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Biefeld–Brown Effect: Misinterpretation of Corona Wind Phenomena

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With its theoretical origins dating back to the early 1920s, the Biefeld–Brown effect was believed to be responsible for the generation of thrust in capacitor configurations exposed to high voltage. This thrust was claimed to be unrelated to corona wind phenomena and to exist in vacuum. These claims, although only published in patents, survived until recent publications for very advanced propulsion concepts. Brown's and similar work, as well as credible theoretical and experimental studies relating to the Biefeld–Brown effect, are reviewed. Moreover, an experiment was carried out to investigate any thrust not related to corona discharges. No thrust was detected within the accuracy of the experimental setup. This puts new boundaries on any anomalous Biefeld–Brown force. Measurements indicate that such anomalous force must be at least five orders of magnitude below corona wind phenomena and must have at least a two orders of magnitude higher power-to-thrust ratio compared to traditional electric propulsion thrusters. Hence, even if the effect exists, it would not be attractive for space propulsion. The obtained results suggest that corona wind effects were misinterpreted as a connection between gravity and electromagnetism.

Introduction

BECAUSE the propellant onboard a spacecraft contributes to a large extent to the overall mass, propellentless propulsion with thrust levels at least comparable to existing electric propulsion thrusters could dramatically reduce current costs for space exploration. Conventional concepts developed in the pursuit of this goal use either electromagnetic tethers (utilizing the Earth's magnetic field) or photons (solar sails or laser propulsion). NASA launched the Breakthrough Propulsion Physics Project[1] in 1996 to investigate more speculative and exotic concepts, for instance, possible connections between gravitation and electromagnetism, that could be utilized for propulsion. Often appearing in the popular literature and Internet homepages is the Biefeld–Brown effect,[2] which is widely believed to show just such a connection and promises a breakthrough in propulsion. Although the description of this effect is based solely on patent claims, and even those claims have been shown to be from a different origin than studies on to gravity, recent papers and patents (even by NASA) revive the Biefeld–Brown topic and repeat the original claims.[3–6]

This paper will review the literature, including claims and both theoretical and experimental studies related to the Biefeld–Brown effect. Moreover, an experiment has been carried out in hopes of definitively settling the matter. The results, as well as all previous credible studies, suggest that the Biefeld–Brown effect, within the accuracy of the used instrumentation, is not a connection between gravitation and electromagnetism, but a misinterpretation of corona wind phenomena. The phenomena are indeed used for new propulsion concepts, such as drag reduction systems for supersonic aircraft and future launchers.

Biefeld–Brown Effect

On reviewing unconventional propulsion approaches,[7] one finds the Biefeld–Brown effect, discovered by Paul Biefeld and Thomas Townsend Brown in the early 1920s. They claim that if a capacitor were to be charged up to high dc potentials, it would generate a thrust from the negative toward the positive terminal. The effect is enhanced by the use of an asymmetrical electrode configuration (Fig. 1), causing an additional thrust in the direction from the low-flux to the high-flux region (in this case from the plate/disk to the wire) with respect to the ambient dielectric medium (usually air). In such configurations, ac currents might also be used to generate the effect. Brown claimed[8] that this effect remained even if the ambient medium were a vacuum (up to 10^{-6} torr). Hence, the thrust must be independent of electric wind effects, usually created by corona discharges, that are proportional to the air pressure.[9] Brown thought that this effect may show a possible connection between gravitation and electromagnetism. Unfortunately, nearly all of his work is summarized only in patents and a popular magazine article,[8,10–14] rather than in scientific publications. Hence, these studies lack detailed information about the behavior of this effect with respect to voltage, current, or ambient pressure. No data are given at all about thrust amplitudes. Brown studied the effect by putting the electrode configuration on pendulums. Based on his empirical findings, the effect depends on the following:

1) The effect depends on the separation of the plates of the capacitor, the closer the plates, the greater the effect.

2) The effect depends on the dielectric strength of the material between the electrodes, the higher the strength, the greater the effect.

3) The effect depends on the area of the conductors, the greater the area, the greater effect.

4) The effect depends on the voltage difference between the plates, the greater the voltage, the greater effect.

