Thrust Mechanism of the Shawyer EM Drive

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- Greg Egan and Juan Yang correctly derive the same thrust force equation, based on the Divergence of the stress energy tensor and momentum density:

$$\frac{\partial}{\partial t}\int_V \left(\mathbf{g_f}\right) dV = \oint_S \mathbf{n}\cdot\mathbf{T}\, dS, \quad \mathbf{g_f} = \frac{\mathbf{S}}{c^2} = \mathbf{D}\times\mathbf{B}$$

- Yang correctly derives a representation for the Q factor, as the power flow in the LC resonator in equilibrium with the total losses of the cavity: $\left|P_e\right| + \left|P_h\right| = Q_{cavity} P_r = Q_{cavity} P_{input}$
- Yang expresses the force as the *"real part"* of the integrals:

$$\left\langle F_e \right\rangle = \frac{Q}{4}\left[\iint_{S1} \varepsilon_0 \operatorname{Re}\left(\dot{E}\cdot\dot{E}^*\right) dS - \iint_{S2} \varepsilon_0 \operatorname{Re}\left(\dot{E}\cdot\dot{E}^*\right) dS + \iint_{S3} \varepsilon_0 \operatorname{Re}\left(\dot{E}\cdot\dot{E}^*\right)\cos\theta\, dS\right]$$

$$\left\langle F_m \right\rangle = \frac{Q}{4}\left[\iint_{S1} \mu_0 \operatorname{Re}\left(\dot{H}\cdot\dot{H}^*\right) dS - \iint_{S2} \mu_0 \operatorname{Re}\left(\dot{H}\cdot\dot{H}^*\right) dS + \iint_{S3} \mu_0 \operatorname{Re}\left(\dot{H}\cdot\dot{H}^*\right)\cos\theta\, dS\right]$$

$$\left\langle F_{total} \right\rangle = \left\langle F_e \right\rangle + \left\langle F_m \right\rangle$$

- However, Yang does not specify in detail, the expressions for E and H. She writes $E(r,t) = \mathrm{Re}\left[\dot{E}(r)e^{j\omega t}\right]$, *"where Re represents the real part."*, but there is no definition of $\dot{E}(r)$, and from the context, the "dot" represents a harmonic field.
- Zeng and Fan present a better derivation of the E field. Where, α is the Attenuation and β is the Phase:

$$E(r,\theta,\varphi) = A(\theta,\varphi)e^{jk\cdot r},$$

$$-\frac{1}{E}\frac{\partial E}{\partial r} = jk = \alpha + j\beta \quad \rightarrow \quad \frac{1}{E}\frac{\partial E}{\partial r} = -jk = -\alpha - j\beta,$$

$$\frac{1}{2}\varepsilon_o\left\langle E^2\right\rangle = \frac{1}{2}\varepsilon_o A^2 e^{-2\alpha\cdot r}$$

- Evanescent waves; waves whose amplitude is exponentially increasing or decreasing, rather than the time varying harmonic waves considered by Egan and implied by Yang, can result in a NET force that will depend on the geometry of each surface.

- How do we amplify the pressure with materials?

$$\varepsilon_0\left(E\cdot E^*\right)\rightarrow\left(D\cdot D^*\right)/\varepsilon_0,\quad D=\varepsilon_{rel}\varepsilon_0 E=\varepsilon_0 E\left(1+\chi_e\right)$$

$$\mu_0\left(H\cdot H^*\right)\rightarrow\left(B\cdot B^*\right)/\mu_0,\quad B=\mu_{rel}\mu_0 H=\mu_0 H\left(1+\chi_m\right)$$

- Dielectrics and Ferro electric materials can increase the field pressure on select surfaces by increasing the surface charge density D, and noting that B is constant when transitioning from inside to outside the material.
- De Aquino suggested using Metglass to increase B.
- NASA used a dielectric to increase D and reportedly saw no thrust without it.
- For a perfect conductor, Attenuation does not involve dissipation. So how does Attenuation happen?

- It is the relative phase between the incoming wave and the evanescent wave. From Zeng and Fan:

$$jk = \alpha + j\beta \;\rightarrow\; \alpha = j\left(k - \beta\right),$$

$$\frac{\alpha}{k} = j\left(1 - \frac{\beta}{k}\right), \;\; \alpha \rightarrow jk \text{ as } \beta \rightarrow 0$$

- When k and β are in phase there is no attenuation, there are only standing waves. The wave has the usual dispersion relationship for standing waves:

$$\frac{\omega^2}{k^2} = c^2$$

- When they are out of phase however, constructive and destructive interference will cause a pressure imbalance that momentarily exerts forces on the cavity.
- The phase shift, shifts the Power Factor toward 1, toward the *"Real part"*.

- The dispersion relationship can be expressed as:

$$\frac{\omega^2}{\alpha^2 + \beta^2} < c^2$$

- The attenuation, α reduces the wave velocity! This was Shawyer's original hypothesis, but now we know why.
- Yang's closed form force equation is correct.
- Pulse the input to generate rising evanescent waves, and limit the pulse width to generate falling e-waves to maximize thrust.
- What to plug in for the fields, D, E, B, H?
- What materials to use on each surface?
- How will those materials affect the k and Q?
- Could the EM Drive create an artificial gravitational potential?

$$\Phi_{gravity} = \left(\frac{P}{\mathrm{F}} \right)^2$$

References

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