Gravitational Micro-Thrusters

Fran De Aquino
Professor Emeritus of Physics, Maranhao State University, UEMA.
Titular Researcher (R) of National Institute for Space Research, INPE

Here we show how to produce thrusts of the order of $100kN$ or more, starting from sets of micro-tubes $(diameter << 1cm)$ filled with air at low pressure, subjected to gravity g, and a strong magnetic field H. Under these conditions, these micro-tubes work as micro-thrusters, where the thrust is produced starting from the local potential gravitational energy.

Key words: Gravitational Mass, Gravitational Interaction, Gravitational Thruster.

INTRODUCTION

In this paper we will show that micro-tubes $(diameter << 1cm)$ filled with air at low pressure, subjected to gravity $\vec{g}$, and a strong magnetic field H, can works as micro-thrusters, where the thrust is produced starting from the local potential gravitational energy. In this context, it is also shown that sets of these micro-thrusters can produce thrust of the order of $100kN$ or more.

THEORY

In a previous paper [1] we shown that there is a correlation between the gravitational mass, m_g, and the rest inertial mass m_{i0}, which is given by

$$\chi = \frac{m_g}{m_{i0}} = \left\{1 - 2\left[\sqrt{1+\left(\frac{\Delta p}{m_{i0}c}\right)^2} - 1\right]\right\} = \\ = \left\{1 - 2\left[\sqrt{1+\left(\frac{Un_r}{m_{i0}c^2}\right)^2} - 1\right]\right\} = \\ = \left\{1 - 2\left[\sqrt{1+\left(\frac{Wn_r}{\rho c^2}\right)^2} - 1\right]\right\} \quad (1)$$

where Δp is the variation in the particle's *kinetic momentum*; U is *the electromagnetic energy absorbed or emitted by the particle;* n_r is the index of refraction of the particle; W is the density of energy on the particle (J/kg); ρ is the matter density (kg/m^3) and c is the speed of light.

The *instantaneous values* of the density of electromagnetic energy in an *electromagnetic* field can be deduced from Maxwell's equations and has the following expression

$$W = \tfrac{1}{2}\varepsilon E^2 + \tfrac{1}{2}\mu H^2 \quad (2)$$

where $E = E_m \sin\omega t$ and $H = H\sin\omega t$ are the *instantaneous values* of the electric field and the magnetic field respectively.

It is known that $B = \mu H$, $E/B = \omega/k_r$ [2] and

$$v = \frac{dz}{dt} = \frac{\omega}{\kappa_r} = \frac{c}{\sqrt{\frac{\varepsilon_r \mu_r}{2}\left(\sqrt{1+(\sigma/\omega\varepsilon)^2}+1\right)}} \quad (3)$$

where k_r is the real part of the *propagation vector* $\vec{k}$ (also called *phase constant*); $k = |\vec{k}| = k_r + ik_i$; ε , μ and σ, are the electromagnetic characteristics of the medium in which the incident (or emitted) radiation is propagating ($\varepsilon = \varepsilon_r\varepsilon_0$; $\varepsilon_0 = 8.854\times10^{-12}F/m$; $\mu = \mu_r\mu_0$ where $\mu_0 = 4\pi\times10^{-7}H/m$; σ is the electrical conductivity in *S/m*). From Eq. (3), we see that the *index of refraction* $n_r = c/v$ is given by

$$n_r = \frac{c}{v} = \sqrt{\frac{\varepsilon_r\mu_r}{2}\left(\sqrt{1+(\sigma/\omega\varepsilon)^2}+1\right)} \quad (4)$$

Equation (3) shows that $\omega/\kappa_r = v$. Thus, $E/B = \omega/k_r = v$, i.e.,

$$E = vB = v\mu H \quad (5)$$

Then, Eq. (2) can be rewritten as follows

$$W = \tfrac{1}{2}\varepsilon\, v^2\mu^2H^2 + \tfrac{1}{2}\mu H^2 = \\ = \tfrac{1}{2}\mu H^2\left(\varepsilon v^2\mu\right) + \tfrac{1}{2}\mu H^2 = \\ = \mu H^2 \quad (6)$$

For $\sigma >> \omega\varepsilon$, Eq. (3) gives

$$n_r^2 = \frac{c^2}{v^2} = \frac{\mu\sigma}{2\omega}c^2 \quad (7)$$

Substitution of Eqs. (6) and (5) into Eq. (1) gives

$$\chi=\left\{1-2\left[\sqrt{1+\left(\frac{\mu^3\sigma}{4\pi f\rho^2c^2}\right)H^4}-1\right]\right\} \qquad (8)$$

