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Unclosed Conductor in Alternative Magnetic Field

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Abstract: *Alternative magnetic field creates induced currents in an unclosed conductor located in the magnetic field. Magnetic interaction between current elements of the conductor occurs with violating Newton third law accordingly which the so-called Abraham's force created by displacement current between ends of conductor acts on the unclosed conductor. It this case, there must be some hidden momentum and reactive force that cancel the electromagnetic momentum and the Abraham's force. The magnetic field of induction current in the conductor does not act on the source of the external magnetic field and does not create a force that would compensate for Abraham's force. With some orientation of the conductor, it becomes lighter. This allows to study in detail the behavior of an unclosed conductor in an external magnetic field. The average value of the usual forces acting on a closed or unclosed conductor in an external alterative magnetic field is zero.*

Key Word*: Abraham's force, Hidden momentum, Unclosed conductor, External magnetic field, Alternative current.*

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I. Introduction

A force acts on a conductor in a magnetic field. Diamagnetic materials create an induced magnetic field in a direction opposite to an externally applied magnetic field, and are repelled by the applied magnetic field. In contrast, the opposite behavior is exhibited by paramagnetic materials. And this is true even if the magnetic field is variable. At each moment of time, this force is nonzero and changes its magnitude and direction synchronously with the magnetic field. However, if the induction of the magnetic field changes according to a harmonic law, then the average value of the force is zero.

In some cases, electric currents in an unclosed conductor can act on themselves, producing a force proportional to the square of the current generated by the alternating magnetic field [1]. The value of such a force averaged over the period of alternating magnetic field change is naturally not equal to zero. This makes it possible to experimentally detect and study the so-called Abraham's force through which the displacement current between the ends of an unclosed conductor acts on the conductor [2], producing reactive force.

Until now, this force has not been detected experimentally. Only the torque is measured [3,4]. Such an experiment confirms the conclusions of classical electrodynamics and corresponds to the law of conservation of angular momentum, accordingly which a mechanical moment of force acts on the electromagnetic field [5]. Rotational motion is significantly different from translational one; reactive torque is not yet reactive force [6]. Therefore, the measuring Abraham's force is not only interesting but also relevant. This work is devoted to solving this particular problem. Whether it succeeded or not is described below.

II. Experimental

The unclosed conductor C is a half of copper ring with a height h=8 mm with a inner radius of r=3 mm with an outer radius R=6 mm placed between the poles of Π-shaped core M with alternative current (Fig. 1). The conductor connected to a balance B by means of support S made of nonmagnetic materials.

The magnetic field produced by such a magnet is, of course, not uniform. It is practically impossible to create an absolutely uniform magnetic field in real conditions. On the other hand, the effect is expected to be very small. The way out, therefore, is to measure the force acting on the conductor at different positions. The conductor can be rotated around the horizontal axis. It gives possibility to take into account horizontal and vertical non-uniformities of the magnetic field created by the electromagnet.

Even so, there are two processes that spoil accurate measurements. They are the heating and vibration by passage of an alternating electric current through the winding W of the electromagnet. In this work, vibration action is understood as the influence of the source of an alternating magnetic field on the support S. Heating is slow process that affects the weight only after a long time, while vibration can change the weight of the conductor immediately after the magnetic field is turned out. Therefore the time dependence of weight P must be investigated in order to obtain accurate and one-valued results. Weight measurements should be performed at different magnetic inductions. A quantitative characteristic of such a parameter can be effective magnitude of the magnetic induction *B* in the middle of the conductor's rotation axis. The effect should be proportional to the square of this induction value.

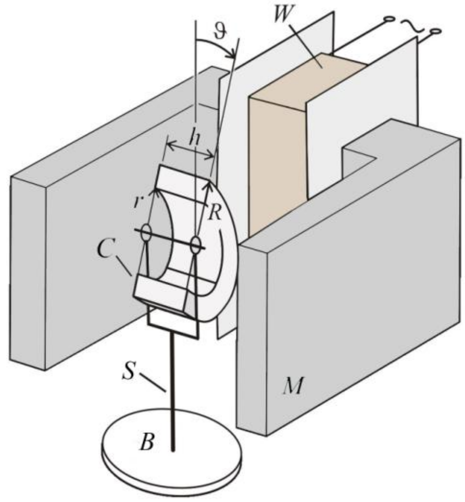

Fig. 1. Unclosed conductor in external magnetic field.

