Homopolar Technology

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ABSTRACT: This article aims to analyze the homopolar motor/generator technology, that is the same Faraday's disc whose functioning principle is based on the Lorentz's Force. It will be explored some variations that can be applied to develop generator/motor based on that principles.

KEYWORDS: Lorentz's Force, Faraday's disk, homopolar motor, homopolar generator, linear propulsion, aerial propulsion, maritime propulsion.

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1 Introduction

In 1821, Faraday carried out an experiment involving electromagnetic rotation produced by a circular force on a metallic wire that partially penetrated metallic mercury inside a container subjected to a magnetic field. The wire rotated around the magnet when an electric current passed between the wire and the magnet through the mercury. Afterwards he made the magnet rotate around the wire. In experiments he observed that, when reversing the electric current, the rotation changed direction. The figure to the side shows a device similar to the one Faraday

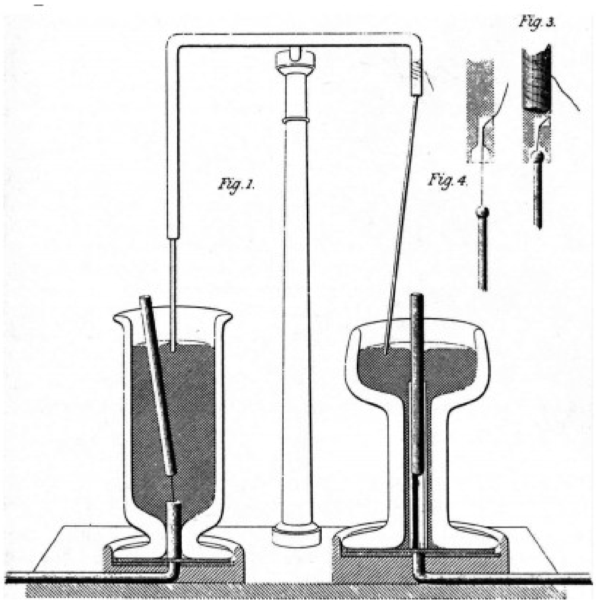

Figure 1: Faraday's experiment.

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used that allows observing the rotation of a wire around a magnet (right side) and the rotation of a magnet around a wire (left side).

In 1831, he built the first electrical generator with a U-shaped magnet (horseshoe) that established a magnetic field across a metallic disc (electrical conductor). When the disc rotated, it induced an electrical current from the center to the periphery of the disc (radial) through a spring-loaded sliding contact to the external circuit and returned to the center of the disc through the shaft. This device became known as the Faraday's disk, and is currently also known as a unipolar or homopolar generator.

The same device can function as generator or as motor:

1. Generator: rotating a metallic disc perpendicular to a magnetic field produces a difference in electrical potential between the axis and the periphery of the disc.
2. Motor: applying an electrical potential between the axis and the periphery of a metallic disc subjected to a magnetic field, makes the disc rotate.

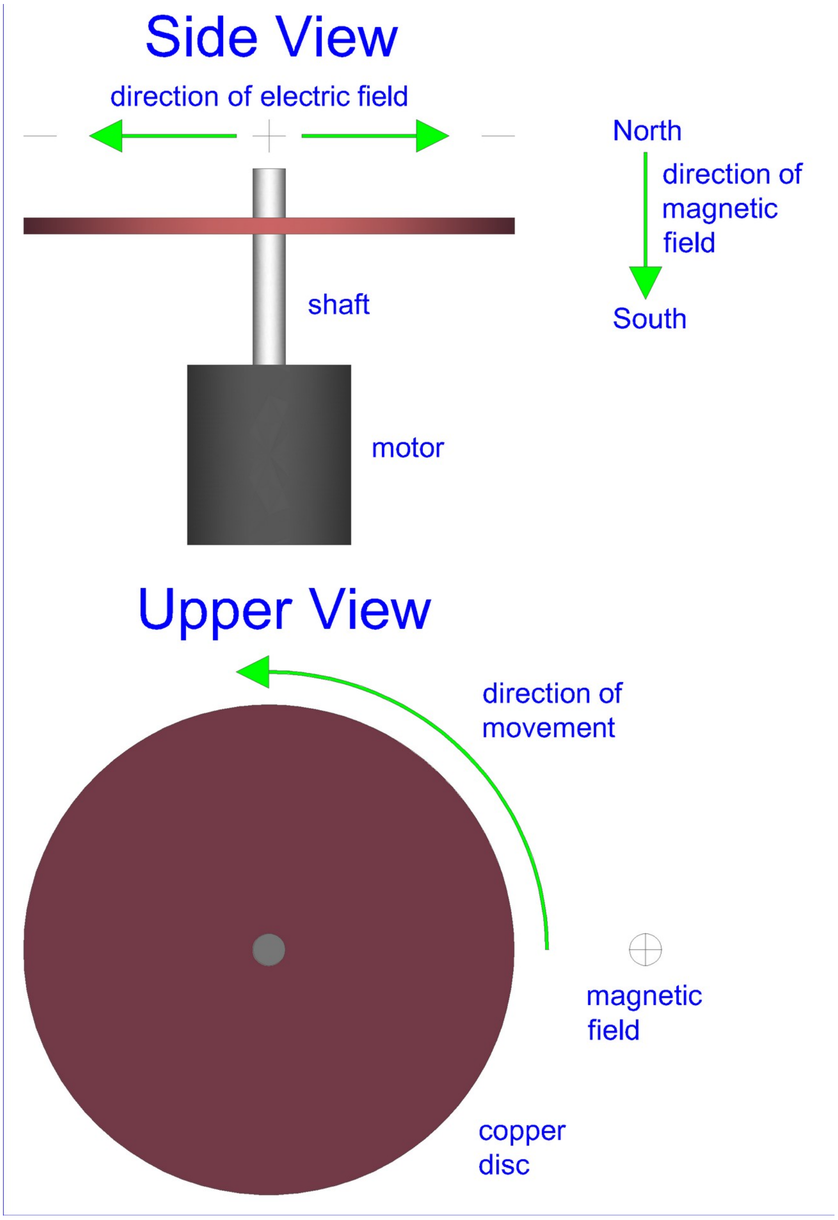

Figure 2: Faraday's disk principle.

What Faraday discovered is a consequence of the Lorentz's Force, which is the principle of the Hall effect: electric charges moving under the influence of a magnetic field suffer a force. When it works as a generator, the rotating metallic disc moves the free electrons (from the valence shell) of the atoms that make up the disc material, which are displaced with force $\vec{F}=q_E(\vec{v}\times\vec{B})$ in the direction perpendicular to the movement of the disc and the applied magnetic field, therefore accumulate in the center or periphery of the disk creating a radial electric field.

The preferred direction of rotation is that in which electrons accumulate at the periphery of the disc, which results in a radial electric field with the positive pole in the center and the negative pole at the periphery of the disc. If in this generator we apply the right-hand orthogonal rule, the one used to identify the Lorentz's force, we will identify the direction of the force applied to the positive electrical charges, which is radial to the center of the disc; a force in the opposite direction is applied to the free electrons of the disc, which is radial from the center to the periphery of the disc.

When the Faraday's disk works as homopolar generator, the accumulation of these electrons at the periphery of the disk creates a radial electric field that increases until the force $\vec{F}=q_E\vec{E}$ of the created electric field is equal to the force $\vec{F}=q_E(\vec{v}\times\vec{B})$. In this way, equating the two forces we have $\vec{E}=\vec{v}\times\vec{B}$. A charge q_E with speed v_x subjected to a magnetic field H_z produces an electric field E_y and an electric potential $V_{Ey}=E_y l_y=v_x B_z l_y$.

