matter. For instance, a typical neutron star consists of nucleons, the number of which equals $\Phi = \frac{M_s}{M_p} = 1.62 \times 10^{57}$, where, the star mass is $M_s = 1.35$ solar masses and M_p is the proton mass. In turn, each nucleon contains Φ praons, and each praon contains Φ graons, in accordance with the similarity principle. The fact that the laws of nature can be invariant at each matter level is proven using the SPΦ symmetry [11], which substantiates the similarity of matter levels and clarifies the meaning of the scale dimension and scale relativity [12].

It is known that relativistic cosmic rays have high energy, appear near neutron stars, and move almost at the speed of light. Similarly, we can imagine the fluxes of charged particles, such as praons, appearing near nucleons and fluxes of graons appearing near the praons. These fluxes, along with corresponding photons and neutrinos, form the basis of the dynamic electrogravitational vacuum. Due to these fluxes, gravitational and electromagnetic interactions occur between massive and charged particles and bodies [13,14].

It is possible to express the gravitational and electrical constants in terms of energy densities of graviton and charged particle fluxes, as well as in terms of corresponding cross-sections of interactions between these fluxes and matter. The inertial mass of a body turns out to be proportional to the luminosity of gravitons, reflecting the rate of energy flux of gravitons interacting with a given body at a given moment. Thus, a body's inertia, its ability to counteract the effect of an external force, is a consequence of constant interaction with graviton fluxes. These fluxes of gravitons not only shape massive bodies but also counteract changes in the state of current motion during acceleration.

In [15], it was shown, that photons must consist of praons, while neutrinos consist of graons [14] moving at a speed close to the speed of light. In this case, under the action of graon fluxes at the nucleon level, strong gravitation occurs, which acts on atomic nuclei and atoms similarly to ordinary gravitation. However, according to [11], the strong gravitational constant is significantly greater and equals $G_a = \frac{e^2}{4\pi \varepsilon_0 M_p M_e} = 1.514 \times 10^{29}$ $m^3 \cdot kg^{-1} \cdot s^{-2}$, where, e is the elementary charge, ε_0 is the vacuum permittivity, M_p is the proton mass, and M_e is the electron mass. Using G_a in [16], the proton radius was calculated.

The main role in the dynamic electrogravitational vacuum is played by relativistic charged particles such as praons and graons, leading to the observed electromagnetic and gravitational interactions between bodies [10]. Under the influence of these particles on matter, secondary interactions occur between the colliding particles of matter, which can be described by the pressure field, dissipation field [17], and macroscopic fields of weak and strong interactions [18, 19]. The total result of these interactions is described by the acceleration field [20, 21], which defines the four-acceleration of typical matter particles in the equation of motion and incorporates the contribution of rest energy to the relativistic energy of the system. All this means that fundamental physics should take into account the electrogravitational vacuum field as a potential source to which all interactions are reduced in one way or another.

The purpose of our research is to provide a more precise principle of operation for a fuel-free electromagnetic engine, based on the concept of electrogravitational vacuum within the framework of the theory of infinite hierarchical nesting of matter. Next, we will consider the motion of the vacuum's charged particles and will show how they can produce thrust in next-generation electromagnetic engines.

2. Principle of Operation of Electromagnetic Engine

2.1. Motion of Electrogravitational Vacuum Particles under Fields' Action

Figure 1 schematically shows the working chamber of the quantum engine described in [7].

