Some Novel Features of the Classical Electromagnetic Theory and their possible impact to understand and enhance Low Energy Nuclear Reaction (LENR)

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Abstract

In this paper we will discuss how we can study some effects associated with LENR from the principles of classical electromagnetic theory. We are aware that this approach has its own risks, because many mainstream physicists consider nuclear fusion should be associated with tunneling through Coulomb barrier, which is a pure quantum effect.

Introduction

Since Pons & Fleischmann reported their experiments around 1989, many labs in the world tried to replicate their results, but many failed. Thereafter, there was a wave of rejection to their claim that table-top nuclear fusion at room temperature is possible. Some establishment physicists even called "cold fusion" idea as *pathological science*. But many non-mainstream physicists and chemists continued their works in underground manner. And some eminent physicists have taken risks to join this underground movement, including Prof. Hagelstein from MIT.

But the rejection of mainstream physics towards cold fusion/LENR remain strong. Even the famous Prof. Brian Josephson from Cavendish Lab in Cambridge University was denied access from arXiv server because of his endorsement to E. Storm's works. He went on to write a paper suggesting that such a denial of many successful experiments related to cold fusion/LENR can be called "*pathological disbelief*."

In this context, allow me to recall a story that was told to me several times by Dr. Iwan Kurniawan, a nuclear engineer from Indonesia.[1] When he was a doctoral student in a University in Japan around 1990s, his professor invited him to do experiment related to cold fusion in physics lab. After setting all the apparatus properly, they went home. In the morning, they were surprised that all the apparatus was blown up and it damaged the window glasses in lab. Dr. Iwan told me that since then he concluded that cold fusion does not work as claimed by Pons & Fleischmann.

He is one of my good friend for a long time, and we often discussed many things. But regarding his cold fusion experiment in lab, I got a different opinion: the fact that the apparatus blew the entire lab indicates that there was huge energy in the device, so huge that it damaged the window glasses. The problems appear to come from at least two aspects: a. poorly understood mechanism of the reaction, and b. the reactor failed to work properly. So, it is basically similar to reactor meltdown in a usual fission reactor. We need to learn what makes their cold fusion reactor failed. It is not because there is no energy inside the system, but it is really because there is so huge energy. Reactor shutdown has recently been admitted as one of the real problems in many LENR reactors, and this is a challenge for experimenters and companies who want to design commercial LENR reactors.[8-10]

However, in this paper we will not repeat such debates which have been discussed many times elsewhere. Instead we will discuss how we can study some effects associated with LENR from the principles of classical electromagnetic theory. We are aware that this approach has its own risks, because many physicists consider that nuclear fusion should be associated with tunneling through Coulomb barrier, and this kind of tunneling is a pure quantum effect. Is that true?

We will discuss that there are some aspects of Classical electromagnetic theories which may have impact on our understanding on LENR phenomena, including: a. nonlinear electrostatic potential as proposed by Eugen Andreev, b. vortex sound theory of Tsutomu Kambe, and c. nonlinear ponderomotive force. The latter aspect has been proposed recently by Lundin & Lidgren in order to understand the mechanism of LENR.

It is our hope that this paper will motivate young electrical engineers to study LENR phenomena from new perspectives starting from classical electromagnetics theories. In short, classical electromagnetic theories still offer many surprises to those who are willing to dig deeper into the hidden mysteries of Nature.

a. **Nonlinear electrostatic potential of Eugen Andreev**

[1] Special thanks to Dr. Iwan Kurniawan for telling his first-hand experiment with cold fusion. Wishing you will be recovered soon, brother!

In modern physics, there is a firm conviction based on the vast empirical material that:

- The electromagnetic and nuclear interactions are of a different nature;
- The field of electric charge (proton, electron) is spherically symmetric;
- The nucleon-nucleon forces depend on the direction.

In his paper, Andreev [1] suggested a hypothesis that the notion of the nuclear interaction could be interpreted as a nonlinear distribution of the electrostatic potential, which manifests itself at the Fermi scale. An analytical form of the potential of the proton is proposed, which coincides with conventional forms used in the nuclear physics at a short scale, but becomes the usual Coulomb potential at a large scale.

The model potential possesses a set of properties that could be called "*nuclear van der Waals forces.*"

Coulomb's law can be written in integral form as follows:[1]

$$\varphi(x,y,z) = \frac{k\varphi}{R} = -k\iiint_v \frac{div(\nabla\varphi(x,y,z))dV}{\sqrt{(x^2+y^2+z^2)}} \tag{1}$$

If we replace R with R_{dd}, which is defined as follows:

$$R_{dd} = \sqrt{x^2+y^2+\beta^2 z^2 + r_o^{\ 2}} \tag{2}$$

Then we will have a two parameter field potential: [1]

$$\phi(x,y,x,\beta,r_0) = \frac{\phi}{R+r_0}, \tag{3}$$

Or

$$\phi(x,y,z,\beta,r_0) = [\varphi].\left(\frac{k_1}{R_{dd}} + \frac{k_2}{|R_{dd}|^2}\right) \tag{4}$$

As a result, we have obtained an explicit analytic form of the *electronuclea*r potential of a proton:[1]

$$\phi_{(proton)} = \frac{r_0}{\sqrt{(x^2+y^2+2z^2+r_o^2)}} + \frac{dz.r_0^2}{(x^2+y^2+2z^2+r_o^2)} \tag{5}$$

Thus, the general form of the potential well, due to the specific distribution of the charge density inside the proton, reminds us to the *van der Waals interaction*.