Note that if $H=H_m\sin\omega t$.Then, the average value for H^2 is equal to $\frac{1}{2}H_m^2$ because H varies sinusoidaly (H_m is the maximum value for H). On the other hand, we have $H_{rms}=H_m/\sqrt{2}$. Consequently, we can change H^4 by H_{rms}^4, and the Eq. (8) can be rewritten as follows

$$\chi=\left\{1-2\left[\sqrt{1+\left(\frac{\mu^3\sigma}{4\pi f\rho^2c^2}\right)H_{rms}^4}-1\right]\right\} \qquad (9)$$

Now consider a metallic cylindrical tube (ϕ internal diameter, h_ϕ height and 0.2mm thick), filled with *air* at low pressure and subjected to gravity, $\vec{g}$, and an oscillating magnetic field $\vec{H}_{rms}$ with frequency f. The metallic tube is inside a *dielectric*, and is *electrically charged* as shown in Fig.1. If $\phi<<1cm$ then, the distances among these electric charges and the atoms of air inside the tube will be very smalls. Consequently, the electrical forces that will act on these atoms will be very strong, and will be sufficient to *ionize* the oxygen and nitrogen atoms of the air, increasing the *electrical conductivity* of the air inside the tube.

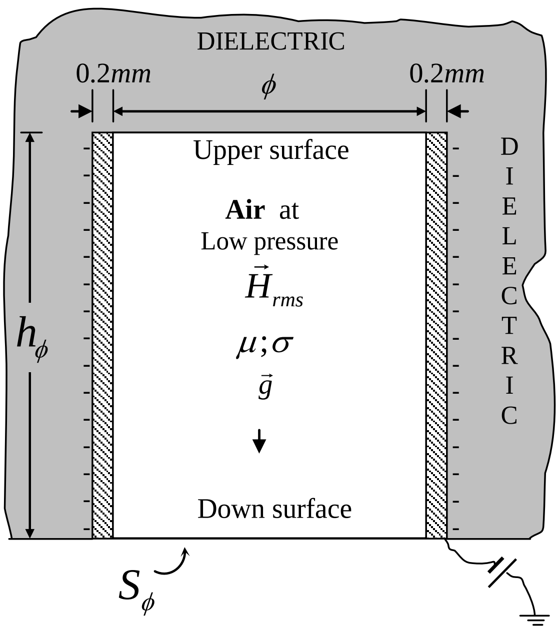


Fig. – 1 *Air Cylindrical tube* (ϕ diameter; h_ϕ height).

It is known that the electrical conductivity is proportional to both the concentration and the mobility of the *ions* and the *free electrons*, and is expressed by

$$\sigma=\rho_e\mu_e+\rho_i\mu_i \qquad (10)$$

where ρ_e and ρ_i express respectively the concentrations $\left(C/m^3\right)$ of electrons and ions; μ_e and μ_i are respectively the mobilities of the electrons and the ions.

In order to calculate the electrical conductivity of the air inside the metallic tube, we first need to calculate the concentrations ρ_e and ρ_i.

Since the number of atoms per m^3, n_a, is given by

$$n_a=\frac{N_0\rho_s}{A_s} \qquad (11)$$

where $N_0=6.02214129\times10^{26}\,atoms/kmole$, is the Avogadro's number; ρ_s is the matter density (in kg/m^3) and A_s is the molar mass ($kg.kmole^{-1}$). Then, for $\rho_s=\rho_{air}=1\times10^{-4}kg.m^{-3}$ $\left(6.62\times10^{-2}Torr\right)$, Eq. (11) gives

$$n_a=\frac{N_0\rho_{air}}{A_{air}}\cong\frac{\left(6.02214129\times10^{26}\right)\left(1\times10^{-4}\right)}{28.0134}=$$

$$=2.15\times10^{21}atoms/m^3 \qquad (12)$$

Using techniques of the Statistical Mechanics we can calculate *the most probable number* of ions, N_i, in the volume $V=\frac{\pi}{4}\phi^2h_\phi$ of air cylindrical tube, by means of the following expression [3].