5) The effect depends on the mass of the dielectric material, the greater the mass, the greater the effect.

The last claim, in particular, led Brown to think of a possible connection of gravitation with electromagnetism. At the time of his last patents, several other people filed patents with practically identical electrode configurations and propulsion claims.[15,16] In one of these, at least data are given about thrust levels and the electric power used. De Seversky reports[16] that an electrode configuration with an area of 0.1 m^2, an electrode separation distance of 5 cm, using 20 kV at 0.5 mA, produced a force of 50 mN. Contrary to Brown, de Seversky also stated that the thrust efficiency varied with humidity and air pressure. This is exactly what one would expect from a corona wind phenomenon.

Christensen and Møller[17] built a similar electrode setup and published measurements of the obtained thrust in ambient air. They also compared their results with theoretical predictions of electric wind effects. The agreement was very good and tended to explain the Biefeld–Brown effect as a purely electric wind phenomenon.

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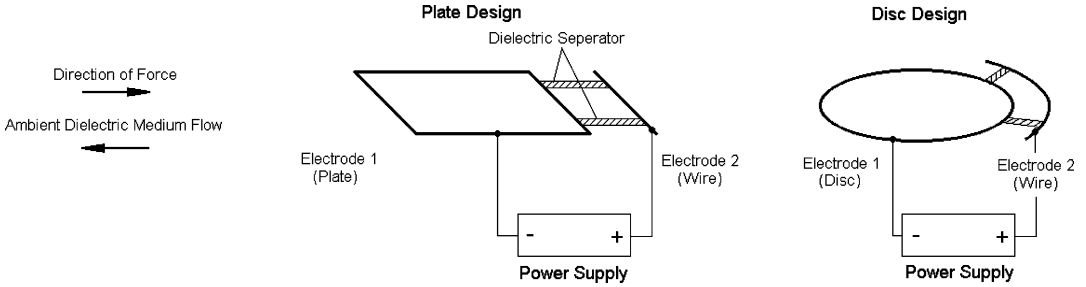

Fig. 1 Brown's asymmetrical plate/disk–wire electrode configuration.

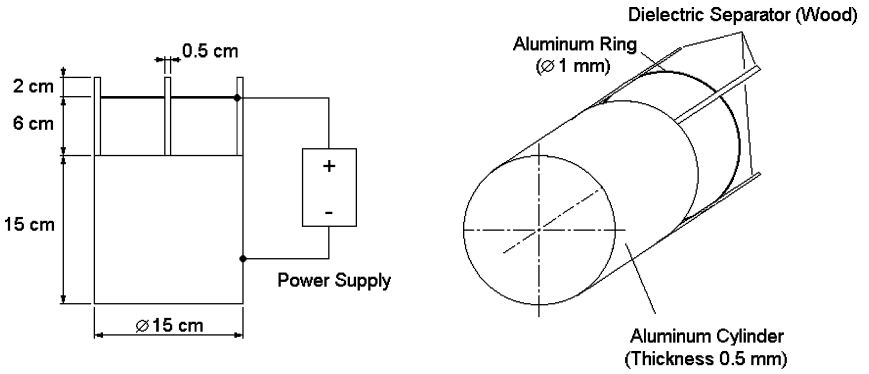

Fig. 2 Electrode configuration.

Similar theoretical studies have been performed by Cheng.[18] However, Brown claimed that the effect remained in vacuum and, therefore, is not due to ionization of the ambient air. This was left unconfirmed.

Two decades later, Talley[19,20] studied Brown's electrode configurations in vacuum chambers up to 10^{-6} torr in great detail. He found no thrust in the case of a static dc potential applied to the electrodes. However, he noticed an anomalous force during electrical breakdowns when a current was flowing.

This force, a result of currents in divergent electric fields (due to the asymmetrical electrode configuration) finds further support in five-dimensional theories coupling the gravitational and electromagnetic field. Williams[21] integrated a mass dependent fifth dimension into the relativistic Maxwell theory and predicted a coupling between both fields (see Ref. 7). In this theory, a divergent current flow results in an induced mass flow if the coupling constant is nonzero.[22]

If we consider an asymmetrical electrode configuration similar to that in Fig. 1, and if we apply a sufficiently high electric potential to initiate a corona discharge, a divergent current flows between both the wire and the plate/disk electrode. According to Williams's five-dimensional coupling theory,[21] such a configuration would then cause an additional mass flow, which would also accelerate the ions in the discharge in proportion to the divergence of the current. This results in a force that would accelerate the whole configuration with respect to its surroundings, a possible explanation for the claimed Biefeld–Brown effect.