When the Faraday's disk works as a motor, the direction of rotation of the disk creates a magnetic field in the same direction as the applied magnetic field. In this way, there is the formation of magnetic poles opposite to the magnetic poles of the external field, which tend to slow down the rotation of the disk. At the braking limit, the homopolar motor will find its balance in the equation $\vec{E}=\vec{v}\times\vec{B}$.

2 Homopolar Generator

To calculate the electrical potential difference V_E generated radially in the Faraday's disk working as unipolar generator, it is important to consider that the tangential speed of the atoms of the material $v=\omega r$ varies as a function of their distance from the center of the disc (the radius of the circumference), therefore, making $l=R-r$ the radial distance between the two points of the potential measurement, with R being the largest radius and r the smallest radius, we have:

$$V_E=v\,B\,l=B\,\omega\int_r^R l\,dl=B\,\omega\left[\frac{l^2}{2}\right]_r^R=\frac{1}{2}B\,\omega\left(R^2-r^2\right)=\frac{1}{2}\mu\,H\,\omega\left(R^2-r^2\right)$$

With:

V_E = Electric potential difference [V];
H = Magnetic field [A m^{-1}];
B = Surface density of magnetic charge [Wb m^{-2}] [T];
μ = Magnetic permeability of the medium [Wb A^{-1} m^{-1}];
ω = 2πf = Angular velocity of displacement [rad s^{-1}];
v = Disc velocity [m s^{-1}];
R = External radius [m];
r = Internal radius [m];
l = Distance between R and r [m].

We can see that the difference in electric potential does not depend on the resistivity of the material used in the disc, that is, on the volumetric density of electrical charges (free electrons) of the material used in the disc. This occurs because the potential generated results from a balance of magnetic and electrical forces on electrical charges. For a given magnetic force, if there are more electrical charges available in the material, when they are displaced, they will create an electric field just enough to oppose this force. If we place two discs of the same dimensions, for example, copper and germanium, under the same speed and magnetic field conditions, the measured voltage will be exactly the same.

In the case of the Hall effect, the electrical potential measurement is made as a function of the electrical current that passes through the material and, as the speed of the electrical charge carriers varies depending on the resistivity of the material, it will indicate different potentials. When the speed of the electrical charge carriers of materials with different resistivities is the same, as is the case with the Faraday's disk, there is no difference in the measured potential values.

Therefore, the resistivity of the disc material only affects the internal resistance of the voltage source, which results in a voltage drop $V_{Ei}=I_E R_i=I_E \rho l/S$. In the case of a conductive wire, l is the length and S is the wire section; in the case of the disc, $l=R-r$ and S is the average area (at radius $½(R-r)$) of the circumference section limited by the brush contact length.

To calculate the electric current equivalent to a metallic disc that rotates about its center, we consider that the force acting on the electric charges is determined by $F=q_E B v=I_E B l$, then $q_E v=I_E l$, therefore:

$$I_E=\frac{q_E v}{l}=\frac{q_E \omega r}{2\pi r}=\frac{q_E \omega}{2\pi}=q_E f=\frac{q_E}{t}$$

With:

I = Electric current [A];
q_E = Electric charge [C];
v = ωr = Tangential velocity [m s^{-1}];
l = 2πr = Disc circumference perimeter [m];
ω = 2πf = Angular velocity [rad s^{-1}];
f = v_{RPM}/60 = Disc rotation frequency [Hz].

In the case of the Faraday's disc, the amount of electrical charge that passes in the unit of time is the total amount of free electrical charges contained in the disc divided by the time of one rotation. The electrical charge quantity on the disc is:

$$Q_E=n_e q_E S d$$

With:

Q_E = Electrical charge on the disc [C];
n_e = Electrons density of the disc [electrons m^{-3}];
q_E = Electric charge of electron = $1.602*10^{-19}$ C;
S = Surface area of the disc [m^2];
d = Thickness of the disc [m].

The equivalent electric current of the Faraday's disk is given by:

$$I_E=\frac{Q_E}{t}=Q_E f=n_e q_E S d f=n_e q_E S d \frac{\omega}{2\pi}=n_e q_E S d \frac{v_{RPM}}{60}$$

With:

I_E = Electric current [C s^{-1}] [A];
Q_E = Electric charge [C];
t = Time of one rotation [s];
f = v_{RPM}/60 = Disc rotation frequency [Hz];
ω = 2πf = Angular velocity [rad s^{-1}];
v_{RPM} = Disc rotation speed [RPM];
n_e = Electrons density of the disc [electrons m^{-3}];
q_E = Electric charge of electron = $1.602*10^{-19}$ C;

S = Surface area of the disc [m^2];
d = Thickness of the disc [m].

If the disk loaded with Q_E charges has a hole in the center, the surface area to be considered will not be the total area. With **l** being the radius of the disc or the radial distance between the two points, we have $l=R-r$ with **R** being the largest radius (of the perimeter) and **r** being the smallest radius (of the axis). Using the integral form of the disk area, we have:

$$S=2\pi\int_r^R l\,dl=2\pi\frac{(R^2-r^2)}{2}=\pi(R^2-r^2)$$

Thus, the equivalent electric current is the average of the electric current of the concentric current rings that are distributed from r to R. As the rotation time is the same for all rings and the amount of charges in each ring is proportional to its circumference, that is 2πr, the largest electric current will be at the perimeter of the disk and the smallest will be in the center. If we consider that the amount of electrical charge on an infinitesimal ring is dQ_E, we can calculate the equivalent current by summing the electrical charges of the rings between r and R by the integral:

$$I_E=\int dI_E=\int dQ_E f=\int n_e q_E d f\,dS=n_e q_E d f\int_r^R 2\pi r\,dr=2\pi n_e q_E d f\left[\frac{r^2}{2}\right]_r^R=n_e q_E d f\,\pi(R^2-r^2)$$

We know that the speed of the disc's electrical charges $v=\omega r$ is greater at the periphery than at the center of the disc and, because $\vec{F}=q(\vec{v}\times\vec{B})$, we know that the electrical charges at the disc's periphery are subjected to a greater radial force perpendicular to its direction than the charges located at the center of the disc. In fact, there is an increasing gradient of force from the center to the periphery which, by displacing the charges radially, creates an electric field between the center and the periphery of the disc. As long as there is a magnetic field on the rotating disc, this force will act on the free electrical charges of the disc material and, as the material is a good conductor of electricity, they will be pushed and move according to this force, producing an electric field between the center and the periphery of the disc.

Example 1:

Copper disk 20 cm in diameter and 5 mm thick rotating about its center at 1,800 RPM and 3,600 RPM (rotations per minute), subjected to an axial surface density of magnetic charges of 1 Tesla on its entire surface. The disk axis has a diameter of 2 cm and the electrical voltage will be measured between the disk axis and its periphery.

<u>For 1,800 RPM we have:</u>

$$V_E=B\omega\frac{R^2-r^2}{2}=1*188.496*\frac{(0.1)^2-(0.01)^2}{2}=0.933\,V$$

With:

V_E = Electric potential difference [V];
B = Magnetic field = 1 T;
ω = Angular speed = 2πf = 2π*1,800/60 = 188.496 rad s^{-1};
R = External radius = 0.1 m;
r = Internal radius = 0.01 m.

The equivalent electric current can be calculated by:

$$I_E = n_e q_E S d f = 8.4538*10^{28}*1.602*10^{-19}*3.11*10^{-2}*5*10^{-3}*30 = 6.318*10^{7}\,A$$

With:

I_E = Electric current [C s^{-1}] [A];
n_e = Electrons density of the disc = $8.4538*10^{28}$ electrons m^{-3};
q_E = Electric charge of electron = $1.602*10^{-19}$ C;
S = Surface area of the disc = $\pi(R^2 - r^2) = 3.14159*(10^{-2} - 10^{-4}) = 3.110*10^{-2}$ m^2;
d = Thickness of the disc = $5*10^{-3}$ m;
f = $v_{RPM}/60$ = Disc rotation frequency = 1,800/60 = 30 Hz.

