A Motor driven by Electrostatic Forces

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Abstract

A new type of motor is presented, at which the electrostatic field produced by an electric charge brings a rotor into rotation. The physical principle of the motor is explained on the basis of Coulomb-forces with additional aid of the image-charge method. Furthermore a possible proposal for an experimental setup for the purpose of practical verification is presented. The assembly described contains a rotor of 20 centimeters in diameter, taking up a torque in the order of magnitude of about $10^{-7}\,Nm$. The setup is not yet technically optimized for later applications, but it is designed in a way to be easy understandable. The origin of the energy driving the rotor can be lead back to the energy of the vacuum.

Article body

Fundamental principle:

Reference [1] can be regarded as a preparation of the explanations presented here. There it is demonstrated, that every electrical charge permanently emanates energy carried by the electrical field produced by this charge. Therefore the finite speed of propagation of the electrostatic field has to be taken into account, and thus we see a close connection with retarded fields and retarded potentials known from electromagnetic field-theory (see [2], [3]).

At the end of preceding article we will come back to the question of the origin of the energy driving the rotor. But now we describe how electrical field-energy emitted by an electrical charge can be converted into mechanical energy. The method of energy-conversion developed here, consists in a special guidance of the electrical flux[1] (which is illustrated in textbooks by drawing field strength lines) with the use of metallic surfaces, in such a way that mechanical forces will act onto the guiding metallic surfaces, so that the guiding metal surfaces will see a force and consequently will begin to move. An imaginable setup to do this is shown in fig.1. There, the electrical charge q is constant and the rotor-blades are electrically connected to ground.

Of course it would be possible, to imagine many different types of constructions for the electrostatic motor. For instance if the point-charge q would be replaced by a flat plate (which has the same diameter as the rotor or even more) parallel to the xy-plane, the forces onto the metallic rotor-blades would be remarkably larger than in our example of fig.1. Furthermore it would be possible to change the angle between the rotor-blades and the xy-plane as well as several other geometrical parameters in order to optimize the forces onto the metallic blades, but such an optimization would be subject to further development of the engine for technical applications. For the principle explanation of the concept of the engine it is advantageous to find a setup as easy to understand as possible. And just therefore the use of a point-charge as field-source is very convenient, because it is easy to calculate its electric field and its electric potential using Coulomb's law. This is the reason, why we decide to construct the assembly with a point-charge q as field-source as shown in fig.1.

[1] The electric flux Φ_e can be defined in analogy to the magnetic flux $\Phi_m = \int_C \vec{B} \cdot d\vec{A} = \mu_0 \cdot \int_C \vec{H} \cdot d\vec{A}$ through a closed area C as $\Phi_e = \varepsilon_0 \cdot \int_C \vec{E} \cdot d\vec{A}$.

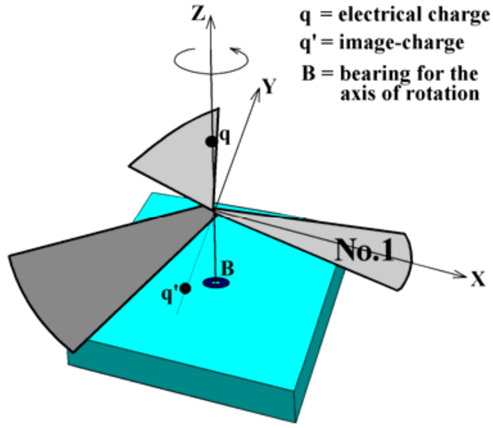

Fig.1:
Possible setup of an electrostatic motor, consisting of a rotor with three metallic blades. An electrical charge q causes a permanent electrostatic force onto the rotor and so it permanently drives the rotor, as long as the practical setup guarantees, that the forces of friction are not stronger than the driving electrostatic forces.
In the picture we see the charge q and the corresponding image-charge q' with regard to the rotor-blade no.1, as it will be subject to the considerations following now.

