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A FEW REMARKS REGARDING V. E SHAPIRO'S OBJECTIONS ABOUT MAGNETIC RESONANCE FORCES

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Ponderomotive action of the electromagnetic field and the choice of the energy-momentum tensor $\hat{T}$ in macroscopic electrodynamics are still the topic of heated debate and experimental research [1-10].

The reason for both existing and ongoing discussions is the lack of an opportunity to unambiguously determine the density of the ponderomotive force and the relationship associated with it

$$f_i = \partial T_{ik}/\partial x_k \quad (1)$$

energy-momentum tensor.

Therefore, the authors of [6] used the definition of ponderomotive forces from the expression of energy to interpret the observed ponderomotive effects in the region of nonlinear ferromagnetic resonance on loose samples. Often, for assessments, such a definition is simpler (see. [5] §18), than a direct definition by formulas (1) [2, 5, 10].

In the opinion of V. E. Shapiro, all this [6] is erroneous [8]. "... The main thing is that "magnetic resonance forces" do not exist ..." and the superfluous term doesn't exist in the authors of [6] (proportional $\sim H_k \partial M_k/\partial x_i$, where $\vec{H}$ magnetic field strength, $\vec{M}$ magnetization vector).

Let us now give a complete expression for the density of ponderomotive forces acting from the electromagnetic field on bodies in which magnetization occurs. This expression for ponderomotive forces is associated only with Maxwell's equations and takes place under any Ohm's laws, laws of magnetization (see. [2] p. 343). The three-dimensional pondemotor force per unit volume, taking into account the magnetization, differs from the Lorentz force and, according to formula (1), if the Minkowski tensor is taken as the energy-momentum tensor of the electromagnetic field, has the following form

$$f_i^M = f_i^\Lambda + \frac{1}{2}\left(M_k \frac{\partial H_k}{\partial X_i} - H_k \frac{\partial M_k}{\partial X_i}\right) \quad (2)$$

and

$$f_i^\Lambda = f_i^M - \frac{1}{2}\left(rot[\vec{M} \times \vec{H}]\right)_i + \frac{1}{c}\frac{\partial}{\partial t}[\vec{E} \times \vec{M}]_i \quad (3)$$

if the Abraham tensor is taken as the energy-momentum tensor (here $\vec{f}^\Lambda$ - Lorentz force, $\vec{E}$ - electric field strength).

It is not difficult to see that the term $\sim H_k \partial M_k/\partial X_i$ both Minkowski and Abraham have. Thus, by denying the existence of the term $\sim H_k \partial M_k/\partial X_i$ V. E. Shapiro [8] managed to criticize not only the work [6], but also the work of Abraham and Minkowski, and it is quite simple to solve all the controversial issues [1-5].

As for V. E. Shapiro's separation of mechanical motion from magnetic ("... additional work associated with changing $\vec{M}(\vec{z})$...is not mechanical"), then it is not so. It is difficult to separate mechanics from magnetism for the ponderomotive action of the electromagnetic field. Otherwise, the total energy-momentum tensor of the closed field-medium system could easily be split into two parts and there would be no discussion about ponderomotive forces, which has been going on for more than half a century.

Further, the explanation of the results of the experiment [6] - intricate movements of a loose sample along the bottom of the test tube, separation of two samples from each other at resonance V. E. Shapiro bases on the expression for the force

$$f_i = M_k \partial H_k/\partial X_i \quad (4)$$

obtained by I. E. Tamm [5] from the Lorentz force, under the assumption of constancy $\vec{M}$ and weak heterogeneity $\vec{H}$. But it is well known that the forces of dipole-dipole interaction between two samples (for the case [6, 9]) are attractive forces and cannot lead to the repulsion of the samples, which was found at resonance [6, 9] and is not explained by the author of the work [8].

Thus, V. E. Shapiro's objections are not substantiated as theoretically [2, 5, 10], and experimentally [6, 7, 9].

In conclusion, it should be noted that under conditions of magnetic resonance, it becomes possible to experimentally measure the difference between the Abraham and Minkowski forces (3-2)

$$\Delta \vec{f} = -\frac{1}{2} \, rot[\vec{M} \times \vec{H}] + \frac{1}{c} \frac{\partial}{\partial t}[\vec{E} \times \vec{M}] \quad (5)$$

due to precession $\vec{M}$ in phase with $\vec{H}, \vec{E}$ at resonance.

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