"Non Local Motional EM Induction"

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Following our investigation on motional electromagnetic induction [1,2,3,4], we search for electromotive force (emf) generation in *"confined **B**-field"* homopolar engines. Four independent experiments are here presented. The above experiments suggest the *non local* nature of motional induction.

Keywords: *"Confined **B**-field"*. Torque location. Rotating field lines.

Electromotive Force due to Spinning Magnets

As advanced in this journal [1] and widely spread subsequently [2,3,4,5,6,7,8,9,10], a spinning magnet induces a Lorentz-type electric field responsible for a motional Hall effect [11,12] in the bulk of nearby conductors (Figure 1).

The figure corresponds to a clockwise north pole magnet rotation beneath two conducting wires: a *probe* and a *closing (circuit) wire* at rest in the lab. In both the above pieces electrons move centripetally. Each wire becomes an electromotive force (emf.) source. If the ends

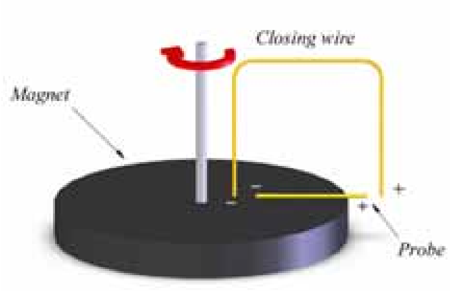

Figure 1 – Basic homopolar setup

of the wires are connected, the whole circuit behaves as two identical emf. sources connected in opposition and current cannot flow. If, enabling electrical continuity between the wires, the probe is anchored to the magnet, then direct current (DC) flows through the whole circuit [1,2]. When the probe is at rest relative to the magnet, induction only takes place on the closing wire, which is in motion relative to the magnet. The probe plays a passive role: to provide a current path [1,2,3].

The above experimental discovery, in full agreement with Weber's electrodynamics [11,12], puts an end to frequent misconceptions concerning motional electromagnetic induction [13,14,15,16,17] and gives some credit to "rotating field lines" advocates [18].

Torque Acting on Magnets free to Spin

The engine sketched in figure 1 exhibits a reversible behaviour: Injecting DC through the electrically connected but mechanically decoupled wires, a motor configuration takes place [1,3,4].

Laplace force, $d\boldsymbol{f} = id\boldsymbol{r}\times\boldsymbol{B}$ is that responsible for two equal and opposite torques produced by the magnet on the probe ($\tau_{M,P}$) and on

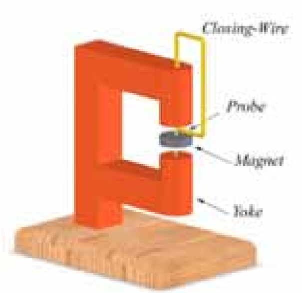

Figure 2 - Confined B-field Engine

the closing wire ($\tau_{M,CW}$). The probe rotates in a clockwise sense when it carries a centrifugal DC near the north pole of the magnet.

Conversely, the closing wire rotates in a counter-clockwise sense. By attaching the probe to the magnet, both co-rotate in the clockwise sense. Now the magnet itself is acted on by the closing wire via the reaction torque $\tau_{CW,M} = -\tau_{M,CW} = \tau_{M,P}$. All happens as if the magnet were dragged by the probe, when it is in fact the magnet which drags the probe.

Obviously, if the probe is soldered to the closing wire giving rise to a closed loop, torque cancellation precludes both magnet and loop rotation.

Concluding, two active plus to reactive torques govern the rotational dynamics in "open-field" homopolar motors. Total angular momentum remains null: $\mathbf{L} = \mathbf{L_M} + \mathbf{L_P} + \mathbf{L_{CW}} = 0$, which means that $(I\omega)_P = -(I\omega)_{CW}$ and $\omega_M = 0$ when both the probe and the closing wire are free to rotate, and $(I\omega)_{M+P} = -(I\omega)_{CW}$ when the probe is attached to the magnet. Here ω means angular rotational velocity, as measured in the lab, and I means moment of inertia.

"Confined B-field" Homopolar Motor

A slight variation of our former experiments [1,3,4] was developed in order to study the behaviour of homopolar motors when the magnetic field remains confined in an iron core.

Figure 2 sketches an iron core, the "yoke" from here on, available to confine the ***B**-field* generated by a uniform cylindrical permanent magnet able to rotate about its symmetry axis.

Traversing the yoke, collinearly aligned with the magnet shaft, is the left branch of a carrying DC wire loop. This wire is inefficient for developing rotational torque. Both the upper horizontal branch and the right vertical one are located in a region free (neglecting leakage) of ***B**-field* actions. The lower horizontal branch, the *probe* from here on, lies in the intense ***B**-field* region (air gap). The loop itself can be considered as consisting of a probe connected to a closing wire.

Whilst coil dynamical behaviour is trivially predicted according to customary electrodynamics, the same cannot be said when referring to the magnet. From theoretical considerations we cannot expect continuous magnet rotation, since it would imply angular momentum creation. In fact, and due to spatial constraints imposed by the yoke, the coil is unable to describe a full rotation and, after a limited angular excursion, it will collide with the yoke remaining at rest. A continuous magnet rotation would imply the generation of an unbalanced angular momentum, without any identifiable source. Conversely, in a generator configuration, a magnet's rotation would be unable to develop emf on the active branch of the coil. Moreover, if we admit the coincidence between kinematical and dynamical rotations [19], we would expect a force interaction between the coil and the magnet plus the core as a whole magnetised bulk. An exhaustive set of carefully performed experiments confirmed the above rationale [20,21,22].