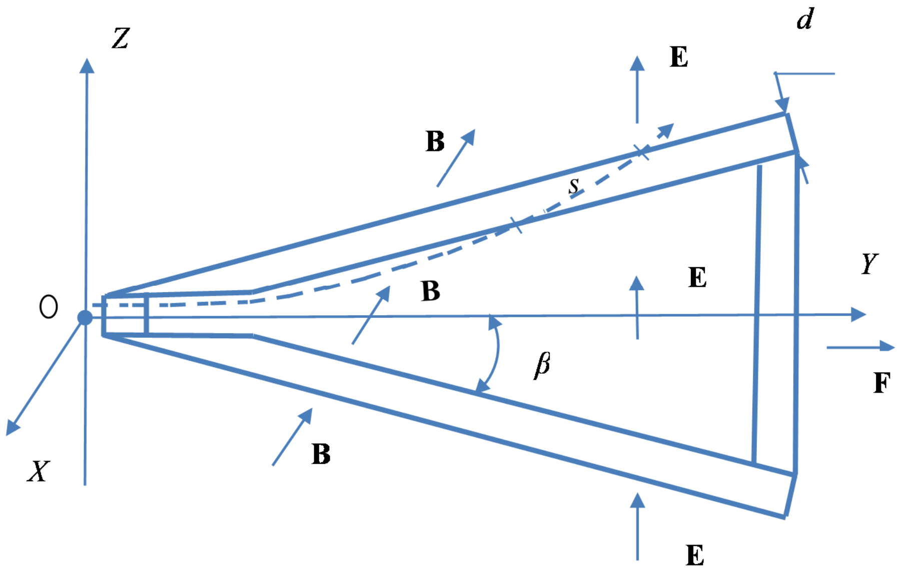

FIG. 1. Section of the cone of the working chamber of the quantum engine by the plane *ZOY*. The dashed line shows the trajectory of a positively charged vacuum particle, *s* defines the path length of the particle in the cone wall.

In Fig. 1, d is the thickness of the cone walls, and β denotes the cone opening angle. The electric field **E** is directed along the axis *OZ*, the magnetic field **B** is directed against the axis *OX*, and the thrust **F** accelerates the engine along the axis *OY* of the coordinate system.

We consider the motion of the charged particles of the electrogravitational vacuum inside the cone in Fig. 1. Let us assume that a positively charged particle flies from the left side into the cone's narrow base, moving along the axis OY. Here, the crossed electric and magnetic fields start acting on the particle. As a result, under the action of the Lorentz force, the particle starts to move in accordance with the following equation [22]:

$$m\frac{d(\gamma \mathbf{V})}{dt} = q\mathbf{E} + q[\mathbf{V}\times\mathbf{B}], \qquad (1)$$

where m and q are the mass and charge of the particle, γ and $\mathbf{V}$ denote the Lorentz factor and the particle's velocity, $\mathbf{E}$ and $\mathbf{B}$ define the electric field strength and the magnetic field induction, respectively.

We will project the vector Eq. (1) onto the axis OZ, taking into account that $\mathbf{E} = (0,0,E_z)$, $\mathbf{B} = (B_x,0,0)$:

$$m\frac{d(\gamma V_z)}{dt} = qE_z - qV_y B_x. \qquad (2)$$

When the considered particle flies into the cone, the particle's velocity is $\mathbf{V}=\left(0,V_y,0\right)$. From Eq. (2) it follows that under the action of the Lorentz force, the particle acquires the velocity component V_z in the course of motion and begins to deflect toward the axis OZ. Thus, the particle can deflect so much that it reaches the inner wall of the cone and then begins to move inside it, passing a certain distance s in the matter of the wall.

Now, let us assume that a positively charged particle flies from the right side into the cone's wide base near its axis, moving against the axis OY. Because the velocity of such a particle at the initial moment is $\mathbf{V}'=\left(0,V'_y,0\right)=\left(0,-V_y,0\right)$, instead of Eq. (2), we have the following:

$$m\frac{d(\gamma V'_z)}{dt}=qE_z+qV_yB_x. \qquad (3)$$

We consider an ideal case and choose the values of the components of the electric and magnetic fields such that the right-hand side of (3) vanishes. For electrogravitational vacuum particles, we can assume that their velocity is equal to the speed of light; thus, at the initial moment, when the particle flies into the cone, $V_y=c$. Then the equality $E_z=-cB_x$ must be satisfied in Eq. (3), while the component of the magnetic field B_x is negative in accordance with Fig. 1. In this case, $V'_z=0$ will always occur, and the positively charged particles from the right side will fly through the cone without deflection and then exit through the narrow base without interacting with the matter of the cone walls. The same will be true for the negatively charged particles entering the cone from the right side. If the negatively charged particles enter the cone from the left side, they deflect not upward, but downward, as shown in Fig. 1, and can then pass through the bottom wall of the cone.