The above result is quite significant, because it explained Coulomb barrier suppression starting from classical electromagnetics theory. Furthermore, Andreev has shown that PP potential as described above can be compared with:[1]

- Lennard-Jones potential (resulting from the van der Waals interaction):

$$V_{LJ} = \frac{0.01}{r^{12}} - \frac{1}{r^5} \tag{6}$$

- Reed potential:

$$V_{\mathrm{Reed}} = -10\frac{e^{-r}}{r} - 1650\frac{e^{-4r}}{r} + 6484\frac{e^{-7r}}{r} \tag{7}$$

b. **Vortex sound theory of Tsutomu Kambe** [2][3][4]

The above electronuclear potential starts with electrostatics/Maxwell equations. Now it is very interesting to remark here that Prof. T. Kambe from University of Tokyo has made connection between equation of vortex sound and fluid Maxwell equations.

He wrote that it would be no exaggeration to say that any vortex motion excites acoustic waves.

He considers the equation of vortex sound of the form: [2]

$$\frac{1}{c}\partial_t^2 p - \nabla^2 p = \rho_0 \nabla.L = \rho_0 div(\omega \times v) \tag{8}$$

He also wrote that dipolar emission by the vortex-body interaction is:[3]

$$p(x,t) = -\frac{P_0}{4\pi c}\pi_i(t - \frac{x}{c})\frac{x_c}{x^2} \tag{9}$$

Then he obtained an expression of fluid Maxwell equations as follows:

$$\begin{aligned} &\nabla \cdot H = 0 \\ &\nabla \cdot E = q \\ &\nabla \times E + \partial_t H = 0 \\ &a_0^2 \nabla \times H - \partial_t E = J \end{aligned} \tag{10}$$

Where :

a_0 denotes the sound speed, and

$$\begin{aligned} &q = -\partial_t(\nabla \cdot u) - \nabla \hbar, \\ &J = \partial_t^2 v + \nabla \partial_t h + a_o^2 \nabla \times (\nabla \times v) \end{aligned} \tag{11}$$

To our opinion, this new expression of fluid Maxwell equations suggests that there is deep connection between vortex sound and electromagnetic fields. Therefore, it may offer new ways to alter the form of electronuclear potential as described in the previous section.

c. Nonlinear ponderomotive force

According to Brechet et al. [6], a ponderomotive force results from the response of inhomogeneous matter fields to the presence of electromagnetic fields. Ponderomotive forces are generally overlooked since the electromagnetic community is not much concerned with continuum mechanics and the continuum mechanics community is not dealing usually with electromagnetic systems.

The nonrelativistic ponderomotive force as proposed by Miller (1958) is as follows: [7]

$$F = m\bar{\ddot{r}} = -\frac{q^2}{4m\omega^2}\nabla\left|\vec{E}(r,t)\right|^2 \tag{12}$$

Equation (12) can obviously be derived from the ponderomotive potential:

$$\phi_{(p)}(r,t) = \frac{q^2}{4m\omega^2}\left|\vec{E}(r,t)\right|^2 \tag{13}$$

Other than Miller's force, there are other types of ponderomotive forces ee: [5]

- Abraham force (1903),
- Barlow (1958),
- Lundin & Hultqvist (1989),
- Bolotovsky & Serov (2003).

It can be noted here that the Miller force is independent of wave frequency for $\omega^2 << \Omega^2$ and **attractive** for the entire frequency range below resonance. The Miller force is **repulsive** at frequencies above resonance, but decays strongly at higher frequencies.

Ponderomotive forcing by electromagnetic waves is capable of causing attraction of solid bodies.

Brechet et al. [6] discuss electromagnetic force density of magnetoelectric ponderomotive force, which is different from Miller's force.

In a recent paper, Lundin & Lidgren proposed that Miller ponderomotive force may offer an explanation to nuclear spallation as observed in some LENR experiments. Although their study is not yet conclusive, it opens an entirely new way to discuss LENR from purely classical electromagnetic theory.

Summing up & Concluding Remarks

We have discussed a new expression of electronuclear potential starting from electrostatics law. This explains Coulomb barrier suppression from purely classical origin, without the use of nuclear potential such as Woods-Saxon potential. The model potential possesses a set of properties that could be called "*nuclear van der Waals forces*." In our opinion, this is a quite surprising result which offers a novel way to explain low energy nuclear reaction (LENR) from Classical Electromagnetic theories.

Moreover, Kambe's new expression of fluid Maxwell equations suggests that there is deep connection between vortex sound and electromagnetic fields. Therefore, this result may offer a new insight on how to alter the electronuclear potential using vortex sound equation. This requires further investigations.

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