<u>For 3,600 RPM we have:</u>

$$V_E = B\omega\frac{R^2 - r^2}{2} = 1*376.991*\frac{(0.1)^2 - (0.01)^2}{2} = 1.866\,V$$

With:

V_E = Electric potential difference [V];
B = Magnetic field = 1 T;
ω = Angular speed = 2πf = 2π*3,600/60 = 376.991 rad s^{-1};
R = External radius = 0.1 m;
r = Internal radius = 0.01 m.

The equivalent electric current can be calculated by:

$$I_E = n_e q_E S d f = 8.4538*10^{28}*1.602*10^{-19}*3.11*10^{-2}*5*10^{-3}*60 = 1.264*10^{8}\,A$$

With:

I_E = Electric current [C s^{-1}] [A];
n_e = Electrons density of the disc = $8.4538*10^{28}$ electrons m^{-3};
q_E = Electric charge of electron = $1.602*10^{-19}$ C;
S = Surface area of the disc = $\pi(R^2 - r^2) = 3.14159*(10^{-2} - 10^{-4}) = 3.110*10^{-2}$ m^2;
d = Thickness of the disc = $5*10^{-3}$ m;
f = $v_{RPM}/60$ = Disc rotation frequency = 3,600/60 = 60 Hz.

Example 2:

Copper disk 2 m in diameter and 10 mm thick rotating about its center at 1,800 RPM and 3,600 RPM (rotations per minute), subjected to an axial surface density of magnetic charges of 1 Tesla on its entire surface. The disk axis has a diameter of 4 cm and the electrical voltage will be measured between the disk axis and its periphery.

<u>For 1,800 RPM we have:</u>

$$V_E = B\omega\frac{R^2 - r^2}{2} = 1*188.496*\frac{(1)^2 - (0.02)^2}{2} = 94.21\,V$$

With:

V_E = Electric potential difference [V];
B = Magnetic field = 1 T;
ω = Angular speed = 2πf = 2π*1,800/60 = 188.496 rad s^{-1};
R = External radius = 1 m;
r = Internal radius = 0.02 m.

The equivalent electric current can be calculated by:

$$I_E = n_e q_E S d f = 8.4538 * 10^{28} * 1.602 * 10^{-19} * 3.141 * 10^{-2} * 30 = 1.276 * 10^{10}\,A$$

With:

I_E = Electric current [C s^{-1}] [A];
n_e = Electrons density of the disc = 8.4538*10^{28} electrons m^{-3};
q_E = Electric charge of electron = 1.602*10^{-19} C;
S = Surface area of the disc = $\pi(R^2 - r^2)$ = 3.14159*(1 – 2*10^{-4}) = 3.141 m^2;
d = Thickness of the disc = 10^{-2} m;
f = v_{RPM}/60 = Disc rotation frequency = 1,800/60 = 30 Hz.

For 3,600 RPM we have:

$$V_E = B\,\omega \frac{R^2 - r^2}{2} = 1 * 376.991 * \frac{(1)^2 - (0.02)^2}{2} = 188.42\,V$$

With:

V_E = Electric potential difference [V];
B = Magnetic field = 1 T;
ω = Angular speed = $2\pi f$ = 2π*3,600/60 = 376.991 rad s^{-1};
R = External radius = 1 m;
r = Internal radius = 0.02 m.

The equivalent electric current can be calculated by:

$$I_E = n_e q_E S d f = 8.4538 * 10^{28} * 1.602 * 10^{-19} * 3.141 * 10^{-2} * 60 = 2.552 * 10^{10}\,A$$

With:

I_E = Electric current [C s^{-1}] [A];
n_e = Electrons density of the disc = 8.4538*10^{28} electrons m^{-3};
q_E = Electric charge of electron = 1.602*10^{-19} C;
S = Surface area of the disc = $\pi(R^2 - r^2)$ = 3.14159*(1 – 2*10^{-4}) = 3.141 m^2;
d = Thickness of the disc = 10^{-2} m;
f = v_{RPM}/60 = Disc rotation frequency = 3,600/60 = 60 Hz.

In practice, it can be seen that the homopolar generator does not generate a radial electric field with the disc stationary and the magnet rotating because the magnetic field does not act directly on the electric field of the electrical charges on the disc but, when the disc rotates, with the magnet stationary or rotating together, its free electrical charges (electrons from the conduction layer of the atoms that make up the disc material) in movement generate a magnetic field and it is this that interacts with the external magnetic field, causing the deflection of the electrical charges.

3 Homopolar Motor

As we have seen, the Faraday’s disk is a device that can also function as a homopolar motor, applying an electrical potential between the center and the periphery of the disc. When it works as a motor, the electrons of the electric current that runs radially through the disc are displaced by the force $\vec{F} = q_E(\vec{v} \times \vec{B})$ in a direction perpendicular to the direction of the electric current and the applied magnetic field, therefore, the disc rotates following the speed at which the electrons are dragged. The electrons are accelerated by the force, but because of their collisions, the result is a constant average speed that is transferred to the disk.

All the equations applied in the development of the theory of the homopolar generator can be applied to the homopolar motor, however, in this case, it is important to know the rotation speed of the disc, which is given as a function of the magnetic field and the voltage applied between the center and the perimeter of the disk, like this:

$$V_E = B\omega \frac{R^2 - r^2}{2} \quad \Rightarrow \quad \omega = \frac{2V_E}{B(R^2 - r^2)} \quad \Rightarrow \quad v = \omega R = \frac{2V_E R}{B(R^2 - r^2)}$$

With:

V_E = Electric potential [V];
B = Surface density of magnetic charge or Magnetic Induction [Wb m^{-2}] [T];
ω = 2πf = Angular velocity [rad^{-1}];
v = ωr = Tangential velocity [m^{-1}];
R = External radius of disc [m];
r = Internal radius of disc [m].

The rotation speed of the disc is determined by:

$$f = \frac{v_{RPM}}{60} \quad \Rightarrow \quad \omega = 2\pi f = 2\pi \frac{v_{RPM}}{60} = \frac{2V_E}{B(R^2 - r^2)} \quad \Rightarrow \quad v_{RPM} = \frac{60V_E}{\pi B(R^2 - r^2)}$$

With:

V_{RPM} = Rotation speed of the disc [RPM].

Example:

Copper disc 20 cm in diameter and 5 mm thick rotating about its center, subjected to an axial magnetic field of 1 Tesla across its entire surface. The disk axis has a diameter of 2 cm and the electrical potential applied between the disk axis and its periphery is 1.5 Volts.

$$v_{RPM} = \frac{60V_E}{\pi B(R^2 - r^2)} = \frac{60 * 1.5}{\pi * 1((10^{-1})^2 - (10^{-2})^2)} \approx 2{,}900\, RPM$$

With:

v_{RPM} = Rotation speed of the disc [RPM];
V_E = Electric potential = 1.5 V;
B = Surface density of magnetic charge or Magnetic Induction = 1 T;
R = External radius of disc = 10^{-1} m;
r = Internal radius of disc = 10^{-2} m.

3.1 Homopolar Motor with Electrizable Material

In the article Searl Technology [1], we can see that the rollers used in the Searl Generator have propulsion independent of external energy supply. In fact, the continuous movement of the rollers is a consequence of the same principles as the homopolar motor and, as they have both electric and magnetic fields stored statically in the rollers, they continue to rotate driven by the Lorentz's force.

