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Electromagnetic Thrust Force Of Closed System With Unclosed Foucault Currents

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Abstract:
The weight of a closed system consisting of a source of an alternating magnetic field and an asymmetric conductor depends on the orientation of the conductor in the magnetic field. The electromagnetic force is the result of the interaction of unclosed Foucault currents with the magnetic field of an electromagnet, inside which there is a semi-cylindrical conductor. The law of conservation of momentum is ensured by displacement currents between the flat faces of the conductor.
***Keyword**: Electromagnetic Thruster, Self-force, Alternative Magnetic Field, Electromagnetic Force, Displacement Current, Foucault Currents*

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I. Introduction

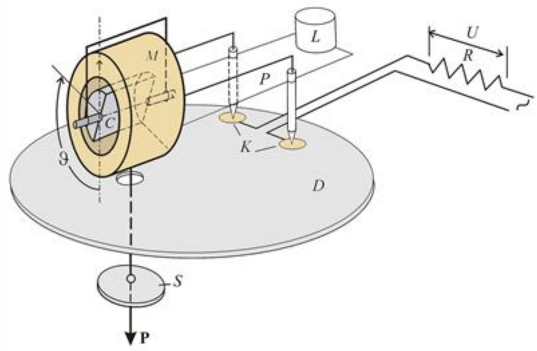
Foucault currents, also known as eddy currents, are induced electrical currents that flow in a conductor when it is exposed to a changing magnetic field. The magnitude of the current in a given contour is proportional to the strength of the magnetic field, the area of the contour, and the rate of change of flux, and inversely proportional to the resistivity of the material [1]. The induction current created by a variable source of a magnetic field may not be closed. Otherwise, alternating current could not flow through the capacitor connected to the winding of the alternator. The continuity of the total current in the circuit is ensured by the displacement currents flowing between the capacitor electrodes. On the other hand, the openness of the conduction current leads to the appearance of a self-action force with which an unclosed conductor acts on itself [2]. This force is proportional to the product of the current in an unclosed conductor and the difference in vector potentials created by the same conductor at the ends of the conductor. Even with a current of tens of amperes, this force is very small. Self-action also occurs in a system that is a source of a magnetic field and an unclosed conductor [3]. In this case, the force of self-action is proportional to the product of the current strength in the conductor and the difference in vector potentials created by a source of alternating or constant magnetic field. If a magnetic field is created by an electromagnet with a large number of turns, then such a self-action force can be not only noticeable, but also very large, allowing the creation of a large traction force [4]. Theoretical results [5] describing this phenomenon are not sufficient. Experimental confirmation is necessary, without which the possibility of creating such an alternative non-reactive method of movement in space seems doubtful.

II. Direct Measurements

It is premature to measure the weight of the entire closed system, which includes not only a thruster, but also a current source with an alternating magnetic field generator. One can hardly hope that the traction force will be greater than the weight of the current source and generator. You must first verify the reality of the phenomenon in laboratory conditions by examining all the side effects that affect weight change. By the way, this is approximately what was done when testing the so-called EM-drive [6], the traction force of which is very low. An alternating electric current with a frequency of 50 Hz enters the electromagnetic propulsion unit bypassing electromechanical contacts *K* installed on the current non-magnetic disk *D* between the propulsion unit and the scales *S* (Fig 1). The electromagnetic thruster *C*+*M* is installed on a platform balanced with the help of a load *L*. This allows you to measure small changes in weight with an accuracy of no worse than 10^{-5} N.

The thruster is an electromagnet with a height of 16 mm, an outer diameter of 60 mm, an inner diameter of 40 mm, an inductance of 0.15 H, inside which there is an aluminum semi-cylindrical electrode with a diameter of 20 mm, a height of 16 mm, playing the role of an open conductor. Such simple design makes it possible to measure weight *P* at different angles □□of inclination of the conductor relative to the vertical. The large difference between the inner diameter of the conductor and the diameter of the electrode *C* decreases the effect of heating the conductor. On the other hand, one may consider that the magnetic field in the conductor is uniform.

Fig 1. Electromagnetic thruster *M+C* on balanced platform *P*.



It is better to carry out measurements in periodic mode, say every 5 minutes including current for 2 minutes (Fig. 2). On the one hand, this makes it possible to estimate the measurement error, and on the other hand, to take into account the drift caused, among other things, by the heating of the electromagnet and the conductor. The weight changes shown in Fig. 2 are quite contradictory. Electrodynamic processes must occur quickly enough, which means the weight of the thruster should not change slowly within one minute. Most likely, such a slow change in weight is due to the interaction of the thruster with the environment, including electrodynamic interaction with electrical charges on the conductors through which the electric current enters the electromagnet. Such side effects, of course, do not depend on where and how the conductor *C* is located inside the magnet, and therefore can be taken into account after measuring the average values of the weight change ΔP at different angles of inclination ϑ.

