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Vortex Electromagnetic Thrust Force

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Abstract: *Attention is drawn to the method of creating a significant electromagnetic force created by a vortex electric field. Action of the vortex electric field on the dielectric is not compensated by the action of the bound charges of the dielectric on the source of the vortex field, but it satisfies the momentum conservation law.*
Key Word*: Vortex field, Alternative electric current, Dielectric, Bound charges, Lift force*

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I. Introduction

Despite the Breakthrough Propulsion Physics Program [1] and Greenglow Project [2] have been terminated, the search for non-reactive and propeller-less methods of propulsion in space continues. Such unsupported motion can be created by the so-called self-force in an unclosed conductor, compensated by the hidden force acting on the electromagnetic field [3]. In this case, the self-force is created by Foucault currents flowing in a massive conductor located in an alternating electromagnetic field of an electromagnet [4]. In order to increase this force, the conductor must be heavier, which is a contradiction Moreover, the experimentally detected force turned out to be too small [4].

There is another way to create unsupported movement in space. It is known that the vortex electromagnetic force acting on a stationary electric charge is not compensated by the effect of an electric charge on a conductor that creates a vortex electric field [5]. This may well solve the problem. However, before talking about this method of creating an electromagnetic force, you need to make sure that the law of conservation of momentum is fulfilled, according to which the sum of all forces acting in a closed system must be strictly equal to zero. Without such verification, it may be the result of an error, misconception, or paradox [5].

II. Vortex electric field and hidden force

At the point of location of the point charge e, the electric field $\mathbf{E}$ created by the alternating electric current I flowing in the loop L is determined by the change in the vector potential $\mathbf{A}$ (fig. 1)

$$\mathbf{E} = -\frac{\partial}{\partial t}\mathbf{A} = -\frac{\mu_0 \dot{I}}{4\pi}\int_L \frac{d\mathbf{p}}{R}, \tag{1}$$

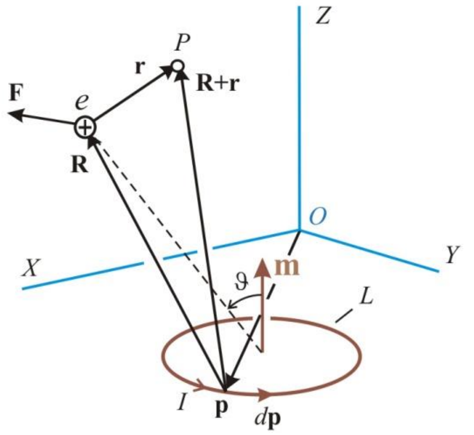

Fig. 1. Electric charge in the field of alternative vector potential.

so there is the force $\mathbf{F}$ acting on the charge

$$\mathbf{F} = -e\frac{\partial \mathbf{A}}{\partial t}. \tag{2}$$

The charge is at rest, so it does not act on the source of the magnetic field. It will not work to calculate the force attributed to the field $\mathbf{F}^{/}$, and in fact, acting on the field, as a derivative of the hidden momentum, which is the product of the electric field strength and the magnetic field induction [5]. The fact is that often there is no magnetic field, but there is an electric field. For example, the magnetic field induction is non-zero only inside a long solenoid or inside a tor magnet, while the vector potential is not equal everywhere outside of them. Almost the only way to calculate this force is remembering that force is minus the potential energy gradient [6], that is

$$\mathbf{F}' = -\varepsilon_0 \frac{1}{2}\int_V \nabla\left(\frac{e\mathbf{r}}{4\pi\varepsilon_0 r^3} - \frac{\partial \mathbf{A}}{\partial t}\right)^2 dv. \tag{3}$$

The gradient theorem [7] enables to transform volume integrals from *grad* to surface integrals over surface *S* of infinite radius, that gives

$$\mathbf{F}' = -\varepsilon_0 \frac{1}{2}\left(\oint_S \frac{e^2}{(4\pi\varepsilon_0)^2 r^4} d\mathbf{s} - 2\int_V \nabla\left(\left(\nabla \frac{e}{4\pi\varepsilon_0 r}\right)\cdot\frac{\partial \mathbf{A}}{\partial t}\right)dv + \oint_S \left(\frac{\partial \mathbf{A}}{\partial t}\right)^2 d\mathbf{s}\right). \tag{4}$$

The first integral, of course, equals zero. For long distances, a loop with current can be considered as magnetic dipole, for which

$$\mathbf{A} = \frac{\mu_0}{4\pi}\frac{[\mathbf{m}\times\mathbf{R}]}{R^3}.$$

and, therefore

$$\oint_S \left(\frac{\partial \mathbf{A}}{\partial t}\right)^2 d\mathbf{s} = \frac{\mu_0^2}{16\pi^2}\dot{m}^2 \oint_S \frac{\sin^2\vartheta}{R^4} d\mathbf{s}.$$