$$N_i=\frac{N}{S}a_i \qquad (13)$$

where $N=n_a\times1m^2$ is the total number of atoms; S is the area total of the box $\left(1m^2\right)$ and a_i is the area of the cell $\left(h_\phi\phi\right)$. Therefore, Eq. (13) can be rewritten as follows

$$N_i=\frac{n_a\left(1m^2\right)}{\left(1m^2\right)}\left(h_\phi\phi\right) \qquad (14)$$

For $\phi=1.6mm$ and $h_\phi=12cm$, Eq.(14) yields

$$N_i = 4.1 \times 10^{17} \, ions \quad (15)$$

Obviously, the number of free electrons will be equal the number of ions, thus we can write that

$$N_e = N_i = 4.1 \times 10^{17} \, ions \quad (16)$$

Now, we can calculate the concentrations ρ_e and ρ_i $\left(C/m^3\right)$ of electrons and ions by means of the following expression

$$\rho_e = \rho_i = \frac{eN_i}{V} = \frac{eN_1}{\left(\frac{\pi}{4}\phi^2\right)h_\phi} = 2.7 \times 10^5 \, C/m^3 \quad (17)$$

This corresponds to a strong concentration level in the case of *conducting materials*. For these materials, at temperature of 300K, the mobilities μ_e and μ_i vary from 10 up to100 $m^2V^{-1}s^{-1}$ [4]. Assuming that $\mu_e = \mu_i \cong 30 \; m^2V^{-1}s^{-1}$ (*Geometric mean of mobility level for conducting materials*), the electrical conductivity of the air inside the tube is given by

$$\sigma_{air} = \rho_e\mu_e + \rho_i\mu_i = 2\left(2.7 \times 10^5\right)(30) =$$

$$\cong 2 \times 10^7 \, S.m^{-1} \quad (18)$$

The pressure, $\vec{P}$, exerted on the area S_ϕ, by of the *air* confined inside the tube, according to Eq.(1), is given by

$$\vec{P} = \frac{m_g \vec{g}}{S_\phi} = \frac{\chi m_{i0} \vec{g}}{S_\phi} = \frac{\chi m_{i0} h_\phi \vec{g}}{S_\phi h_\phi} = \chi \rho_{air} h_\phi \vec{g} \quad (19)$$

Substitution of Eq.(9) into Eq. (19) gives

$$\vec{P} = \left\{\rho_{air} - 2\left[\sqrt{\rho_{air}^2 + \left(\frac{\mu_{air}^3 \sigma_{air}}{4\pi f c^2}\right) H_{rms}^4} - \rho_{air}\right]\right\} h_\phi \vec{g} \quad (20)$$

For, $f = 0.2Hz$, $\sigma_{air} \cong 2 \times 10^7 S/m$, Eq.(20) gives

$$\vec{P} = \left\{\rho_{air} - 2\left[\sqrt{\rho_{air}^2 + 1.75 \times 10^{-28} H_{rms}^4} - \rho_{air}\right]\right\} h_\phi \vec{g} \quad (21)$$

For $\rho_{air} = 1 \times 10^{-4} \, kg.m^{-3}$ $\left(6.62 \times 10^{-2} \, Torr\right)$, and $H_{rms} = 7.96 \times 10^5 A/m$ $(1 \; T)$, Eq. (21) gives

$$\vec{P} = -0.0164 h_\phi \vec{g} \quad (22)$$

Note the sign (-) in Eq. (13). It indicates that, in this case, the pressure $\vec{P}$ acts on the contrary direction of the gravity $\vec{g}$. This means that the pressure will be exerted on the *upper surface* of the cylindrical tube (See Fig.1). Thus, the cylindrical tube works as a *gravitational micro-thruster*, producing a thrust F, given by

$$\vec{F} = \vec{P} S_\phi = -0.0164 h_\phi S_\phi \vec{g} = -0.0129 \phi^2 h_\phi \vec{g} \quad (23)$$

If $h_\phi = 12cm$; $\phi = 1.6mm$ and $g = 9.81 m.s^{-2}$, then the intensity of the force $\vec{F}$ is given by

$$F = 3.89 \times 10^{-8} N \quad (24)$$

In the case of a plate with N_ϕ *gravitational micro-thrusters*, the Eq. (24) can be rewritten as follows