If a corona discharge is ignited inside a sealed Faraday cage box, the known side effects of a discharge like the corona wind would only contribute to oscillations of the box. However, a successful five-dimensional coupling would result in a movement of the whole box with respect to its surroundings. This measurement can clarify whether or not a Biefeld–Brown type of effect exists under electric breakdown conditions, such as those indicated by Talley's report,[20] without using expensive vacuum facilities.

Experiment

The design of the electrode configuration used is shown in Fig. 2, and the box configuration is shown in Fig. 3. Contrary to the Biefeld–

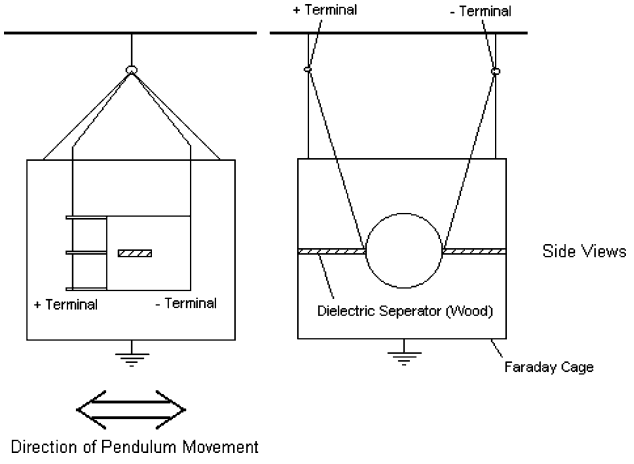

Fig. 3 Box configuration.

Brown plate/disk and wire-shaped design, a cylinder and a ring-shaped electrode, similar to that used by Christensen and Møller,[17] have been used to limit possible ion propulsion effects (electrons leaving the end of the wire electrode) and to concentrate only on the corona discharge. Both cylinder and ring electrodes are made out of aluminum and are separated by four dielectric rods. The separation distance of 6 cm in air corresponds to the maximum applied potential of 40 kV to prevent sparks that would disturb the corona discharge.

The box is made out of wood and has the dimensions $50 \times 50 \times 50$ cm^3, with a wall thickness of 5 mm. The walls are covered with an aluminum foil that is grounded and, hence, acts as a Faraday cage. The electrode configuration is fixed to a bar made out of wood that is located in the middle of the box. The cables to connect the electrodes to the terminals outside are high-voltage insulated. Both the cables, as well as the box (through strings), are connected to two rings that are fixed through steel rods to a plate. This steel rods are finally connected to the terminals of a high-voltage power supply (Heinzinger HNCs 40,000-3ump). Therefore, the whole box, including the cables, can swing around the fixed rings.