The third integral in (4) also equals zero. Remaining integral can be evaluated using the Lorentz condition div($\mathbf{A}$)=0 for vector potential and the vector identities

$$(\mathbf{A}\cdot\nabla\varphi) = (\nabla(\varphi\mathbf{A})) - \varphi(\nabla\mathbf{A}),$$

and

$$\nabla(\nabla\cdot(\mathbf{A}\varphi)) = \Delta(\varphi\mathbf{A}).$$

This gives

$$\mathbf{F}' = -\int_V \Delta\left(\frac{e}{4\pi r}\frac{\partial \mathbf{A}}{\partial t}\right)dv\cdot \tag{5}$$

The entire contribution to the force $\mathbf{F}^{/}$ is made by the region where the point charge is located. In this region, the vector potential is practically independent of the distance *R*, therefore

$$\mathbf{F}' = -\int_V \Delta\left(\frac{e}{4\pi r}\right)\frac{\partial \mathbf{A}}{\partial t}dv = e\frac{\partial \mathbf{A}}{\partial t}, \tag{6}$$

Since [8]:

$$\Delta\left(\frac{1}{r}\right) = -4\pi\delta(r)\cdot$$

The vortex electromagnetic force $\mathbf{F}$ acting on the charge is offset by the hidden force $\mathbf{F}^{/}$ attributed to the field. Formally speaking, an alternating current coil and an electric charge are repelled by an electromagnetic field.

III. Electric field of tor with alternating electric current

The position of the charge *e* with respect to the current element $Id\mathbf{p}$ of each of the four sides of a rectangular turn of width *b-a* and height *h* of the toroid *T* with current *I* (fig. 2) is determined by the following vectors, parameters and conditions:

$$R_{0\zeta} = (r^2 + b^2 - 2br\cos\varphi + (z-\zeta)^2)^{1/2}\ ;\ 0 < \zeta < h\ ;\ d\mathbf{p} = -d\zeta\mathbf{e}_z,$$

$$R_{0\xi} = (r^2 + \xi^2 - 2\xi r\cos\varphi + z^2)^{1/2}\ ;\ a < \xi < b\ ;\ d\mathbf{p} = -d\xi(\cos\varphi\mathbf{e}_r + \sin\varphi\mathbf{e}_y),$$
$$R_{h\xi} = (r^2 + \xi^2 - 2\xi r\cos\varphi + (z-h)^2)^{1/2}\ ;\ a < \xi < b\ ;\ d\mathbf{p} = d\xi(\cos\varphi\mathbf{e}_r + \sin\varphi\mathbf{e}_y),$$
$$R_{h\zeta} = (r^2 + a^2 - 2ar\cos\varphi + (z-\zeta)^2)^{1/2}\ ;\ 0 < \zeta < h\ ;\ d\mathbf{p} = d\zeta\mathbf{e}_z\,.$$

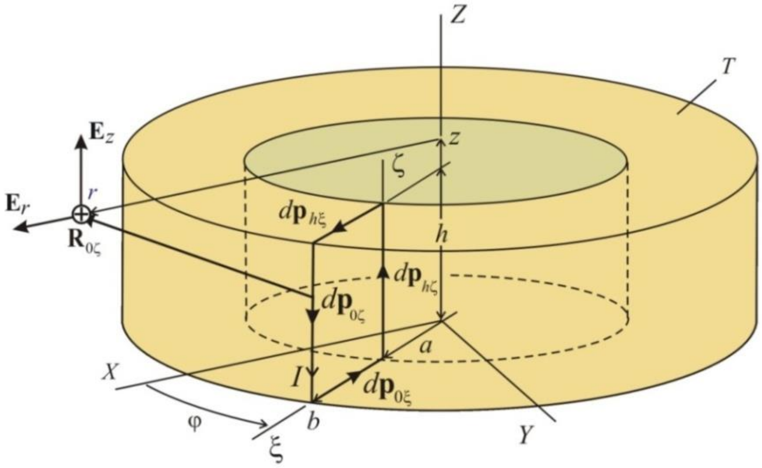

Fig. 2. Electric field of tor magnet.