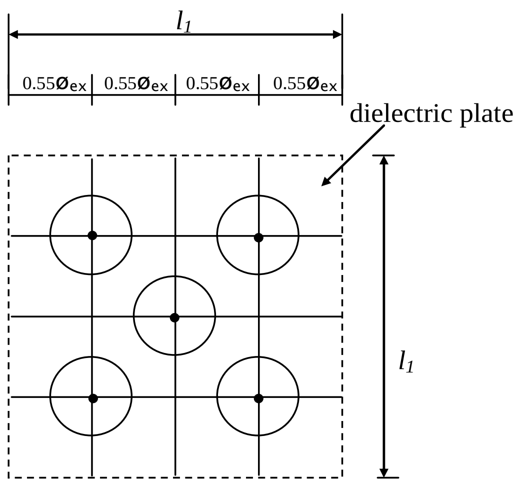
$$F_N = 3.89 \times 10^{-8} N_\phi \quad (25)$$

For example, if $N_\phi = (560 \times 560) = 313600$, then Eq. (25) gives

$$F_N = 0.0122 N = 1.2 \times 10^{-3} kgf = \underline{1.2gf} \quad (26)$$

Assuming that, the 313600 *metallic* cylindrical tubes (external diameter= $\phi_{ex} = \phi + 0.4mm = 2.0mm$ and height $= h_\phi$) are distributed into a *square* dielectric plate with sides l, according to the pattern shown in Fig.2, then we can write that $l = 2.2\phi_{ex}\sqrt{N_\phi/5}$ (See Fig. 2). This means that the dielectric plate will have

$$l = 1.10m \quad (27)$$



$(2.2Ø_{ex})^2$ 5

S .... $N_Ø$

$$S = \frac{N_\phi}{5}\left(2.2\phi_{ex}\right)^2 = l^2 \quad \Rightarrow l = 2.2\phi_{ex}\sqrt{\frac{N_\phi}{5}}$$

Fig. 2 – Distribution of metallic cylindrical tubes into a *dielectric* plate.

Figure 3 shows an experimental set-up in order to check the total thrust produced by the dielectric plate, with N_ϕ *gravitational micro-thrusters*, subjected to an oscillating magnetic field, given by

$$H_{rms} = (N_{turns}/y)i_{rms} = (300/0.01)i_{rms} =$$
$$= 3\times10^4 i_{rms}$$

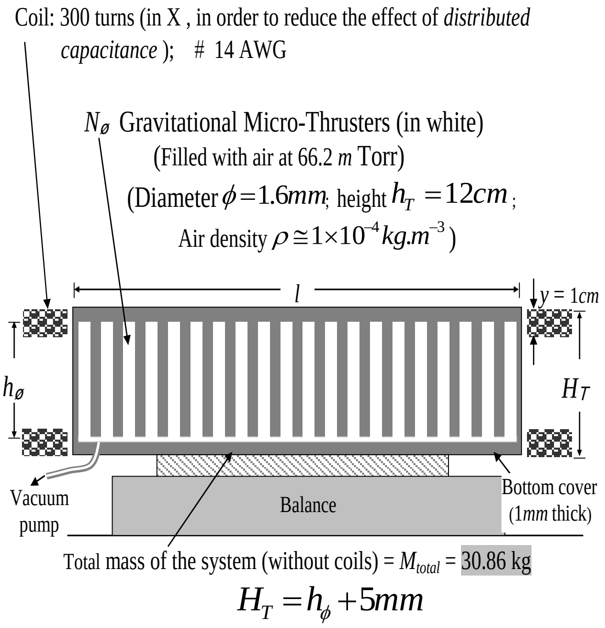


Fig. 3 – Schematic Diagram of the dielectric plate, with N_ϕ *Gravitational Micro-Thrusters*, on a balance, and inside a magnetic field produced by two *external coils*.

The mass of one *dielectric* plate (High-density polyethylene (HDPE), $970\ kg.m^{-3}$), 12.2cm thickness $(12.2cm = h_\phi + 2mm)$ (See Fig 3), *without* the micro-thrusters is given by.

$$m_{Mg} = l^2(12.2cm)(970) = 143.19kg$$

The mass of one *dielectric* plate, 12.2cm thickness, *with* N_ϕ cylindrical tubes, is given by

$$m_{Mg\phi} = m_{Mg} - N_\phi\left(970\tfrac{\pi}{4}\phi_{ex}^2 h_\phi\right) = 28.51kg$$