The difference between the homopolar motor and the Searl Effect Generator (SEG) rollers is that in these the electric field is applied to a material capable of acquiring permanent electrical polarization and, being subjected to an axial magnetic field, it provides a velocity vector even if no radial electric current occurs. Therefore, the calculations only consider the dielectric area that is subjected to the applied electric field, considering that the area of the magnets is conductive and, as no electric current circulates, it has its entire surface equipotential and does not contribute to the rotation of the rollers.

In this way, a Faraday's disk made with a cylinder of electrizable material subjected to an axial magnetic field and a radial electric field can function as a homopolar motor without the passage of electric current through the cylinder. The disc may consist of a cylindrical magnet with an electrical insulating layer or several concentric layers of magnetized material interspersed with layers of electrizable material. It is also possible to press magnetic and electrizable materials into powder and magnetize this disc axially and electrify radially. The important thing is that a radial electric field can be applied without the passage of electric current.

Below, we see the example of a variation of the homopolar motor that allows speed control and rotation inversion and that could be used for numerous purposes in replacement of conventional motors, coupling an axis to the center of the cylindrical magnets and can, sizing appropriately, serve as engine to turn the wheels of a vehicle. The energy consumption to move the device is very low.

Example:

Cylinder composed of four cylindrical neodymium magnets (Nd-Fe-B) with magnetic induction of 1.38 T, 4 cm in diameter and 2.5 cm thick, stacked one on top of the other, totaling a height of 10 cm, externally surrounded by a 4 cm thick layer of material that allows non-permanent electrification and, on the outside, a 5 mm thick metallic layer of stainless steel to provide structure and prevent wear on the roller when rolling. The magnets have a 5 mm central hole where the assembly axis is fixed. A variable voltage from 0 to 12 V is applied between the shaft and the outer metallic layer, with the positive on the shaft and the negative on the outer layer. The minimum speed of the device is 0 RPM when a voltage of 0 V is applied between the shaft and the outer layer. Reversing polarity reverses the direction of rotation.

The maximum rotation speed of the device is:

$$v_{RPM}=\frac{60\,V_E}{\pi B\left(R^2-r^2\right)}=\frac{60*12}{\pi*1.38\left(\left(6*10^{-2}\right)^2-\left(2*10^{-2}\right)^2\right)}=5.19*10^4\,RPM$$

With:

v_{RPM} = Rotation speed of the disc [RPM];
V_E = Electric potential = 12 V;
B = Surface density of magnetic charge or Magnetic Induction = 1.38 T;
R = External radius of disc = $6*10^{-2}$ m;
r = Internal radius of disc = $2*10^{-2}$ m.

The maximum linear speed of the roller when rolling on a surface, which is its tangential speed, is:

$$v=\omega R_e=\frac{2\,V_E\,R_e}{B\left(R^2-r^2\right)}=\frac{2*12*6.5*10^{-2}}{1.38\left(\left(6*10^{-2}\right)^2-\left(2*10^{-2}\right)^2\right)}=3.53*10^2\,m\,s^{-1}=1.27*10^3\,km/h$$

With:

v = Tangential velocity [m s^{-1}];
ω = 2πf = Angular velocity [rad s^{-1}];
R_e = External radius of disc = $6.5*10^{-2}$ m;

4 Further developments

The original Faraday’s disk has some limitations when using it as generator/motor:

- It presents counter-electromotive force when the output current flows to the load;
- The brushes to collect the voltage from the disc take only a fraction of the disc’s perimeter and this limits the output current that can be extracted from the device.

- The output voltage is low compared to actual generators and to get greater voltage would need a large disc and a large area of magnetic field.

These limitations can partially be overcome with some alterations in the Faraday's disk.

4.1 First Change in the Faraday's Disk

The direction of rotation of the Faraday disk determines the direction of the equivalent electric current. So, using the circular right-hand rule, the one used to identify the direction of the magnetic field inside a solenoid, we can identify the direction of rotation of the disk so that the generated magnetic field is in the same direction as the applied magnetic field. Thus, the homopolar generator/motor will find its balance in the equation $\vec{E}=\vec{v}\times\vec{B}$. It must be remembered that the direction of movement of electrical charges is the conventional one, that is, that of positive charge carriers.

There are three situations to consider regarding the magnetic field applied to the disk:

1. External fixed magnetic field
Created with fixed magnets or electromagnets in which the disc rotates within the magnetic field. One North or South pole above or below the disk can be used, as well as two opposite poles, one above and one below the disk. The distribution of magnetic charges from the magnets creates the magnetic field that is applied to the disk. The disc material must not have ferromagnetic characteristics so that a magnetic field in the opposite direction does not form on the disc.
2. External rotating magnetic field
Created with magnets or electromagnets fixed in the disc. The distribution of magnetic charges from the magnets creates the magnetic field that is applied to the disc. The disc material must not have ferromagnetic characteristics so that a magnetic field in the opposite direction does not form on the disc.
3. Internal rotating magnetic field
The disc material is ferromagnetic and has a permanent magnetic field.

Initially, Faraday did not place the magnetic field over the entire surface of the rotating disk because he used a horseshoe-shaped magnet. In this condition, when the disc is made of diamagnetic material (a good conductor of electricity such as copper, aluminum, etc.), the electric Foucault's currents induced in the disc generate a magnetic field of the same direction and, therefore, have poles of opposite polarity to the original magnetic field that tends to brake the rotation of the disc. Currently, this technology is used in electromagnetic braking systems.

Nicola Tesla, in 1889, patented an electric Dynamo Machine, called Unipolar Dynamo, which consisted of metallic discs that rotated between magnets to produce electrical current. The difference is that the magnets completely covered the rotating metal discs and the addition of a flange on the periphery of the discs facilitated the collection of electrical current. This improved the Faraday generator because it prevented the formation of an opposing magnetic field.

Tesla noticed that the current drawn from the Faraday generator did not pass entirely through the external circuit, and by far the largest portion of the current generated did not appear externally. Thus, by making the magnet completely cover the disk, Tesla made use of its entire surface in generating the current, instead of just a portion adjacent to the magnetic bar.

Furthermore, Tesla make the electrical current generated to cross the disc circularly, going from the center to the periphery through an innovative design: the disc was composed of spiral sections that forced the current to circulate around the axis of the disc. The assembly of the parts was such that the current generated, when consumed by the load connected to the device, circulated around the axis of the disc, increasing the magnetic field on the disc. This eliminated one of the biggest problems with current electrical generating systems: armature reaction, also called counter-electromotive force.

In article “Notes on a Unipolar Dynamo” published by Tesla in the newspaper The Electrical Engineer, N.Y., Sept. 2, 1891, Tesla declares: [2]

… But since the current is forced to follow the lines of subdivision, we see that it will tend either to energize or de-energize the field, and this will depend, other things being equal, upon the direction of the lines of subdivision. Is the subdivision be as indicated by the full lines in Fig. 295, it is evident that if the current is of the same direction as before, that is, from center to periphery, its effect will be to strengthen the field magnet; whereas, if the subdivision be as indicated by the dotted lines, the current generated will tend to weaken the magnet. In the former case the machine will be capable of exciting itself when the disc is rotated in the direction of arrow D; in the latter case the direction of rotation must be reversed.

…

Instead of subdividing the disc or cylinder spirally, as indicated in Fig. 295, it is more convenient to interpose one or more turns between the disc and the contact ring on the periphery, as illustrated in Fig. 296.