Photo 1 - Actual Confined Field homopolar generator

"Confined B-field" Homopolar Generator

Since the homopolar dynamotor is a reversible engine [1,2,3,4] the conclusions drawn for the motor configuration can be applied, *mutatis mutandis*, to a generator configuration. In order to check the above physical reversivility, a free to rotate 100 turns coil was employed in four independent experiments (photos 1 and 2).

The magnetic strength, in the air gap in which the active (5 cm length) probe is enabled to spin, amounts some 800 gauss (0.08T). The coil can be manually launched up to at least $\omega = 0.5\ rps$.

Rotating Coil, with Magnet and Yoke Stationary

Spatially constrained rotation of the coil must deliver a $N\omega BR^2/2$ emf which changes sign when rotation is reversed. These qualitative experiments were manually performed, with outputs higher than *30 mV*. No signal amplification was required.

Within a *local action* rationale, the above finding is trivially explained taken into account the motion of the active wires *with respect to the magnet*. If, remembering confined motor's behaviour, an *action at a distance* model is advocated, then what matter here is

Photo 2 - Dismantled engine

the motion of the active wire *with respect to the whole magnetised bulk* (magnet plus yoke).

Spinning Magnet, with the Coil and the Yoke Stationary

When the magnet was spun up to *10 rps*, no signal was detected. This experiment clearly plays against the local action model. It isn't the magnet/wire relative motion which governs motional induction. Incidentally, we must to quote that *additive* homopolar engines (*emf [N loops] = N emf [1 loop]*) would be possible if the rotating magnet were able to polarise the active wires when confined in the yoke.

Coil attached to the Magnet, both spinning with the Yoke Stationary

Although redundant, this experiment is valuble, since remaining magnet and coil at relative rest, this pair is unable to develop emf. When the pair manually was spun in an identical way as in the first experiment, the same signal as above was detected. This experiment shows, beyond any doubt, that the *observed voltage is due to the interaction between the active wires and the whole magnetised bulk.*

Probe attached to the Magnet in the Singularity

We coined the term *singularity* [1,2,3] when referring to a modified Faraday-disk setup in which a small circular sector of the uniform magnet was removed. This modification introduces a *short-range singularity* in which ***B**-field* reverses without denaturalizing the global ***B**-pattern* beyond the radial probe. Was this singularity which allowed the disclosure of the physics underlying motional induction [1].

The active branch of the coil was anchored inside the singularity (photo 3).

Photo 3 - Locating the active wires in the singularity

Then, the couple coil/magnet was spun up to some 0.5 rps (*i.e.* in the same way as in experiments 1 and 3). Again, a net output amounting up to 30 mV was detected. We need to emphasize that the measured signals have the *same polarity* as in experiments 1 and 3. This simple fact definitively disproves old absolutistic conceptions as such advocated by Panofsky [15], Feynman [16] and many others [13,14,17]. Otherwise, emf would change polarity due to the field reversion on the active wires.

The fourth experiment tells us that, despite field reversion on the active branch, induction is governed by the motion of the active wires with respect to the whole magnetised yoke. A full correspondence between motor and generator motional behaviour has been proven. The observed facts are easyly understood within a *relational* rationale. The active wires are simultaneously acted on by two magnetic fields;

1. The external one, generated by the magnet and confined by the yoke.
2. The reverse field, generated in the singularity.

Since the coil is at relative rest with the magnet, the above pair is unable to develop emf. Motional induction takes place due to the motion of the active wires with respect to the yoke and, all happens as if the singularity were absent.

Conclusions

Homopolar phenomena have been a troublesome issue for the theory of electrodynamics for almost two centuries [23,24]. The whole set of experiments performed on both *"open"* and *"confined"* motor configurations exhibits a common feature when dealing with motor configuration [20,21,22]: *angular momentum conservation.*

Reactive forces, which have their seat on the magnet in *"open"* configurations, "shift" to the whole magnetised bulk when *"confined"* arrangements are employed.

The above findings are fully consistent with the Amperian surface-currents responsible for magnetic effects [25]. The source of magnetic field (the magnet itself) *induces* Amperian surface currents on the *whole yoke*. In a generator configuration, the charges located in the wire, at relative motion with the yoke, "see" *all the microscopic Amperian closed currents* located in the magnetised matter.

A few words on the (in archaic language) "rotating"/ "fixed" field-lines controversy can be said in the light of our experiments:

For *"open"* configurations all happens as if ***B**-lines* rotate anchored to the magnet, whereas the above lines appear to be attached to the whole magnetised bulk, when dealing with *"confined"* arrangements.

Our experiments confirm Müller's measurements concerning homopolar motional induction, as applied to emf generation [26,27,28]. Unfortunately, Müller (as well as Wesley [28]) failed when attempting to rationalize the observed facts. The above due to a misconception about the relevant parts involved in the whole interaction. Müller centered his analysis in the magnet/wire pair, rather than in the (magnet + yoke)/wire one which is, in fact, the physically relevant pair.

Concerning the motivations that triggered the present investigation, we only wish to stress the growing interest in the search for the location of forces and torques in actual electrodynamical systems [29,30,31,32,33].

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