The influence of the angle of rotation on the weight of the conductor is shown in Fig. 2. The balance measures vertical force. When the angle of rotation is equal to zero, the position of the conductor is symmetrical with respect to the horizontal. Therefore, in this case, the change in weight when the magnetic field is turned on should be zero, but ΔP at $\vartheta = 0$ is not equal to zero. Moreover, when the field is turned on, the weight of the conductor is reduced for any value of the angle of rotation. Apparently this is due to the vibration that occurs when an alternating electric current passes through the winding of the electromagnet. This contribution must be measured and removed.

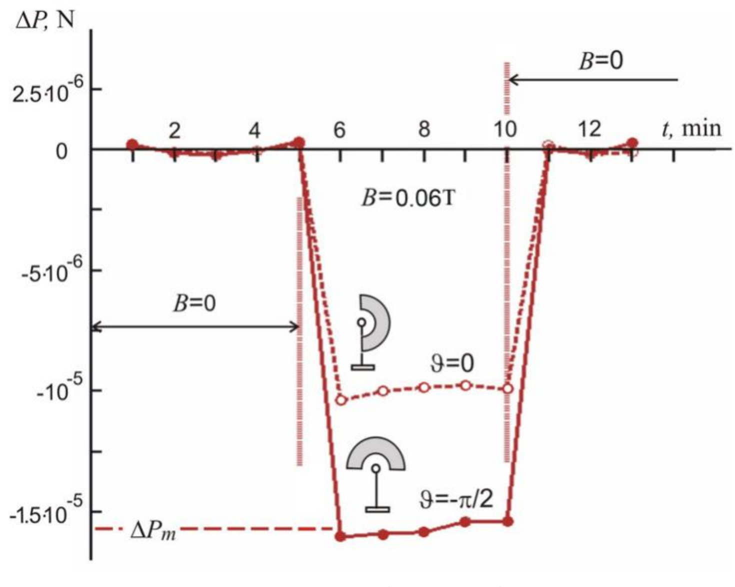

Fig. 2. Time dependence of weight of the conductor.

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At the magnetic field inductance *B*=0.06 T, the change in the weight of the support ΔP_{vm} without the conductor (Fig. 3) is different from the change in the weight ΔP_m at $\vartheta=-\pi/2$ of the conductor (Fig. 2). When the magnetic field inductance is halved, the vibration component is reduced by more than 5 times. This difference is enough to feel Abraham's force. That is why the dependence of the change in weight on the angle of rotation must be measured and studied in detail.

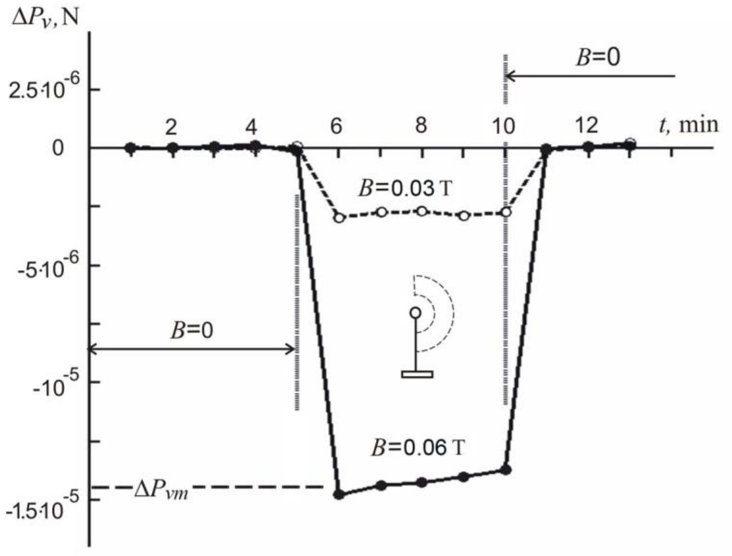

Fig. 3. Background component.