We substitute the conditions $E_z=-cB_x$ and $V_y=\sqrt{c^2-V_z^2}$ into Eq. (2) and solve the differential equation under the condition $\gamma=const$, assuming that a positively charged particle flies from the left side into the cone along its axis:

$$\frac{dV_z}{dt}=\frac{qE_z}{\gamma m}\left(1+\frac{V_y}{c}\right)=\frac{qE_z}{\gamma m}\left(1+\frac{\sqrt{c^2-V_z^2}}{c}\right),$$

$$-c\arccos\frac{V_z}{c}-\frac{c^2-c\sqrt{c^2-V_z^2}}{V_z}=\frac{qE_zt}{\gamma m}+C_1. \qquad (4)$$

The constant C_1 is found based on the condition that at $t=0$, it should be $V_z=0$. Hence, we have $C_1=-\frac{\pi c}{2}$.

With this in mind, from Eq. (4) we can find the time t_1, during which the particle in Fig. 1 reaches the inner surface of the cone. As an initial estimate, we can assume that at this moment, the angle between the direction of the particle's velocity and the axis OY is approximately equal to the cone's opening angle β. Then, we have:

$$\operatorname{tg}\beta\approx\frac{V_z}{V_y}=\frac{V_z}{\sqrt{c^2-V_z^2}},\ V_z=c\sin\beta,$$

$$t_1=\frac{\gamma mc}{qE_z}\left(\frac{\pi}{2}-\arccos\left(\sin\beta\right)-\frac{1-\cos\beta}{\sin\beta}\right). \qquad (5)$$

By multiplying t_1 in Eq. (5) by the speed of light, we can obtain the length of the curve along which the particle flies until it reaches the inner surface of the cone. We will assume that the length of this curve does not exceed the length L of the cone generatrix, connecting the narrow and wide bases of the cone and passing across the cone wall. Hence, the following condition relates the required electric field E_x to the particle parameters and to the length L of the cone generatrix:

$$\frac{\gamma mc^2}{qE_z}\left(\frac{\pi}{2}-\arccos\left(\sin\beta\right)-\frac{1-\cos\beta}{\sin\beta}\right)<L,$$

$$E_z>\frac{\gamma mc^2}{qL}\left(\frac{\pi}{2}-\arccos\left(\sin\beta\right)-\frac{1-\cos\beta}{\sin\beta}\right). \qquad (6)$$

If we assume that praons are the main charged particles of the electrogravitational vacuum, then we can use the parameters determined in [14]: the praon mass $m_{pr}=\frac{M_p}{\Phi}=1\times10^{-84}$ kg, the Lorentz factor $\gamma=1.9\times10^{11}$, and the praon charge $q_{pr}=\frac{e}{S\sqrt{\Phi P}}=4.6\times10^{-57}$ C, where e is the elementary charge,

$P = 1.4 \times 10^{19}$ is the coefficient of similarity in size, and $S = 0.23$ is the coefficient of similarity in speeds of similar processes. To obtain an estimate of the electric field strength E_z in Eq. (6), we choose the first approximation of the cone opening angle $\beta = \pi/9$, and $L = 1$ m. Taking these data into account, we find: $E_z > 0.6$ V/m.

Ideally, we can assume that there is no difference in the bases of the cone, as in a hollow cone cut off on both sides. Then, under suitable conditions, such as $E_z = -cB_x$, for crossed electric and magnetic fields, it becomes feasible for the charged particles of the electrogravitational vacuum to enter the cone from the right side near the cone axis and pass through both bases of the cone without interacting with the cone walls. In contrast, the charged particles, which enter the cone base from the left side near the cone axis, can hit the cone walls and transfer their momentum to the matter of the walls. This will generate the engine's thrust.