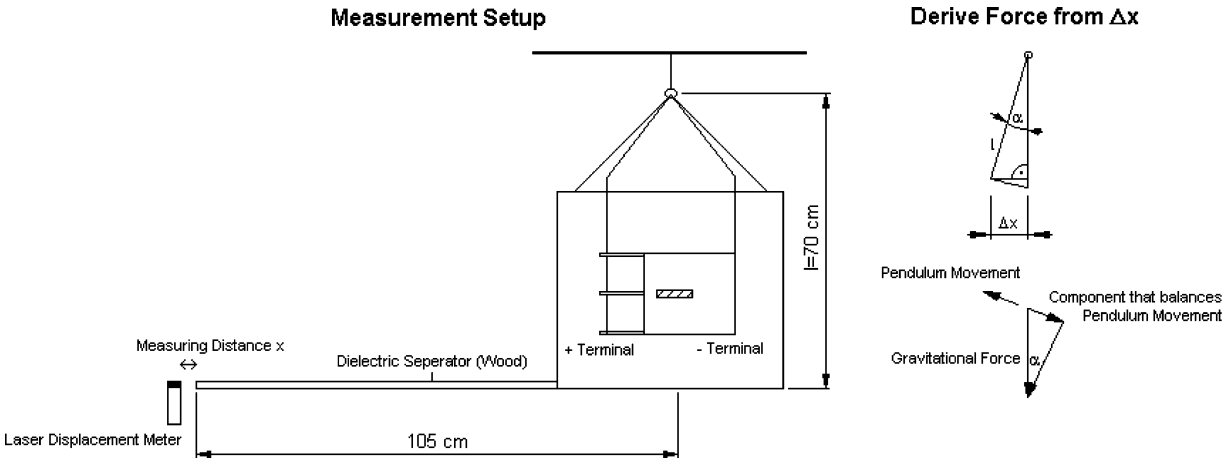

Fig. 4 Geometry of force measurement.

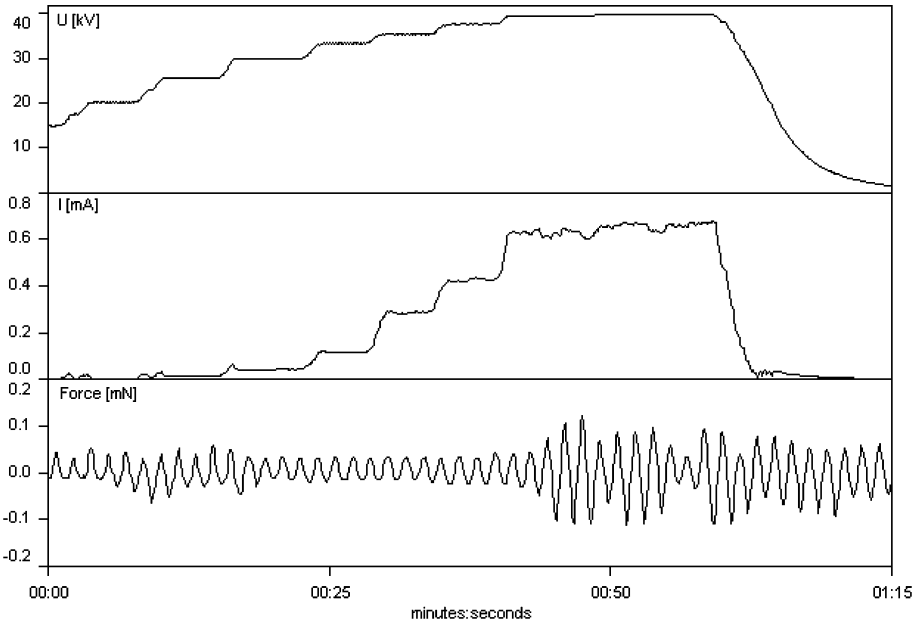

Fig. 5 Measurement of potential (top), current (middle), and force (bottom).

This movement is measured with a laser displacement meter (Keyence LC-2400 W), as shown in Fig. 4. The laser was operated 105 cm away from the middle of the box to prevent possible electrostatic influence. The positioning data can be used to calculate whether the corona discharge inside the box produces a mass flow that causes the whole box to move with respect to its surroundings. The force of the box can be derived from

$$F = m \cdot g \cdot \sin\alpha = m \cdot g \cdot (\Delta x/d) \qquad (1)$$

where m is the mass of the box, including the experiment and cables, g the acceleration in the Earth's gravitational field, and l the length from the rings to the bottom of the box, from where Δx, the difference from the box's position from its zero position, is measured. The parameters during the measurement were $m = 7.499$ kg, $l = 70$ cm, and $g = 9.81$ m/s^2. With a sensitivity of the laser unit indicating positions of ± 0.1 μm, the achieved accuracy of the force measurement was 10.5 μN. This is within the range of low-thrust electric propulsion devices and is, therefore, the type of representation necessary to investigate if an observed Biefeld–Brown effect could be utilized for space propulsion purposes. The potential on the high-voltage power supply was manually increased from zero to approximately 38 kV, and the positioning data, as well as the potential and current information, were transferred to a computer via an Institute of Electrical and Electronics Engineers interface. The results are shown in Fig. 5.