Fig. 2. Change in the weight of the thruster with periodic switching on of the electric current.

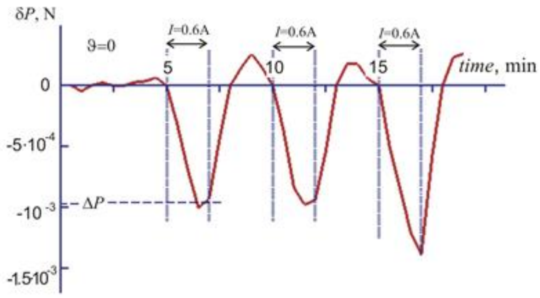


Fig. 3 demonstrates the dependence of the average change in weight ΔP on the angle of inclination of the conductor ϑ. The orientation of the conductor actually changes the weight of the mover with a maximum change equal to *A*. On the other hand, it should be noted that the dependence of ΔP on ϑ must be symmetrical with respect to $\vartheta = \pi$, and the equilibrium state must correspond to the value ΔP=0. This didn't happen. Moreover, large measurement errors are also cause for concern.

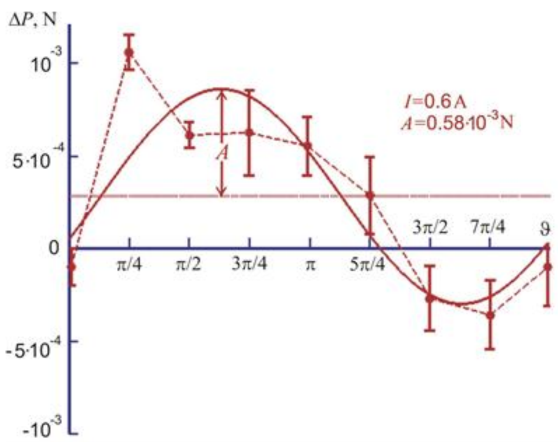


Fig. 3. Dependence of weight change on the angle of inclination of the conductor.
Solid curve - approximation by a harmonic function with amplitude *A*.

The interaction of closed and unclosed Foucault currents in conductor *C* with conductors through which electric current flows from contacts *K* to the magnet is the only thing that can influence the dependence of δP on ϑ. Heating of the magnet, the external electrical circuit, and the atmosphere do not depend on the orientation of the conductor located inside the magnet. This makes it possible to almost completely eliminate the interaction of Foucault currents with parts of the moving system located on platform *D*.

The axial asymmetry of the magnetic field inside the electromagnet can affect the dependence of the weight of the mover on the angle of inclination of the conductor. This can only be judged after changing the orientation of the magnet relative to the vertical. We should not forget about the interaction of Foucault currents with measuring equipment. At small distances between the conductor and the balance *S*, this influence can be significant. To take it into account, measurements should be taken at different distances between the conductor and the scale pan *S*. Despite the result shown in Fig. 3, there is no confidence yet that the change in weight is not caused by side effects.

III. Weight Of The Conductor In Alternative Magnetic Field

Of course, you can try to measure changes in the weight of the thruster and, of course, at different angles of inclination ϑ and currents in the circuit. However, each manipulation of parts of the experimental setup shown in Fig. 1, increases the methodological error. Another option: measure the change in weight of only the conductor *C* located inside the stationary magnet (Fig. 4), and compare the results obtained with what is shown in Fig. 3.

If the result shown in Fig. 3 is the result of self-action, with which a conductor with unclosed Foucault currents acts on itself, and not the interaction of closed Foucault currents with the anisotropic magnetic field of the electromagnet and with the metal parts of the equipment, then the dependence of the change in weight on the angle of inclination ϑ, should be similar to that shown in Fig. 3. In order to exclude interaction with the electromagnet and the scale pan *S*, measurements should be carried out at different orientations of the electromagnet (↑ or ↓) and different diameters, commensurate with the diameter of the conductor *C*.

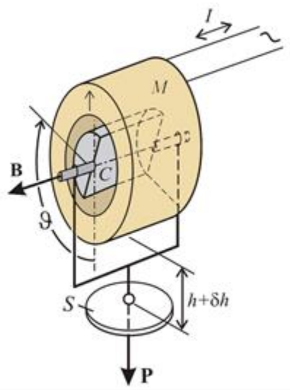


Fig. 4. Measuring the weight of the conductor *C* in the alternating magnetic field of the stationary electromagnet.

Such measurements seem to be more accurate. The weight of the conductor changes very quickly when the electric current is turned on and off (Fig. 4).