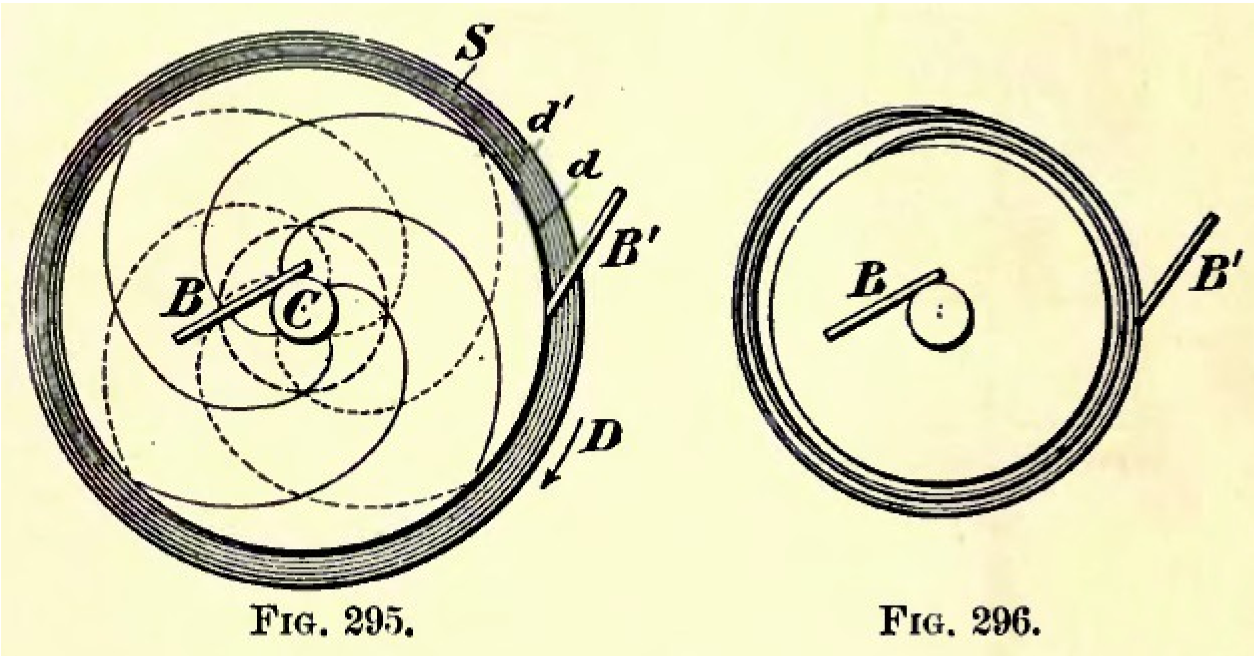

Figure 3: Change in the unipolar dynamo proposed by Tesla.

In the Faraday’s generator, the electric current flowing to the load passes through the disc in a radial direction from the center to the periphery. Using the orthogonal right-hand rule, we can identify a force generated by the load current that opposes the rotation of the disk given by $\vec{F}=I\,\vec{l}\times\vec{B}$, where I is the current flowing to the load. In Tesla's unipolar generator, when the electric current of the load rotates around the axis, it adds a magnetic field proportional to the current. For this to occur, using the right-hand circular rule, we can identify that the direction of rotation of the load's electric current must be the same as that of the disc.

So, to make the most of the gain of the homopolar generator we can use, instead of the disc, a winding of insulated copper or aluminum wire, like a coil, or assemble a disc with a flat winding of insulated copper or aluminum tape, since, as we know, this will provide the maximum increase in the device's magnetic field. The direction of the winding will be, starting from the center to the periphery, the same as the rotation of the disc, taking the precaution of, at the end of the winding, connect a ring on the periphery of the disc to collect the voltage. The counter-electromotive force will still exist and will reduce the rotation of the disc, however, the increase in the magnetic field caused by the winding of the coil that makes up the disc will maintain the generated electric field.

Knowing the maximum value of the load's electric current, we can calculate the magnetic field generated in the center of the winding by calculating the magnetic field formed in the center of a circular electric current loop:

$$H\,l = n\,I \quad \Rightarrow \quad H = \frac{n\,I}{2r} \quad \Rightarrow \quad B = \mu\,H = \mu\frac{n\,I}{2r}$$

With:

H = Magnetic field [A m^{-1}];
B = Surface density of magnetic charge or Magnetic Induction [Wb m^{-2}];
μ = Magnetic permeability of the material [Wb A^{-1} m^{-1}];
l = Diameter of the turns = 2r [m];
n = Number of turns;
I = Electric current [A].

4.2 Second Change in the Faraday’s Disk

One of the difficulties in collecting the radial electrical voltage in the homopolar generator is that the electric field produced between the center and the periphery of the disc is small and the use of brushes reduces this voltage even further. Another difficulty, if we use larger diameter discs, is maintaining a uniform magnetic field across the entire surface of the disc. To overcome these difficulties we need to make the electric field be produced along the turns of a toroidal winding, instead of a disc, so that the voltage produced in each turn of the toroid adds to the others. The final electrical voltage $\mathbf{V_{Ef}}$ will be the voltage of each turn $\mathbf{V_E}$ multiplied by the number of turns **n**. Thus, $V_{Ef} = n\,V_E$.

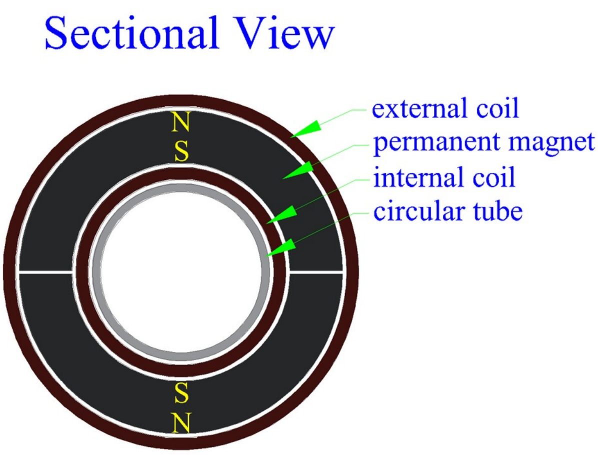

Figure 4: Section of the homopolar toroid.

Homopolar toroid components:

1. A magnetic stainless steel toroidal core that allows the geometric center of the toroid to be attached to the motor shaft, similar to a motorcycle's rim. It also allows the fixation of the collector rings (brushes) where the winding poles are connected.
2. A first winding with turns of enameled copper wire over the toroidal core, separated from this by insulating paper for transformer and covered by the same paper.
3. A cover over the first winding made of a permanent magnet, similar to a hollow toroid, with radial magnetic poles (the hollow magnetic toroid can be composed of six or more pairs of magnets with half-cane shape).
4. A second winding with turns of enameled copper wire over the toroidal magnet, separated from this by insulating paper for transformer and covered by the same paper.
5. A cover over the second winding made of magnetic steel tape, with a protecting end cover.

The steel core bar or tube of the rim can be circular, hexagonal or square in section. The fixing rods in the center can be six in number to give a hexagonal shape to the rim and prevent the permanent magnets from being curved. If the section of the bar or tube is circular, the permanent magnets must have a half-round shape with radial magnetic polarization, that is, outer north pole and inner south pole, or vice versa. For hexagonal or square sections, magnets can have a rectangular section. The length of the magnets is determined by the length of each of the six parts that make up the rim.

Thus designed, the toroidal homopolar generator allows both windings, inside and outside the magnetic toroid, to be subjected to a magnetic field H_Y perpendicular to the direction of rotation v_Z and the direction of the E_X windings. Consequently, the electrical voltages generated in each turn will add up.