For the sake of simplicity, we do not consider all the other particles falling on the cone from other directions. In the absence of the fields, the contributions of all the particles falling on the cone are balanced, so the thrust does not emerge. However, in the presence of crossed electric and magnetic fields, additional contributions to the thrust can also occur from those particles that enter the cone at different angles to the cone axis. In fact, trajectories should be calculated for all these particles, which would allow us to choose the best configurations of the electric and magnetic fields inside the engine's working chamber.

If the sources of crossed electric and magnetic fields are fixed on the engine and move with it, one should also take into account the interaction of charged particles of the electrogravitational vacuum with these fields inside the engine. The Lorentz force changes the direction of the momentums of the particles; therefore, the sources of the fields and the engine itself receive some return force by virtue of Newton's second law. The total force of recoil from all particles passing through the cone from all directions must be summed in vector form with the force of interaction of particles with the matter of the cone to determine the total thrust force of the engine.

2.2. Calculation of the Engine Thrust

We use the approach developed in [14] and define the cubic distribution for the particles' density in the form of a mixed derivative for a one-way flux of charged particles of the electrogravitational vacuum:

$$D_{0q} = \frac{d^2 N_0}{dt dA}, \tag{7}$$

where the fluence rate D_{0q} denotes the number of charged particles dN_0 that per time dt reached the area dA, perpendicular to the flux, which is the area of one of the faces of a certain cube, that bounds the volume under consideration.

For the dependence of the fluence rate of the charged particles on the distance ℓ traveled in the charged matter, we have:

$$\frac{dD}{d\ell} = -D\vartheta\eta, \quad D = D_{0q} \exp(-\vartheta\eta\,\ell). \tag{8}$$

Here, $\vartheta = 2.67 \times 10^{-30}$ m^2 is the cross-section of interaction between the moving charged particles and the charges in the matter and η is the concentration of uncompensated charges in the matter.

Let us assume that a flux of particles from the left side in Fig. 1 passes through the cone's narrow base of thickness δ, which leads to a change in the fluence rate:

$$D_1 = D_{0q} \exp(-\vartheta\eta_b\,\delta),$$

$$\Delta D_1 = D_{0q} - D_1 = D_{0q}[1 - \exp(-\vartheta\eta_b\,\delta)] \approx D_{0q}\vartheta\eta_b\,\delta. \tag{9}$$

This flux of particles is then deflected by the Lorentz force and travels a distance s in the cone's sidewall, which again changes the fluence rate. From Eq. (9), we find:

$$D_2 = D_1 \exp(-\vartheta\eta_c\,s),$$

$$\Delta D_2 = D_1 - D_2 = D_1[1 - \exp(-\vartheta\eta_c\,s)] \approx D_1\vartheta\eta_c\,s \approx D_{0q}\vartheta\eta_c\,s\exp(-\vartheta\eta_b\,\delta). \tag{10}$$

In Eq. (9), η_b denotes the concentration of uncompensated charges in the cone's narrow base, while in Eq. (10), η_c is the concentration of uncompensated charges in the cone's sidewall.

Let us denote the area of the inner surface of the upper part of the cone by A and express the area of the cone's narrow base on the left in Fig. 1 as the area of a circle of radius r. From the viewpoint of the cubic distribution, all the possible fluxes of vacuum particles must be divided into six fluxes falling perpendicularly onto the six faces of the cube containing the matter. Taking this into account, the product $\pi r^2 D_{0q}$ according to (7) gives the number of positively charged particles of the electrogravitational vacuum, flying from the left side into the narrow base of the cone per unit time. In this case, according to (9), most of the particles will pass through the matter without interaction, and the number of the particles interacting per unit time with the matter of the cone's narrow base will equal $\pi r^2 \Delta D_1 \approx \pi r^2 D_{0q} \vartheta \eta_b \delta$.