The mass of one *dielectric* plate, 2mm thickness (Bottom cover, see Fig.3), is

$$m_{Mg(2mm)} = l^2(2mm)(970) = 2.35kg\ .$$

Thus, the total mass of the system is given by

$$M_{total} = m_{Mg\phi} + m_{Mg(2mm)} = 28.51 + 2.35 = \underline{30.86kg}$$

Therefore, the *balance* (see Fig.3) can have the following characteristics:

Maximum capacity	$35kg$
Measuring accuracy	$0.1g$

If the magnetic field H_{rms} is increased to $5.57\times10^8 A/m$ $(700T)$ * ($\rho = 1\times10^{-4} kg.m^{-3}$), then Eq. (21) gives

$$P = -9.66\times10^3 N/m^2 \tag{28}$$

Therefore, the thrust F_ϕ produced by *one* micro-thruster (diameter $\phi = 1.6mm$ and height $h_\phi = 12cm$), is given by

$$F_\phi = PS_\phi = \pi r_\phi^2 P = 0.0194N \tag{29}$$

Consequently, the total thrust produced by the system (*one* plate) with $N_\phi = 313600$ micro-thrusters will be given by

$$F_{N_\phi} = N_\phi F_\phi = 6090.9N \tag{30}$$

In practice, we can overlap several similar plates in order to increasing the total thrust. In this case, if the number of plates is N_{plates} , the result is

$$F_{total} = N_{plates} F_{N_\phi} \tag{31}$$

For example, if number of overlapping plates (with $N_\phi = 313600$ micro-thrusters) is $N_{plates} = 27$, then the total thrust produced by the stack of plates (~3.4c*m* total height) will be given by

$$F_{total} \cong 164.4kN \tag{32}$$

This thrust is of the order of the thrust of a fifth-generation jet fighter F-22 Raptor, which reaches 160,000N.

* Recently, a magnetic field of 1200 T was generated by the electromagnetic flux-compression (EMFC) technique with a newly developed megagauss generator system [5].

It is important to note that the vertical direction $(-\vec{g})$ of the thrust produced by the plates can be turned of 90°, in order to produce *horizontal* displacements (See Fig.4 and Fig.5).

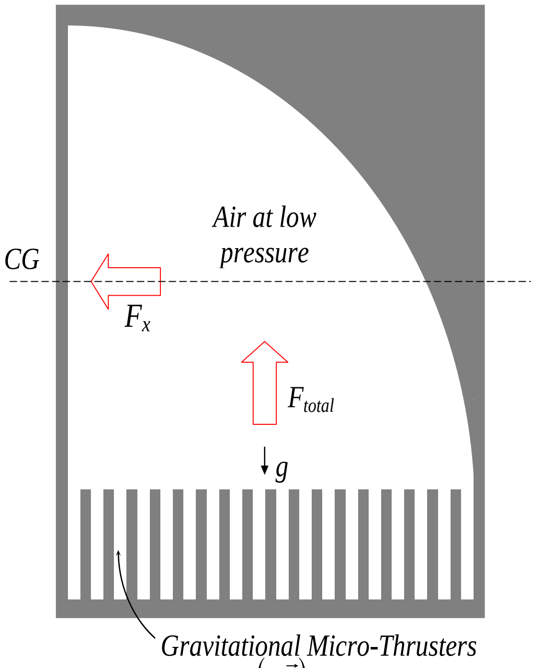


Fig. 4 - The vertical direction $(-\vec{g})$ of the thrust produced by a plate, with N_ϕ gravitational micro-thrusters, can be turned of 90°, in order to produce *horizontal* displacements.

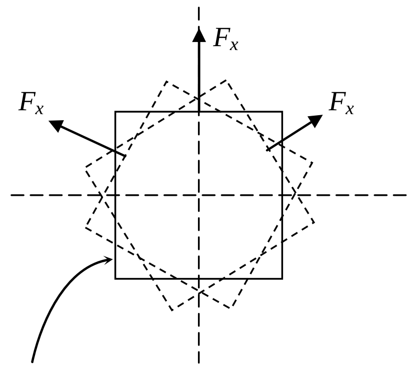


Fig. 5 – Horizontal displacement of F_x in several directions, simply rotating the plate with N_ϕ *Gravitational Micro-Thrusters*
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Thus, gravitational micro-thrusters can be used to produce vertical or horizontal thrusts (in respect to $\vec{g}$). It is easy to see that, due to the magnitude of the thrust produced by these systems and their versatility, they can be can be used to move several types of vehicles.

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