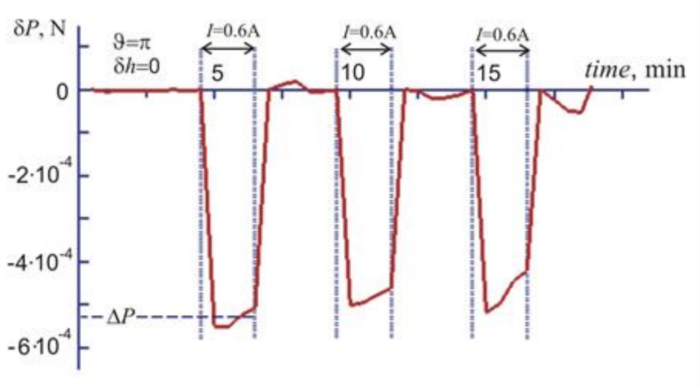


Fig. 5. Change in the weight of the conductor with periodic switching on of the electric current.

It turns out that the average change in weight pp depends only on the orientation of the conductor in space and weakly depends on where and how the source of the alternating magnetic field is located relative to it (Fig. 6). This does not contradict other results [6], since the rotation of the conductor leaves it in the region where the magnetic field is almost uniform. Moreover, the maximum change in weight in these measurements $0.47\cdot10^{-3}$ N at a current of I=0.6 A is close to the amplitude value A=$0.58\cdot10^{-3}$ N in direct measurements (Fig. 3). All experimental results presented in Fig. 6 are approximated quite accurately by the dependencies $A\cos(\vartheta-\pi)$ (solid, dashed and dotted lines in Fig. 6).

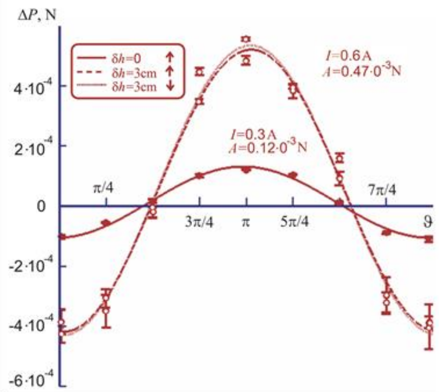


Fig. 6. Dependence of weight change on the angle of inclination of the conductor inside the stationary electromagnet.

In addition to the unclosed, comparatively weak Foucault currents, closed Foucault currents arise in a conductor placed in an alternating magnetic field. If the alternating magnetic field is uniform, then the force acting on the closed current is zero, since the closed turn with the current is pushed into the region of maximum field non-uniformity. In fact, the magnetic field inside the electromagnet is non-uniform (Fig. 7). The region of non-uniformity at r = 0 is small compared to the dimensions of the conductor inside the electromagnet, and therefore cannot exert a noticeable effect on the change in weight created by the closed Foucault currents. Weak non-uniformity at distances commensurate with the radius of the conductor C cannot be noticeable for closed Foucault currents. If this non-uniformity were decisive for the effect on the closed currents, then after changing the orientation of the magnet from position ↑ to position ↓, the change in weight shown in Fig. 6 would change sign. Instead of the maximum change in weight at $\vartheta = \pi$, the value of vp would become negative.

As a result, it is impossible to explain the appearance of this force by the interaction of closed Foucault currents with an almost uniform magnetic field inside the electromagnet. Any magnetic field, including a uniform one, is created by closed currents, and the rule of equality and collinearity of action and reaction (Newton's third law) for the interaction between closed currents is satisfied and what is shown in Fig. 7 is the main justification for the fact that the electromagnetic force acting on the mover is a self-action force and is the result of the interaction of an alternating magnetic field with open Foucault currents flowing in an asymmetric conductor.

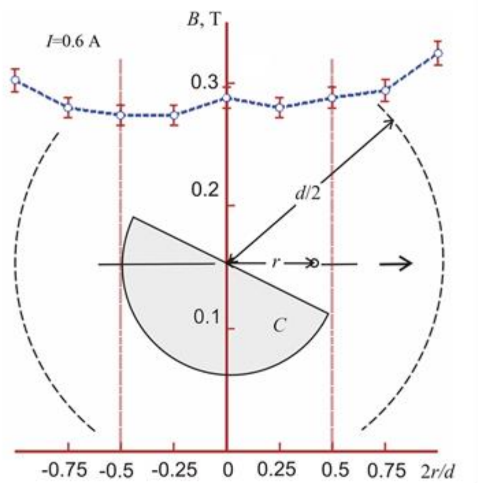


Fig. 7. Magnetic field inside the electromagnet.

IV. Conclusion

The thrust force of an electromagnetic propulsion device with unclosed Foucault currents has been detected and measured. Taking into account the dependence of the thrust force on the current strength and frequency of the alternating magnetic field, this force is many times greater than the force created by the EM-drive [6] and the Casemir force [8]. Doubling the current leads to a fourfold increase in the electromagnetic traction force. Increasing the frequency of the alternating current flowing in the electromagnet to 500 Hz will lead to a hundredfold increase in this force, since the Foucault current density is proportional to the frequency of the alternating magnetic field, and the self-force is proportional to the product of the current density and the difference in vector potentials created by the field source on the flat surfaces of the conductor. This is about the efficiency of such a method for creating an aerospace traction force.

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