Let p_q be the average momentum of a charged particle of vacuum, which, when interacting with matter, can be transferred to the cone walls. Then, for the force acting on the cone's narrow base, we can write:

$$F_1 = \pi r^2 D_{0q} p_q \vartheta \eta_b \delta. \qquad (11)$$

Let us assume that the average angle relative to the axis OY, at which the particles move in the wall of the upper part of the cone, is equal to α, while $\alpha > \beta$. The number of particles interacting with matter per unit time, in view of (10), will be equal to:

$$\pi r^2 \Delta D_2 \sin(\alpha - \beta) \approx \pi r^2 D_{0q} \vartheta \eta_c s \exp(-\vartheta \eta_b \delta) \sin(\alpha - \beta). \qquad (12)$$

In Eq. (12), $\sin(\alpha - \beta)$ reflects the fact that the particle flux does not fall on the sidewall surface at a right angle, as is required for the cubic distribution of the particle fluxes. Multiplying by $p_q \cos\alpha$, for the force acting on the sidewall surface along the OY axis, taking into account the relation $s \sin(\alpha - \beta) = d$, we have:

$$F_{2y} = \pi r^2 D_{0q} p_q \vartheta \eta_c s \exp(-\vartheta \eta_b \delta) \sin(\alpha - \beta) \cos\alpha = \pi r^2 D_{0q} p_q \vartheta \eta_c d \exp(-\vartheta \eta_b \delta) \cos\alpha, \qquad (13)$$

where $\cos\alpha$ occurs because each particle entering the cone contributes to the total force in the direction of motion, that is, approximately in the direction at an angle α to the axis OY, which leads to the force F_2. We are interested in the projection F_{2y} of this force onto the OY axis.

Let us sum the forces F_1 in (11) and F_{2y} in (13) to find the force arising from the fluxes of the vacuum's positively charged particles, entering the cone from the left side near the axis OY. The contribution to the force is also made by the negatively charged particles of the electrogravitational vacuum, which fly from the left side of the cone and then deflect toward the lower part of the cone, where they interact with the charged matter of the cone wall. This leads to a 2-fold increase in the total force:

$$F_L = 2(F_1 + F_{2y}) = 2\pi r^2 D_{0q} p_q \vartheta \eta_b \delta + 2\pi r^2 D_{0q} p_q \vartheta \eta_c d \exp(-\vartheta \eta_b \delta) \cos\alpha. \qquad (14)$$

Let us now consider the result of the action of the vacuum's positively charged particles falling on the cone from the right side near the axis OY. These particles, passing through the cone's wide base through the cross-sectional area πr^2, are not deflected by the Lorentz force in any way and exit through the cone's narrow base again through the cross-sectional area πr^2. The force F_3 from the interaction of the particles with the wide base of the cone is equal in magnitude to F_1 in (11) and is directed against the axis OY. If $D_3 = D_{0q} \exp(-\vartheta \eta_b \delta)$ is the number of particles passing through the cone's wide base of thickness δ, then $D_4 = D_3 \exp(-\vartheta \eta_b \delta)$ will be the number of the same particles passing through the cone's narrow base against the axis OY. The change in the particle fluence equals:

$$\Delta D_4 = D_3 - D_4 = D_3 [1 - \exp(-\vartheta \eta_b \delta)] \approx D_3 \vartheta \eta_b \delta \approx D_{0q} \vartheta \eta_b \delta \exp(-\vartheta \eta_b \delta). \qquad (15)$$

Multiplying (15) by $\pi r^2 p_q$, we find the force acting on the narrow base of the cone and directed against the axis OY:

$$F_4 = \pi r^2 D_{0q} p_q \vartheta \eta_b \delta \exp(-\vartheta \eta_b \delta). \qquad (16)$$

Let us sum the forces F_3 and F_4 in (16) and multiply by 2 to take into account the contribution from the action of the negatively charged vacuum particles:

$$F_R = 2(F_3 + F_4) = 2\pi r^2 D_{0q} p_q \vartheta \eta_b \delta + 2\pi r^2 D_{0q} p_q \vartheta \eta_b \delta \exp(-\vartheta \eta_b \delta). \quad (17)$$

For the thrust from the considered particle fluxes, the following equation is obtained:

$$F = F_L - F_R \approx 2\pi r^2 D_{0q} p_q \vartheta \exp(-\vartheta \eta_b \delta)(\eta_c d\cos\alpha - \eta_b \delta). \quad (18)$$