When rotating the toroid about its geometric center, the free electrons in the copper of the turns are displaced along the coil wire, because the magnetic field is radial and the speed is axial in relation to the section of the toroid, which causes the formation of an electric field along the conductor wire. The generated DC electrical voltage is collected by brushes that are in contact with the collector rings. A simple reversal in the direction of rotation causes the device to generate DC voltage of reverse polarity. The disadvantage is that the counter-electromotive force appears when electric current is drawn from the device.

This device can function as a motor, in addition to the generator described, simply by connecting a DC voltage to the poles of the windings, because the moving electrons (electric current) in the copper wire undergo axial displacement as a consequence of the interaction with the radial magnetic field. Simply inverting the polarity of the DC voltage causes the device to rotate in the opposite direction.

Example:

Calculation of the electrical voltage induced in a coil of 350 turns of 4 mm diameter copper enameled wire wound on a 1 cm diameter magnetic toroidal core that forms a 40 cm diameter toroid. Superimposed on the winding is a permanent magnet cover made of several cylindrical sections (six or more sections to complete the 360°), each section is formed by two overlapping half-canes, with a radial magnetic field of 0.8 Tesla, with diameter 2 cm internal and 4 cm external (1 cm wall). Superimposed on the magnet assembly is a coil of 350 turns of 4 mm diameter copper enameled wire. The coils, toroidal core and toroidal magnet are protected by transformer electrical insulating paper and the entire assembly is fixed to the shaft of a motor that rotates at 600 RPM (revolutions per minute).

<u>Rotation speed:</u>

$$v=\frac{l}{t}=l\,f=2\pi r_T f=2*3.14*0.2*10=12.56\,m\,s^{-1}$$

With:

- v = Rotation speed [m s^{-1}];
- B = Magnetic field = 0.8 T;
- r_T = Toroid radius = 20 cm = 0.2 m;
- l = Toroid perimeter = $2\pi r_T$ = 1.2566 m;
- f = Rotation frequency = 600/60 = 10 Hz.

<u>Induced potential in the internal winding:</u>

$$V_E=B\,v\,l=0.8*12.56*6.28*10^{-2}=0.631\,V\,turn^{-1}$$

$$V_{Et}=B\,v\,l_t=0.8*12.56*21.98=221.0\,V$$

With:

- V_E = Electric potential of each turn [V];
- V_{Et} = Electric potential of winding [V];
- r = Radius of each turn = 1 cm = 10^{-2} m;
- l = Perimeter of each turn = $2\pi r$ = $2\pi*10^{-2}$ = $6.28*10^{-2}$ m turn^{-1};

n = Number of turns in the winding;
l_t = Winding length [m] = n l = n*2πr = 350 * 6.28*10^{-2} = 21.99 m.

Induced potential in the internal winding:

$$V_E = B\, v\, l = 0.8 * 12.56 * 1.256 * 10^{-1} = 1.262\, V\, turn^{-1}$$

$$V_{Et} = B\, v\, l_t = 0.8 * 12.56 * 43.98 = 441.9\, V$$

With:

V_E = Electric potential of each turn [V];
V_{Et} = Electric potential of winding [V];
r = Radius of each turn = 2 cm = 2*10^{-2} m;
l = Perimeter of each turn = 2πr = 2π*2*10^{-2} = 1.256*10^{-1} m turn^{-1};
n = Number of turns in the winding;
l_t = Winding length [m] = n l = n*2πr = 350 * 1.256*10^{-1} = 43.98 m.

5 Homopolar Linear Propulsion

Using the same principle as the homopolar motor, it is possible to obtain linear propulsion with a speed that depends solely on the electric and magnetic fields applied to a device containing electrically conductive material within a magnetic field. In this case, we will apply the electric field on the X axis, the magnetic field on the Z axis and the resulting velocity will appear on the Y axis.

$$\vec{F} = q_E (\vec{v} \times \vec{B}) = q_E \vec{E} \quad \Rightarrow \quad \vec{E} = \vec{v} \times \vec{B} = \begin{bmatrix} \vec{i} & \vec{j} & \vec{k} \\ v_x & v_y & v_z \\ B_x & B_y & B_z \end{bmatrix} \quad \Rightarrow \quad E_x = v_y B_z \quad \Rightarrow \quad v_y = \frac{E_x}{B_z}$$

With:

v_y = Device velocity [m s^{-1}];
q_E = Electric charge [C];
E_x = Electric field [V m^{-1}];
B_z = Surface density of magnetic charge or Magnetic Induction [Wb m^{-2}] [T].

In addition to the obvious option of using the rolling of a Faraday's disk on a surface for linear displacement, the equations show that it is possible to directly perform linear displacement on an electrically conductive object subjected to a magnetic field perpendicular to the applied electric field. As the direction of the electric current is in the direction of the electric field, the electrons are subjected to the Lorentz's Force and are accelerated in a direction perpendicular to the two applied fields and, by dragging, move the object with a speed determined by the equation above.

However, in the practical application of this principle, it is more interesting to use a configuration of multiple turns, instead of a bar of conductive material. The Second Change in the Faraday's Disk suggests the use of a coil of enameled copper wire wrapped around a permanent magnet, which can be circular, hexagonal or square in section.

Example 1:

Rectangular ferromagnetic steel tube 10 cm wide, 1 cm high and 15 cm long mounted on a chassis with four wheels to allow the assembly to be moved. Two 1 T magnets measuring 10 cm wide and 15 cm long are mounted at the top and bottom of the tube with their North magnetic poles facing outward and their South poles facing the tube. On the assembly there is a winding of enameled copper wire making up 300 turns, the ends of which are connected to a variable voltage source from 0 to 120 VDC.

The electrical current that circulates through the coil depends on the resistance of the winding, and this depends on the diameter of the wire used. There is a compromise between the applied voltage and the diameter of the wire so that it does not overheat. The minimum speed is 0 m/s, when the voltage on the winding is 0 V; will be maximum when the voltage is 120 V and, in this situation, the electric field applied to each 10 cm section of the winding that is under the influence of the magnetic field is:

$$E=\frac{l_B}{l}\frac{V_E}{nl}=\frac{0.1}{2.2*10^{-1}}\frac{120}{300*2.2*10^{-1}}=8.26*10^{-1}\,V\,m^{-1}$$

With:

E = Electric field in 10 cm [V m^{-1}];
V_E = Electric potential applied = 120 V;
n = Number of turns = 300;
l_B = Loop length under magnetic field = 0.1 m;
l = Perimeter of each turn = $2*10^{-2}+2*10^{-1} = 2.2*10^{-1}$ m;

$$v=\frac{E}{B}=\frac{8.26*10^{-1}}{1}=8.26*10^{-1}\,m\,s^{-1}$$

With:

v = Device velocity [m s^{-1}];
E = Electric field = $8.26*10^{-1}$ V m^{-1};
B = Surface density of magnetic charge or Magnetic Induction = 1 Wb m^{-2} [T].

The same principle applies when using electrizable materials.

Example 2:

Device composed of a block of electrizable material that is 10 cm wide, 5 cm high and 15 cm long mounted on a support with four wheels that allow it to move horizontally. The electric field is applied horizontally across two side plates and its voltage varies from 0 to 10 Volts, and vertically a magnetic surface charge density of 1 Wb/m^2 [T] is applied.

Electric field:

$$E=\frac{V_E}{l}=\frac{10}{0.1}=10^2\,V\,m^{-1}$$

With:

E = Electric field [V m^{-1}];
V_E = Electric potential applied = 10 V;
l = Block width = 0.1 m.

Displacement velocity:

$$v=\frac{E}{B}=\frac{10^2}{1}=10^2\,m\,s^{-1}=360\,km/h$$

With:

v = Block velocity [m s^{-1}];
E = Electric field = 10^2 V m^{-1};
B = Surface density of magnetic charge or Magnetic Induction = 1 Wb m^{-2} [T].