Density of turns in the toroid is $n/2\pi$; n is number of turns. We are interested in E_r and E_z components of the vortex electric field. Therefore, the electric field at point P is sum of integrals:

$$E_r(r,z) = -\frac{\mu_0 \dot{I}}{4\pi}\frac{n}{2\pi}\int_0^{2\pi}\cos\varphi d\varphi\left(\int_a^b \frac{-d\xi}{R_{0\xi}} + \int_a^b \frac{d\xi}{R_{h\xi}}\right), \tag{7}$$

$$E_z(r,z) = -\frac{\mu_0 \dot{I}}{4\pi}\frac{n}{2\pi}\int_0^{2\pi} d\varphi\left(\int_0^h \frac{-d\zeta}{R_{0\zeta}} + \int_0^h \frac{d\zeta}{R_{h\zeta}}\right). \tag{8}$$

Integration over all ξ and ζ is trivial:

$$E_z(r,z) = -\frac{\mu_0 \dot{I} n}{8\pi^2}\int_0^{2\pi}\ln\frac{D_{0b}(r,h,\varphi)D_{ha}(r,z,\varphi)}{D_{0a}(r,h,\varphi)D_{hb}(r,0,\varphi)}d\varphi, \tag{9}$$

where

$$D_{lq}(r,z,\varphi) = l - z + (r^2 + q^2 - 2rq\cos\varphi + (l-z)^2)^{1/2}\ , \tag{10}$$

and

$$E_r(r,z) = -\frac{\mu_0 \dot{I} n}{8\pi^2}\int_0^{2\pi}\ln\frac{G_{bh}(r,z,\varphi)G_{a0}(r,z,\varphi)}{G_{ah}(r,z,\varphi)G_{b0}(r,z,\varphi)}\cos d\varphi, \tag{11}$$

with

$$G_{lq}(r,z,\varphi) = q - r\cos\varphi + (r^2 + q^2 - 2rq\cos\varphi + (l-z)^2)^{1/2}\ . \tag{12}$$

The problem is self-similar, so these components depend only on b/a, h/a, r/a and z/a. In a sense, shown in fig. 3 dependences of the vertical and horizontal components on the position of the observation point in the hole of the torus are universal.

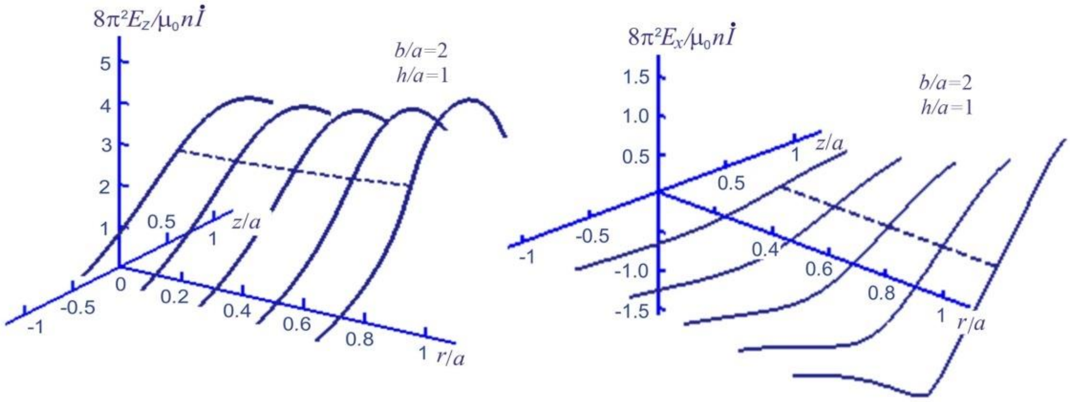

Fig. 3. Vertical and horizontal components of electric field.

Depending on r, the vertical component E_z of the electric field strength changes very slightly, while the E_r component increases sharply at close a (fig. 3). This, however, can play a weak role if the charge and its simultaneous with E_z the change are supported by the technical device. The fact is that the average value of the lifting force, the role of which is played by the vertical component, is equal to zero. However, it is better if nature takes over the responsibility for changing the magnitude of the charge at the same time as changes in the vector potential.

IV. Vortex electromagnetic lift force

The action of an electric field on a substance is accompanied by its polarization. If the substance is a dielectric, then a bound surface charge is formed on its surface, the surface density of which is

$$\sigma' = (\varepsilon - 1)\varepsilon_0 E_r(r, z), \tag{13}$$

where ε is dielectric constant.