In order to determine the Coulomb-force acting onto the rotor-blades, we will now apply the image-charge method (see for instance [4]). For this purpose we begin with a consideration of the geometry of the apparatus. For the sake of simplicity, we arrange an angle of 45° between the blade no.1 and the xy-plane. In the moment of our consideration, the middle line of the rotor-blade shall be oriented along the x-axis. Consequently the blade no.1 defines a plane $z := z(x,y)$ following the functional equation $z = -y$. Thus the position vectors of the points of this plane are $\vec{r} = \begin{pmatrix} x \\ y \\ -y \end{pmatrix}$ with two free parameters x and y.

Because of the symmetry of the assembly, the considerations for the determination of the forces do not alter by principle, when the rotor-blades rotate during time. Also because of the symmetry, the forces are analogously for all three rotor-blades. Thus it is sufficient to calculate the force and the torque in the moment of consideration chosen here, and to do this calculation just for the blade no.1. In any case, the axis of rotation is the z-axis, so that all rotor-blades move within the xy-plane.

The charge q is placed at the z-axis with the z-coordinate z_0. The position of the corresponding image-charge q' (with respect to the blade no.1) can be found as illustrated in fig.2. There we see the view from the direction of the x-axis onto the yz-plane. In this view we see the cut of blade no.1 with the yz-plane being the straight line $z = -y$ (in agreement with the parametrisation of the above given function of the plane of the blade). Constructing the position of the image-charge q' will lead us to y-axis, and there to the point with the y-coordinate $y = -z_0$. The x-coordinates of q and q' are zero. This is the reason, why we could construct the position of the image-charge just in a two dimensional cut as we did. Thus the position vector of the charge is $\vec{r}_q = \begin{pmatrix} 0 \\ 0 \\ z_0 \end{pmatrix}$ and the position vector of the image-charge is $\vec{r}_{q'} = \begin{pmatrix} 0 \\ -z_0 \\ 0 \end{pmatrix}$.

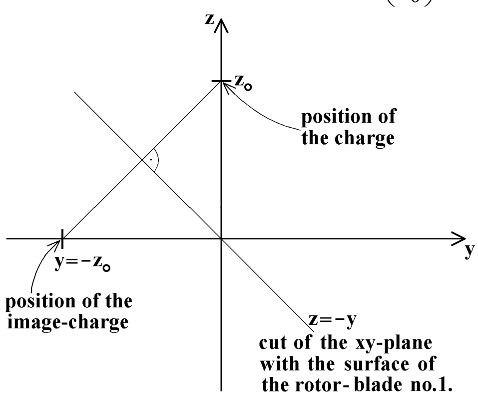

Fig.2:
Sketch for the determination of the position of the image-charge. The charge q as well as the image-charge q' have the x-coordinates $x = 0$. Thus it is sufficient, to construct the position of the image-charge using a two-dimensional cut of the xy-plane with the assembly of the motor, especially with the rotor-blade no.1, for which the position of the image-charge is determined.

For now we know the positions of the field-source q and its image q', we can easily calculate the forces onto the rotor-blades, just by applying Coulomb's law. Therefore we put the value of $q' = -q$ for the image-charge into the formula. So the Coulomb-force between the charge and the image-charge can be written as

$$\vec{F} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{(+q)\cdot(-q)}{|\vec{r}|^2} \cdot \vec{e}_r$$ with $\vec{r}$ = vector from q' to q and $\vec{e}_r$ = unit-vector in the direction of $\vec{r}$,

where $|\vec{r}| = \sqrt{2} \cdot z_0 \Rightarrow |\vec{r}|^2 = 2 \cdot z_0^2$ and $\vec{e}_r = \begin{pmatrix} 0 \\ \sqrt{1/2} \\ \sqrt{1/2} \end{pmatrix}$ with $|\vec{e}_r| = 1$.

$$\Rightarrow \vec{F} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{-q^2}{2 \cdot z_0^2} \cdot \begin{pmatrix} 0 \\ \sqrt{1/2} \\ \sqrt{1/2} \end{pmatrix} = \frac{-q^2}{\sqrt{128} \cdot \pi\varepsilon_0 z_0^2} \cdot \begin{pmatrix} 0 \\ 1 \\ 1 \end{pmatrix}$$ for the force between charge and image-charge.