6 Homopolar Linear Propulsion of Gases and Liquids

In the article Power from Electrostatic Charges [3] in the sub-chapters Electric Charge Gathering by Magnetic Tunnel (for air and seawater) we see how it is possible to collect electrical charges from the air and seawater through a magnetic tunnel, which uses the same principle as the unipolar generator in a linear rather than circular arrangement. Likewise, it is possible to use this principle as a propulsion system by subjecting the electrical charges of the atmospheric air or the ions of the sea to perpendicular electric and magnetic fields. The speed of displacement of charges or ions will be defined by:

$$\vec{F}=q_E(\vec{v}\times\vec{B})=q_E\vec{E} \quad \Rightarrow \quad \vec{E}=\vec{v}\times\vec{B} \quad \Rightarrow \quad \vec{v}=\frac{\vec{E}}{\vec{B}}$$

With:

v = Device velocity [m s^{-1}];
q_E = Electric charge [C];
E = Electric field [V m^{-1}];
B = Surface density of magnetic charge or Magnetic Induction [Wb m^{-2}] [T].

Thus, by placing an electric field perpendicular to a magnetic field in the atmosphere or sea, the electric charges or ions distributed in the atmosphere or sea will be accelerated by the electric field through the force $\vec{F}=q_E\vec{E}$ in the same direction as the electric field. Due to collisions with molecules in the atmosphere or sea, the charges or ions lose speed, dragging them with an average drag speed, which is the equivalent of an electric current. When moving perpendicular to the magnetic field, the charges or ions are deflected and accelerated by the force $\vec{F}=q_E(\vec{v}\times\vec{B})$ and collide with air or water molecules. In this process, the charges or ions lose acceleration and drag the air or sea molecules with an average dragging speed in the direction perpendicular to the applied electric and magnetic fields.

In both cases above, the final velocity imparted to air or seawater is limited by the same condition that imparts velocity to air charges or water ions, that is, by the force $\vec{F}=q_E(\vec{v}\times\vec{B})$, which now deflects the charges or ions perpendicular to the its direction and, therefore, produces an electric field $\vec{E}=\vec{F}/q_E$ that opposes the initial electric field. Then, the final speed is maintained at the condition $\vec{E}=\vec{v}\times\vec{B}$.

Furthermore, it is important to remember that the direction of movement of negative electrical charges or ions is opposite to the movement of positive electrical charges or ions when subjected to an electric field. Therefore, the given accelerated motion given by $\vec{F}=q_E\vec{E}$ has opposite direction for opposite charges. However, if we apply the right-hand orthogonal rule, we will see that the force $\vec{F}=q_E(\vec{v}\times\vec{B})$ will have the same direction for both polarities because the speed of positive charges is positive while it will have the opposite direction for negative charges. The equation becomes $\vec{F}=-q_E(-\vec{v}\times\vec{B})$, that is, the drag speed of atmospheric air and seawater, even containing charges or ions of opposite polarities, will always have the same direction.

The kinetic energy associated with the movement of electrical charges or ions (K = ½ mv^2) will be transferred to molecules and atoms of neutral air or water during collisions, thus, we can estimate the drag speed of atmospheric air or seawater:

$$K_{m3}=\frac{n_e m_e v_e^2}{2}=\frac{n_m m_m v_m^2}{2}$$

With:

K_{m3} = Volumetric energy density associated with movement [J m^{-3}];
n_e = Volumetric density of electrical charges or ions [electrons m^{-3}] or [ions m^{-3}];

m_e = Mass of electrical charges or ions [kg];
v_e = Displacement velocity of electrical charges or ions [m s^{-1}];
n_m = Volumetric density of molecules or neutral atoms [molecules m^{-3}] or [atoms m^{-3}];
m_m = Mass of molecules or neutral atoms [kg];
v_m = Displacement velocity of molecules or neutral atoms [m s^{-1}].

Atmospheric air is composed of a mixture of gases and sea water is composed of a mixture of water and mineral salts, therefore, the value $n_m m_m$ must be replaced by the sum of the volumetric densities of the individual masses of the neutral molecules and atoms that make up the various substances:

$$K_{m3}=\frac{n_e m_e v_e^2}{2}=\sum n_m m_m \frac{v_m^2}{2}$$

By isolating the speed of neutral molecules or atoms, we can calculate the relationship between the speed of electrical charges or ions and the speed of atmospheric air or seawater:

$$v=v_m=\sqrt{\frac{n_e m_e}{\sum n_m m_m}}v_e$$

With:
v = Drag velocity of air or water [m s^{-1}];
v_m = Displacement velocity of neutral molecules [m s^{-1}];
v_e = Displacement velocity of electrical charges or ions [m s^{-1}].

In this way, we can propel an air or sea vehicle by propelling the molecules of gases or liquids that are in contact with its housing. The direction of thrust of the vehicle will be opposite to the direction of movement of the air or seawater. However, salt water behaves as a conductor of electricity, so there will be greater energy consumption the greater the applied electric field.

6.1 Aerial Propulsion

The most abundant gases in the atmosphere are Nitrogen (78.08%) and Oxygen (20.95%), which make up 99.03% of the total volume of gases. Water vapor is an important component and its proportion varies, depending on the location and other conditions, reaching up to around 4% of the volume. To simplify our calculations, we will only consider Nitrogen and Oxygen molecules.

Thus, 1 m^3 of air, which corresponds to 1,000 liters, contains approximately 780.8 liters (78.08%) of Nitrogen molecules (N_2) and 209.5 liters (20.95%) of Oxygen molecules (O_2).

One mole of a gas, under normal temperature and pressure conditions (NTP), occupies a volume of 22.4 liters, therefore, in 1 m^3 of atmospheric air (1,000 liters) we will have:

1. Nitrogen
   78.08% of 1,000 liters = 780.8 liters;
   (780.8 liters/m^3)/(22.4 liters/mole) = 34.857 mole/m^3.
2. Oxygen
   20.95% of 1,000 liters = 209.5 liters;
   (209.5 liters/m^3)/(22.4 liters/mole) = 9.353 mole/m^3.

A gram atom is the mass of 1 mole of atoms of a substance which, in turn, corresponds to the value of its atomic mass. The molar mass is the mass of one mole of a molecule of the substance and its value is formed by the sum of the atomic masses of the constituent atoms of the molecule. Gases in the atmosphere usually combine chemically into pairs of atoms, forming molecules;

Knowing the masses of these molecules, we can estimate the sum of the volumetric mass densities, therefore in 1 m^3 of atmospheric air we will have:

1. Nitrogen (N_2 = 28 g/mole)
   34.857 mole/m^3 * 28 g/mole = 976 g/m^3;
2. Oxygen (O_2 = 32 g/mole)
   9.353 mole/m^3 * 32 g/mole = 299 g/m^3;
3. Total: 1,275 g/m^3 = 1.275 kg/m^3.

The volumetric density of electrical charges (electrons) in the atmosphere varies depending on altitude, however, at sea level it is $2.447*10^{25}$ electrons/m^3. The volumetric electronic mass density is calculated by:

$$n_e m_e = 2.447*10^{25}*9.109*10^{-31} = 2.229*10^{-5}\, kg\, m^{-3}$$

With:

n_e = Volumetric density of electrons at sea level = $2.447*10^{25}$ electrons m^{-3};
m_e = Mass of electron = $9.109*10^{-31}$ kg;

The approximate speed of atmospheric air as a consequence of the drag of air molecules as a function of the speed of electrical charges is defined by:

$$v = v_m = \sqrt{\frac{n_e m_e}{\sum n_m m_m}}\, v_e = \sqrt{\frac{2.229*10^{-5}}{1.275}}\, v_e = 4.181*10^{-3}\, v_e$$

With:

v = Drag velocity of air [m s^{-1}];
v_m = Displacement velocity of neutral molecules [m s^{-1}];
v_e = Displacement velocity of electrical charges [m s^{-1}];
$n_e m_e$ = Volumetric density of electronic mass = 2.229 kg m^{-3};
$n_m m_m$ = Volumetric density of neutral mass = 1.275 kg m^{-3}.