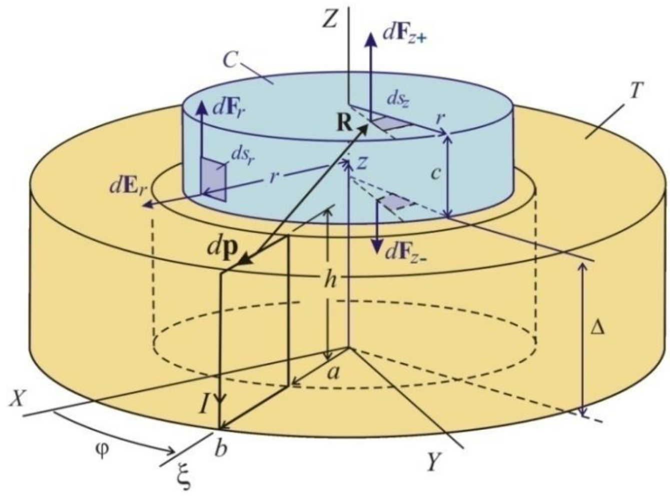

Fig. 4. Action of vortex electric field on cylindrical dielectric C.

If the dielectric is homogeneous, then there are no bound charges in the volume of the dielectric [9]. The force dF_r acting on a element ds_r of the cylindrical surface of the dielectric C can be written as $dF_r = \sigma' ds_r E_z(r,z)$ (fig. 4) which should be integrated over the entire cylindrical surface:

$$F_r = 2\pi r\varepsilon_0(\varepsilon-1)\int_{\Delta}^{\Delta+c} dzE_r(r,z)E_z(r,z), \tag{14}$$

where $E_z(r,z)$ and $E_r(r,z)$ are the integrals (9) and (11).

Bound charges under the action of an external electric field are formed not only on the side surface of a cylindrical dielectric. Since the external field is directed upwards, a surface positive charge is formed on the upper base of the cylindrical dielectric, the density of which is

$$\sigma'' = (\varepsilon-1)\varepsilon_0 E_z(r,\Delta+c), \tag{15}$$

experiencing a force $dF_{z+}=\sigma'' ds_z E_z(r,\Delta+c)$. At the lower end of the cylinder, a negative bound charge arises with a surface density

$$\sigma''_- = -(\varepsilon-1)\varepsilon_0 E_z(r,\Delta), \tag{16}$$

experiencing a force $dF_{z+}=\sigma_-'' ds_z E_z(r,\Delta)$. Therefore, the total force acting on the ends of a cylindrical dielectric with a radius of r and the height c is determined by the integral

$$F_z = 2\pi\varepsilon_0(\varepsilon-1)\int_0^a rdr\{E_z(r,\Delta+c)E_z(r,\Delta+c) - E_z(r,\Delta)E_z(r,\Delta)\}\cdot \tag{17}$$

Now there is everything to calculate the total force $F=F_r+F_z$ for various parameters and positions of the dielectric. Of interest, of course, is the average force, which can be both positive and negative (fig. 5). The asymmetry of the force with respect to $\Delta=0$ is associated with the choice of the initial value of z.

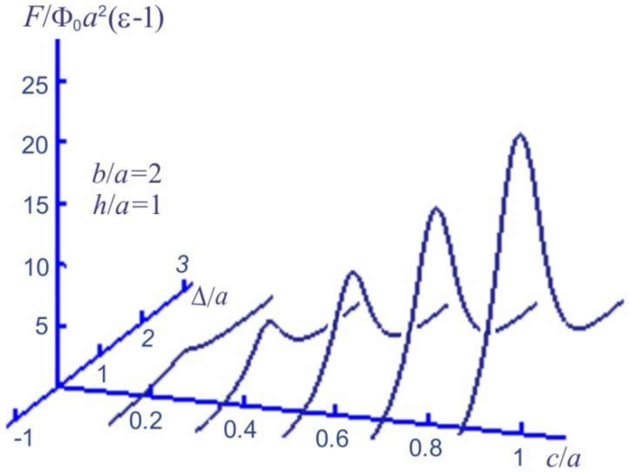

Fig. 5. Vortex lift force as function of position and size of dielectric.

Be sure to emphasize the proportionality of the lifting force to the square of the number of turns n of the toroidal magnet, the square of the frequency f of the alternating current flowing in the magnet winding and the square of the amplitude of the alternating current I_0 :

$$\Phi_0 = \frac{\mu_0^2 n^2 f^2 I_0^2}{16\pi}\varepsilon_0 \cdot \tag{18}$$

With $n=10^4$, $f=10^7$ Hz, and $I_0=10$A, the constant Φ_0 is 0.28 N/m^2, and the force F can be greatly increased by choosing a large value of ε.

V. Conclusion

The search for the optimal parameters of the source of the vortex electric field and the dielectric, which is affected by the vortex electromagnetic force, was not the goal of this work. The main thing was to substantiate and theoretically confirm the existence of a significant electromagnetic force, on the one hand, satisfying the law of conservation of momentum, and on the other hand, not compensated by the action of the bound charges of the conductor on the source of the vortex electric field.

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