III. Abraham's force

For a given form of unclosed conductor, the change in weight is equal to Abraham's force. Now it is clear how to get rid of the background, the role of which is the change in weight due to vibration. In other words, Abraham's force F should represent the difference $F=\Delta P_{vm}-\Delta P_m$, where ΔP_{vm} and ΔP_m are the values of the change in weight when the magnetic field is turned on. All experimental results obtained for two values of induction B are shown in Fig. 4 and Fig. 5.

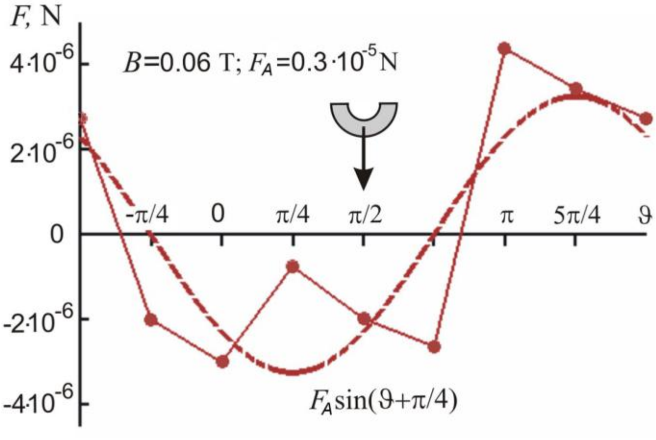

Fig. 4. Abraham's force at *B*=0.06 T.

Experimental data shown in these figures can be approximately described by dependencies: $F=F_A\sin(\vartheta+\pi/4)$. The fact that the maximum of absolute value of this force is not observed $\vartheta=\pi/2$ or $\vartheta=-\pi/2$ is quite explainable by the horizontal non-uniformity of the external magnetic field. The external magnetic field does not distort the Abraham's force, but at small angles ϑ it increases the induction currents. This is confirmed by the experimental results obtained for a weaker external magnetic field (Fig. 5). Attention should be paid to the ratio of the amplitudes F_A. They differ by about four times when the magnetic induction is changed by a factor of two. This, if you will, is an additional confirmation of the secondary nature of the phenomenon.

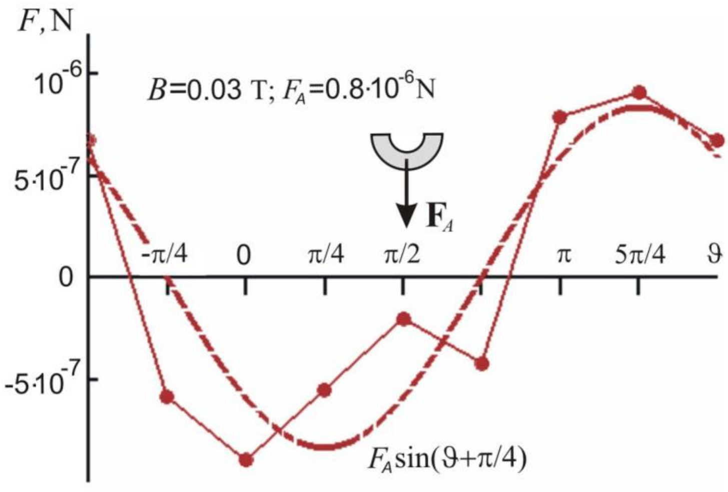

Fig.5. Force acting on the conductor at *B*=0.03 T.

IV. Conclusion

In fact, it was an attempt to register Abraham's force. In the usual way, an alternating magnetic field should not act on an unbalanced conductor, but it does. This is the main result of the work. The force acting on the conductor turned out to be much greater than theoretically predicted. The strength of the current flowing in an unclosed conductor is still unknown. This does not make it possible to unambiguously identify it with the force of Abraham. Even if it is some other force, the study of the action of an alternative magnetic field on conductors does not cease to be important and useful. As a rule, such conductors do not act on a source of an alternating magnetic field..

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