Example:

The device is a chamber made of electrical insulating material that works like a wind tunnel and is mounted in a place where the air is still, but can circulate freely. The chamber is 10 cm wide and 5 cm high. The electric field is applied horizontally across two internal plates and its voltage varies from 0 to 100 Volts, allowing the velocity of the air charges to vary from zero to maximum, and vertically a surface density of magnetic charge of 1 Wb/m^2 or 1 Tesla is applied.

The electric field is calculated by:

$$E = \frac{V_E}{l} = \frac{100}{0.1} = 10^3\, V\, m^{-1}$$

With:

E = Electric field [V m^{-1}];
V_E = Electric potential = 100 V;
l = Chamber width = 0.1 m.

The displacement speed of charges is calculated by:

$$v_e = \frac{E}{B} = \frac{10^3}{1} = 10^3\, m\, s^{-1}$$

With:

v_e = Charges velocity [m s^{-1}];
E = Electric field = 10^3 V m^{-1};
B = Surface density of magnetic charge or Magnetic Induction = 1 Wb m^{-2} [T].

The electrical charges dispersed in the atmosphere will move at the above speed, however, the countless collisions with atmospheric air molecules will considerably reduce their speed. The resulting air drag speed will be:

$$v = 4.181 * 10^{-3} v_e = 4.181 * 10^{-3} * 10^3 = 4.18\, m\, s^{-1}$$

As air behaves as an electrical insulator, it is possible to compensate for the speed reduction by increasing the voltage applied to the plates of this device up to the limit of 3 kV/mm, which is the air insulation limit (breakdown voltage). So, for 5 cm of distance, we can apply up to 150 kV. Our interest is to compensate for the loss caused by collisions, so we will increase the chamber potential difference to 25kV and we will have:

$$v_e = \frac{E}{B} = \frac{V_E}{B l} = \frac{2.5 * 10^4}{1 * 0.1} = 2.5 * 10^5\, m\, s^{-1}$$

$$v = 4.181 * 10^{-3} v_e = 4.181 * 10^{-3} * 2.5 * 10^5 = 1.05 * 10^3\, m\, s^{-1} = 3.76 * 10^3\, km/h$$

With:

v = Drag velocity of air [m s^{-1}];
v_e = Charges velocity = $2.5*10^5$ m s^{-1};
V_E = Electric potential = $2.5*10^4$ V;
B = Surface density of magnetic charge or Magnetic Induction = 1 Wb m^{-2} [T];
l = Chamber width = 0.1 m.

6.2 Maritime Propulsion

Oceanographic expeditions have shown that the main dissolved constituents in sea and ocean water comprise 99.7% of the total dissolved constituents. The main constituents always occur in the same proportions, which are: Cl^- (55.04%), Na^+ (30.61%), SO_4^{-2} (7.68%), Mg^{+2} (3.69%), Ca^{+2} (1.16%), K^+ (1.10%), HCO_3^- (0.42%). These proportions vary only by climatic factors, and in coastal regions these proportions differ mainly because of river discharges. Minor and secondary constituents do not obey any rule of proportion; are gases, nutrients and trace elements. We can approximate the proportion of these constituents by saying that dissolved gases are 100 to 200 times more abundant than nutrients, which, in turn, are thousands of times more abundant than trace elements.

Salinity is the measure of how many grams of material are dissolved in one kilogram of seawater, that is, in parts per thousand grams (‰). Most ocean waters have salinities ranging between 34 and 36 ppt (parts per ton – kg/1,000 kg). A salinity of 35 ppt is considered normal, therefore, in each kilogram of seawater, on average, 35 g of salts are dissolved, which gives it salinity. Variations in salinity occur through physical processes such as evaporation, freezing and precipitation, which add or subtract water from the sea. Surface waters are those that suffer the greatest variations in salinity. In tropical regions, it tends to be higher due to evaporation; in temperate regions, there are seasonal variations. The salinity of deep waters is practically constant and, in general, is lower than that of surface waters, as they are formed at the poles.

The main gases dissolved in seawater are N_2 (12.5 ppm, 10 ml/l), O_2 (7.2 ppm, 5 ml/l) and CO_2 (78.0 ppm, 40 ml/l), occurring in smaller amounts of He, Ar and Kr. Seawater is slightly alkaline and contains cations (Mg, Ca, Na, etc.) and this allows CO_2 to dissolve forming carbonates and bicarbonates.

The salt molecules dissolved in the water disperse and dissociate or ionize, giving seawater an ionic strength. All ions dispersed in the water, in the form of cations and anions, will move in the same direction, therefore, in one kilogram of seawater, we will have 35 g of ions that will move in the same direction, dragging with them one kilogram of water. In the end, we will have a drag speed of approximately:

$$v = v_m = \sqrt{\frac{m_e}{m_m}}\, v_e = \sqrt{\frac{35}{1{,}000}}\, v_e = 1.871 * 10^{-1} v_e$$

With:

v = Drag velocity of water [m s^{-1}];
v_m = Displacement velocity of neutral molecules [m s^{-1}];
v_e = Displacement velocity of electrical charges [m s^{-1}].
m_e = Mass of ions [kg];
m_m = Mass of neutral molecules [kg].

Example:

The device is a chamber made of electrical insulating material that works as a tunnel for impulsion of saltwater and is mounted in a place where the water is still, but can circulate freely. The chamber is 10 cm wide and 5 cm high. The electric field is applied horizontally across two internal plates and its voltage varies from 0 to 10 Volts, allowing the speed of water ions to vary from zero to maximum, and vertically is applied a surface density of magnetic charge of 1 Wb/m^2 [T].

The electric field is calculated by:

$$E = \frac{V_E}{l} = \frac{10}{0.1} = 10^2\, V\, m^{-1}$$

With:

E = Electric field [V m^{-1}];
V_E = Electric potential = 10 V;
l = Chamber width = 0.1 m.

The displacement speed of ions is calculated by:

$$v_e = \frac{E}{B} = \frac{10^2}{1} = 10^2\, m\, s^{-1}$$

With:

v_e = Ions velocity [m s^{-1}];
E = Electric field = 10^2 V m^{-1};
B = Surface density of magnetic charge or Magnetic Induction = 1 Wb m^{-2} [T].

The ions dispersed in the seawater will move at the above speed, however, the countless collisions with the constituent molecules of salty sea water will considerably reduce their speed. The resulting water drag speed will be:

$$v = 1.871 * 10^{-1} v_e = 1.871 * 10^{-1} * 10^2 = 18.71\, m\, s^{-1} = 67.36\, km/h$$

7 Conclusion

The original Faraday's disk may be explored in other ways to use the homopolar principle in several new technologies. We can get DC high voltage generators with the homopolar toroid and overcome the counter-electromotive force with a disc made of spiral conductive turns.

Using eletrizable materials we can get motors running with almost none energy, as are the Searl's rollers [1].

In the linear motion we can get new aerial and marine propulsion systems for air and saltwater vehicles based on the electrical charges and ions acceleration. These vehicles would produce no noise.

There are many improvements in the electrical generation and propulsion systems using the homopolar technology and, because of this, this technology deserves to be seriously researched.

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