Due to the smallness of the product $\vartheta \eta_b \delta$ compared to unity, we can assume that in (18) $\exp(-\vartheta \eta_b \delta) \approx 1$. According to [14], the electric constant is expressed in terms of the elementary charge e by the following formula:

$$\varepsilon_0 = \frac{e^2}{6 p_q D_{0q} \vartheta^2}. \quad (19)$$

Considering Eqs (18)-(19), the thrust force will be equal to:

$$F \approx \frac{\pi r^2 e^2 (\eta_c d\cos\alpha - \eta_b \delta)}{3 \varepsilon_0 \vartheta}. \quad (20)$$

We can assume that the volumetric uncompensated charge in the upper part of the cone is equal to $Q_c = e \eta_c A d$ and that the volumetric uncompensated charge in the upper part of the cone's narrow base with the area $\pi r^2/2$ equals $Q_b = e \eta_b \pi r^2 \delta/2$. Assuming further that $\cos\alpha \approx \cos\beta$ and that the area of the cone's upper part is approximately equal to $A \approx 2rL$, where L is the length of the cone generatrix, we find the following for the force:

$$F \approx \frac{2e\left(\frac{\pi r}{4L} Q_c \cos\beta - Q_b\right)}{3 \varepsilon_0 \vartheta}. \quad (21)$$

In the first approximation, we assume that the lowest possible value of the difference $\frac{\pi r}{4L} Q_c \cos\beta - Q_b$ is equal to the value of the elementary charge e. Hence, we obtain the estimate of the minimum force in (21):

$$F_{\min} \approx \frac{2e^2}{3 \varepsilon_0 \vartheta} \approx 724\text{N}. \quad (22)$$

For comparison, in a quantum engine [7], the value of 1390 N, averaged over several measurements, was presented as the minimum value of the thrust force. Moreover, the electric power required to generate the pulsed crossed electric and magnetic fields inside the cone reached 12 kW.

Force in Eq. (22) is associated with the interaction of charged vacuum particles with the volumetric charge of the cone walls. The force of interaction of vacuum particles with crossed fields inside the cone should be added to this force, as described at the end of the previous section. If our calculations are correct, the result should be close to the minimum force in [7].

At the moment of turning on the electric field in Fig. 1, charges are separated and redistributed on the inner surface of the upper and lower parts of the cone. In this case, the emerging electric field will be directed opposite to the direction of the initial electric field, tending to reduce the value of the electric field in the space inside the cone. This leads to the need to increase the amplitude of the initial electric field strength so that it should significantly exceed the value of $E_z > 0.6$ V/m, according to Eq. (6). For this purpose, it is necessary to provide for the presence of galvanic connections between the lower and upper parts of the cone. In a solid cone, such galvanic connections are established by the cone's sidewalls.

The above calculation shows that if we consider the motion of the charged particles of vacuum near the cone axis, then the action of such particles, under suitable field values and in the presence of a volumetric charge in the cone matter, leads to the appearance of a thrust force in the engine. In the general case, a more detailed analysis is needed, taking into account all possible trajectories of the charged particles of the electrogravitational vacuum passing through the cone when the engine is running under a given combination of crossed electric and magnetic fields.

Engine operation becomes possible because the magnetic component in the Lorentz force is proportional to the velocity of the particles' motion. As a consequence, the magnetic force has a different sign for the vacuum's particles entering the working area from two opposite directions. At the same time, the electric force does not depend on the velocity direction. Consequently, the particles' trajectories in the working area at the given fields will be determined by the direction of the particles' velocities. With a certain configuration of the fields, it is possible to ensure that the particle flux from one direction will interact more strongly with the engine than the particle flux from the other direction. This leads to the appearance of a thrust force. For the electric and magnetic fields crossed at right angles, changing the direction of one of these fields to the opposite direction is sufficient for the thrust force of the engine to change its direction as well.