The crucial point is: The charge q as well as the rotor-blade feels a component of the force in y-direction, which causes a rotation of the rotor-blades around the z-axis. For illustration we can again have a look to fig.1. This force is attractive, because the image-charge has the opposite algebraic sign as the charge itself. From this consideration we understand the direction of the rotation as indicated in fig.1.

Example for a possible test-setup

For an exemplary calculation of a setup which can really be built, we have to have to chose some arbitrary dimensions – for instance as done in fig.3. The values are just arbitrarily chosen in order to allow an exemplary calculation which might be suitable for a experimental verification in future.

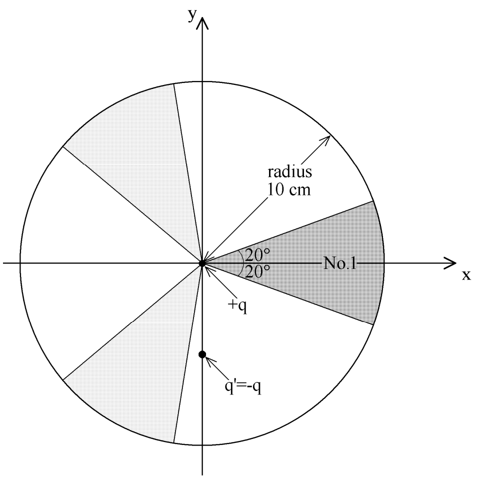

Fig.3:
Rotor with three blades and a diameter of 20 centimeters, rotating around the z-axis. In the picture we see the projection of the rotor onto the xy-plane together with some values of the angles covered by the metal-blades. The charge q is mounted on the z-axis at the position $z_0 = 5cm$, so that the image-charge q' turns out to be on the y-axis at the position $y = -z_0 = -5cm$.

For a really existing setup, the electrical charge q has to be put onto some really existing matter. Let us chose an electrically conducting sphere with a diameter of $2R = 1.0\,cm$, and let us mount its centre at the position $z_0 = 5cm$. The capacity of such a spherical capacitor (against infinity) is $C = 4\pi\varepsilon_0 \cdot R$. If we put this sphere to an electrical voltage of $U = 10kV$ (which should be a good value in order to avoid electrical breakthrough), it will take an electrical charge of $q = C \cdot U = 4\pi\varepsilon_0 \cdot \underbrace{R}_{0.5cm} \cdot \underbrace{U}_{10kV} \approx 5.56 \cdot 10^{-9} C$. The image-charge thus will have a value of $q' \approx -5.56 \cdot 10^{-9} C$.

Putting these values into the formula for the force between the charge and the image-charge, we come to $\Rightarrow \vec{F} = \frac{-q^2}{\sqrt{128} \cdot \pi\varepsilon_0 z_0^2} \cdot \begin{pmatrix} 0 \\ 1 \\ 1 \end{pmatrix} = 3.93 \cdot 10^{-5} N \cdot \begin{pmatrix} 0 \\ 1 \\ 1 \end{pmatrix}$.

The z-component of this force, which is parallel to the direction of the axis of rotation will not be recognized (and not be important at all), but the y-component directly causes the rotation of blade no.1 around the z-axis (if this force is strong enough to overcome the force of friction). Because of the symmetry of the assembly, the forces onto the other blades are understood analogously. This means that the principle of functioning of the motor is already explained now.

It should be mentioned, that our calculation of $\vec{F}$ up to now gives the total force between the charge q and the infinite plane $z := z(x,y) = -y$. But the rotor-blade of our assembly only covers a finite part of this plane. For the determination of the force actually working on the blade, we again want to turn our attention to fig.3 showing a projection of the assembly. And now we have to calculate which percentage of the electric flux through the whole plane $z := z(x,y) = -y$ will pass the finite blade. Therefore we have to calculate the electric flux, and we begin this calculation by writing the potential of the charge and the image-charge, valid for the space between the plane $z := z(x,y) = -y$ and the charge q:

Coulomb's potential of the charge q is $V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{d}$,

and Coulomb's potential of the image-charge q' is $V' = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q'}{d'}$,

with $d = \sqrt{\left(\vec{r} - \vec{r}_q\right)^2} = \sqrt{x^2 + y^2 + \left(z - z_0\right)^2}$ and $d' = \sqrt{\left(\vec{r} - \vec{r}_{q'}\right)^2} = \sqrt{x^2 + \left(y + z_0\right)^2 + z^2}$ being the distances between the charge respectively the image-charge and the space point, at which the potential has to be calculated. From there (and because of $q' = -q$), we come to the total potential within the space between the charge and the plane $z := z(x,y) = -y$, and we find:

$$V_{tot} = V + V' = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{\sqrt{x^2 + y^2 + \left(z - z_0\right)^2}} + \frac{1}{4\pi\varepsilon_0} \cdot \frac{-q}{\sqrt{x^2 + \left(y + z_0\right)^2 + z^2}} .$$

The electrostatic fieldstrength is calculated as usual: $\vec{E} = -\vec{\nabla} \cdot V_{tot}$.

From there we calculate the percentage of the electric flux through the plane of the rotor-blade relatively to the electric flux through the total plane $z := z(x,y) = -y$. This was done in numerical approximation, leading to a result of about $(4 \pm 0.5)\%$.This means, that the force acting onto the finite rotor-blade is about $(4 \pm 0.5)\%$ of the total force $\vec{F}$. Consequently, we get the y-component of the force acting on each single finite rotor-blade as

$\Rightarrow \quad F_y \approx 3.93 \cdot 10^{-5} N \cdot 4\% \approx 1.6 \cdot 10^{-6} N$,

and thus the force acting on all three rotor-blades is $3 \cdot F_y \approx 4.7 \cdot 10^{-6} N$.

At least we want to know the torque, with which the charge q turns our rotor-blades. Therefore we have to take into account, that the force $3 \cdot F_y$ does not act onto one single point, but its action is distributed along several different radii of rotation. The calculation of the torque is a simple mechanical problem, which does not need a detailed demonstration here. Its result is a torque of about $\left|\vec{M}_{tot}\right| \approx 9 \cdot 10^{-8} Nm$ acting in sum on all three rotor-blades. (The value is again given as "approximately", because the values of the forces originate from a numerical approximation.)

Resumée and origination of the energy:

The explanation of the physical principle of the electrostatic motor is done now as well as the calculation of an example of an experimental setup for the purpose of verification. The physical principle of functioning of the motor only needs two very reliable fundamental assumptions, namely the validity of Coulomb's law and the suitability of the image-charge method. These assumptions are reliable enough, that we should expect the engine to work. As soon as the electrical charge is mounted above the rotor, the blades should be accelerated until the forces of friction and perhaps of some additional mechanical burden for some application will compensate the driving electrostatic forces. When this condition is achieved, the engine should run with constant number of revolutions.

This conclusion again awakes the question about the origin of the energy driving the rotor. For the answer to this really crucial question, we have to come back to the article [1] again. There it is demonstrated, that the electrical charge as a source of electrostatic field permanently emits field-energy. But it is also demonstrated, that this field-energy is absorbed by the mere space, when the field propagates into the space. This means that the mere space (with an other word, the vacuum) is not only responsible for the propagation of the field, but also for some absorption and for a re-propagation of the field-energy (doing the latter one without the re-propagation of field-strength). According to this idea, the vacuum would absorb energy from the propagating field, would distribute this energy all over the space, and would provide this energy to field-sources, which take this energy and convert it again back to field-strength. Field-sources typically are called electrical charges. These considerations are new, same as the motor which was developed on the basis of these thoughts.

The fact, that the mere empty space (the vacuum) really contains energy is well known from the cosmological constant Λ of the theory of General Relativity [5], and it is also known from experimental investigations of astrophysics [6], [7] (with values being measured in the order of magnitude of about $10^{-9}\, {}^{J}\!/_{m^3}$), where the standard model of astrophysics comes to the conclusion, that about 65% of the universe consists of invisible vacuum-energy. And also quantumelectrodynamical considerations regarding the nontrivial structure of the vacuum [8] (see for instance vacuum polarisation) confirms the fact, that the vacuum contains energy. Up to now, there is no clarity about the real value of the energy density, but this open question does not affect the functioning principle of the electrostatic driven motor presented here. In this sense, the motor presented here does nothing else, than the conversion of vacuum-energy into mechanical energy.

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