Discussion

The biggest difficulty during the experiment was the maintenance of the initial oscillations from the box at as small a force as possible. At the beginning of the measurement in Fig. 5, the oscillations were limited to approximately 50 μN, which corresponds to 0.95 μm. When the potential was increased from 0 to 20 kV, the corona discharge ignited, and a small current of approximately 0.01 mA started to flow. However, the oscillations remained constant.

During the next increase of the potential to its maximum at 38 kV, the discharge current was increased accordingly, resulting in a maximum current of 0.6 mA. At this maximum, the box oscillations were increasing from 50 to 100 μN. The corona discharge created a corona wind that resulted in an airflow[9] circulating inside the box. This seems to explain the increase of the oscillations. After the potential was reduced back to zero, the discharge current dropped very quickly, and the oscillations were slowly reduced due to the conservation of energy. The most important result is that the box always oscillated around the same mean position during the corona discharge, with a maximum amplitude of 100 μN. This means that no noticeable linear thrust was observed within the accuracy of the

instrumentation used. If a linear thrust exists in the presented configuration, the data suggest that it must be below 10 μN. Given the maximum power used (38 kV $\times$ 0.6 mA = 22.8 W), we can express the specific power-to-thrust ratio as

$$P/F \geq 2280 \text{ W/mN} \tag{2}$$

When this value is compared to other highly efficient electric propulsion devices[23] such as Hall, ion, or FEEP thrusters with power-to-thrust ratios ranging from 20–70 W/mN, we note that this ratio is at least two orders of magnitude above currently existing technologies. Therefore, even given that such a linear thrust exists in the presented configuration and when the advantages of a propellantless propulsion system are taken into account, existing electric propulsion devices would be far superior. Calculating the maximum thrust due to corona winds, we use the measured expression by Christensen and Møller[17]:

$$F = P \cdot (l/U) \cdot [1/b \cdot (1 + \phi)] \tag{3}$$

where F is the thrust, l the electrode separation distance, U the applied potential difference, b the ion mobility ($b_{\text{air}} = 2.15 \times 10^{-4}$ m^{2}V^{-1}s^{-1}), and ϕ the fluid performance parameter ($\phi_{\text{air}} = 2 \times 10^{-2}$). This equation also explains quite well the behavior of the effect described by Brown.

By the reuse of the maximum input power during the measurement, the calculated maximum thrust due to corona winds in dry air is 163 mN. This value is similar to that recorded by de Seversky[16] in a Brown-type electrode configuration.[16] When this value is compared to our obtained upper limit for an additional effect of 10 μN, a possible gravitation-electromagnetism interaction must be at least five orders of magnitude below the electric wind effects. Vacuum tests by Talley[19,20] did not confirm the effect. Therefore, any thrust in vacuum chambers claimed by Brown was most likely a corona wind triggered by insufficient outgassing of the electrode assembly in the vacuum chamber. Hence, the Biefeld–Brown effect in the claimed order of magnitude (movement of similar electrode configurations in vacuum and air) cannot be confirmed. The results suggest that corona wind effects were misinterpreted as a connection between gravitation and electromagnetism.

However, corona winds are indeed used for advanced propulsion concepts such as drag reduction. There is a wealth of literature[24–27] reporting wind-tunnel tests with active components, such as corona discharges, which may be utilized for supersonic aeroplanes or future launchers. Hence, the Biefeld–Brown topic did not slip through mainstream research but is a well-understood phenomena that might indeed be utilized for propulsion purposes, but not along its original claims.

Conclusions

Theory and experiments regarding the Biefeld–Brown effect were reviewed and discussed. An experiment was carried out to investigate any linear thrust excluding corona wind effects. No linear thrust was observed within the accuracy of the instrumentation used. A possible connection between gravitation and electromagnetism that leads to a force due to the divergent currents used must be at least five orders of magnitude below the corona wind forces. A propulsion device based on this five-dimensional concept would be at least two orders of magnitude less efficient than existing electric propulsion thrusters.

The results suggest that corona wind effects were misinterpreted as a possible connection between gravitation and electromagnetism. The author hopes that the paper will help to put an end to a story that has lasted some 80 years and still survives within recent literature.

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