3. Additional Notes

The configuration of electric and magnetic fields in an electromagnetic engine significantly affects the specific thrust force, determined by the following formula:

$$F_c = 1000 \frac{F}{W} \text{ N/kW}. \quad (23)$$

where F is the thrust force of the engine and W is the consumed electric power.

The specific thrust force (23) for the quantum engine in [7] is 115 N/kW; for the EmDrive engine in [1], this value reaches 667 N/kW; and for the engine in [6], the measured value is $1,2\times10^{-3}$ N/kW. The working chamber in [6] was a copper cone truncated on both sides and covered from the inside with a dielectric material (polyethylene). Pulsed high-frequency radiation at a frequency of 1937 MHz, with transverse mode TM212, is supplied into the cone.

In contrast to [7], in [6] the thrust force is directed toward the cone's narrow base, that is, in the opposite direction. This is a consequence of the complex configuration of the electric and magnetic fields in the standing electromagnetic wave inside the resonator. As a result, the charged particles of the electrogravitational vacuum, passing through the resonator in different directions, are deflected by the fields from straight trajectories and generate a small resultant thrust force in the direction of the cone's narrow base. It should be noted that if in Fig. 1 we change the direction of the magnetic field to the opposite direction, that is, direct the magnetic field along the axis OX, then the thrust force of the corresponding engine in [7] will also be directed toward the cone's narrow base.

By comparing Figs. 3 and 4, which are presented in [7] and the structure of the quantum engine and the EmDrive engine described in [1], we can see that with the same arrangement of the crossed electric and magnetic fields, the thrust force in both engines is directed equally toward the cone's wide base. Thus, the idea of relativistic charged particles of the electrogravitational vacuum, which can be controlled using electric and magnetic fields, makes it possible to explain the direction of the thrust force in various types of electromagnetic engines.

In [23], microwave radiation from a magnetron was supplied into the working chamber in the form of a cylindrical cone. As a result, standing electromagnetic waves and corresponding crossed electric and magnetic fields appear in the chamber, and a specific thrust force of 0.288 N/kW appears. Placing periodic structures in the form of conducting layers inside the chamber allows us to increase the thrust force by adjusting the configuration of the fields [24]. In such devices, the specific thrust force can also be increased by selecting a suitable transverse mode of the electromagnetic wave. Thus, in [25], the TM010 mode was used, and the specific thrust force reached 0.952 N/kW.

Almost all the models of electromagnetic engines presented here operate in pulsed mode. Apparently, this is because, in this case, it is possible to create an uncompensated volumetric charge in the working chamber, which is necessary for the operation of the engines in the approach we presented.

4. Conclusion

The operation principle of a fuel-free electromagnetic engine, moving in the atmosphere or cosmic space, revolves around controlling charged particles within the electrogravitational vacuum using electric and magnetic fields, as outlined in this article. These particles move in the working area of the engine under the action of the Lorentz force, deviate from the rectilinear direction of motion, interact with the fields and volume charge of the matter in the working chamber, and transfer part of their momentum to the engine, generating a thrust force.

Essentially, the engine coerces electrogravitational vacuum particles via the fields to propel the working chamber in the desired direction. Energy consumption in such an engine is associated mainly with the generation of the electric and magnetic fields required for the engine to operate. However, converting part of the translational motion into rotary motion enables conventional electricity generation to compensate for energy loss.

The presented conclusions are based on the analysis of trajectories of charged particles of the electrogravitational vacuum moving under the action of fields in the working area of an engine. In addition, an approach is used that describes the interaction of these particles with the volumetric charge in the material of the working chamber. To create such volumetric charges, various methods can be applied, including powerful pulsed electric and magnetic fields and rotation of the working chamber. Thus, the design of new generations of electromagnetic engines can be improved, and their thrust force can increase.

It can be seen from the above that classical physics can be applied to particles of the electrogravitational vacuum, although the masses and charges of these particles, according to the theory of infinite hierarchical nesting of matter, are much less than the masses and charges of known elementary particles. The proposed approach makes it possible to estimate the minimum thrust force of an electromagnetic engine in Eq. (22), which turns out to be of the same order as the minimum thrust force in experiments with the engine in [7].

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