Further Evidence for Magnetic Charge from Aerosol Experiments

V.F. Mikhailov

480082 Almaty, 82, Sadovaya 8, Rep. Kazakhstan

ABSTRACT. Under intense lighting some gas-suspended ferromagnetic particles move in magnetic field similarly to objects having a magnetic charge. This paper is devoted to an experimental investigation of the behaviour of such particles and of the nature of the force acting on the particles under such conditions.

RÉSUMÉ. Sous un éclairage intense des particules ferromagnétiques suspendues dans un gaz se déplacent dans un champ magnétique de manière similaire à des objets possédant une charge magnétique. Cet article est consacré à une étude expérimentale du comportement de telles particules et de la nature des forces agissant sur elles dans de telles conditions.

1. Introduction

We have already reported that under certain conditions some weighted in gaseous medium ferromagnetic particles move in magnetic field along a magnetic field intensity lines as object having a magnetic charge. Such particles behaviour and some theoretical aspects of this phenomenon had been described and discussed time and again [1-3, 5-8, 11-24, 26, 27]. An attempt has been made to estimate the magnitudes of these charges. The detail description of the experiments has been given in above-mentioned publications, so it is not repeated herein. However, there is the necessity for additional investigation of the effect because exists the alternative interpretation one as the magneto-photophoresis (see, for example, [25]).

The major features of the phenomenon is that under intense light beam illumination the ferromagnetic particles move in a magnetic field always along the lines of force (along coaxial trajectories with respect to the current [19]) independently of the angle between the light beam direction, Φ, and the magnetic field intensity vector, H. Reversal of the magnetic field, H, causes a reversal of particle motion (which is not the case vith magnetic dipoles). Reduction of the light causes the particles to stop moving ; an increase in field strength or light intensity causes a rise in particle velocity, while a decrease results in reduced particle velocity ; the number of particles moving in the direction of the magnetic field appears to equal the number of particles moving in the opposite direction.

Note, we had investigated aerosol behaviour of about thirty various substances ($F_e, N_i, C_o, C_u, A_l, A_u$, $W, P_t, A_g, S_e, B_i, A_s, H_2O$, graphite, glycerine, oil, etc.). The effect (for $H \leq 100$ gauss) was observed only on ferromagnetic aerosols (iron, nickel, cobalt and their ferromagnetic oxides) [15-17].

In this experiment we used iron particles and well known Millikan's method and equipment which was described by us repeatedly [14-24).

2. Experiment

The scheme of the experiment is shown in figure 1. The ferromagnetic aerosols are prepared by means of electrospark sputtering of the current interrupter iron contacts in air atmosphere. The pressure of the air is one atmosphere. In this case the iron particles have spherical form and their sizes are $10^{-5} - 10^{-6}$cm [14-17].

The homogeneous magnetic field is obtained by means of two coaxial Helmholtz' coils. As light sources were used the laser having the power $\sim$ 5mW and vawelength of laser light $\lambda = 6328\mathring{A}$.

In this case the magnetic field is parallel to the light beam, Φ (axis OX). In this experiment scanning was used too. The frequency of field switching equal a few hertz. This allows one to exclude completely error in identification because such tracks are observed only in the mode of this experiment.

Under these conditions a particle oscillates along the axis OX with the magnetic field frequency and the amplitude of this oscillations is :

$$x = v\tau = F\tau/K \quad (1)$$

Here :F is acting force, v is the particle velocity, τ is the half-period of the field oscillation and $K = 6\pi\eta r$ is Stokes' coefficient ; η is the gas viscosity and r is the radius of the particle.

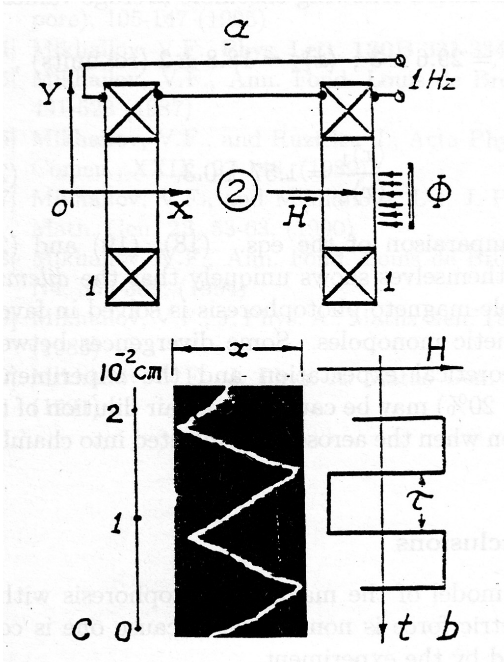

Figure 1. a) Scheme of the experiment for the observation the effect in magnetic, H, field : 1 is Helmoltz' coils, 2 is the observation region.
b) Temporal field diagram for H.
c) A photograph of a track of a magnetic charged particle.
Particles transfer in a vertical direction (along the OY axis) due to the working gas slow blowing off (for a trajectory scanning at time).

Let's examine two versions.

a. F is a radiometric force. Then [25] :

$$F = \frac{\sigma p}{2T_0}\Delta T \quad (2)$$

where ΔT is the temperature difference of a gas between the hot and the cold poles of the particle ; p and T_0 are gas pressure and temperature far from the particle respectively ; σ is some unknown coefficient having dimension of a cross-section.

The most popular interpretation of the magneto-photophoresis is that the particle has a homogeneous temperature of its surface but the accommodation coefficient, γ, differ from point to point and exists a correlation between γ and the magnetic poles of the particle. Only this hypothesis allows to explain the reversal of the particle motion when the magnetic field is reversed, at a limit of a thermal conception. In definition

$$\gamma = \frac{T - T_0}{T_w - T_0}, \quad \gamma \leq 1, \quad (3)$$

where T_w is the temperature of the particle, T is the temperature of the gas near of the particle surface.

Whence

$$T = T_0 + (T_w - T_0)\gamma \quad (4)$$

and

$$\Delta T = T_2 - T_1 = (T_w - T_0)(\gamma_2 - \gamma_1). \quad (5)$$

For energy balance

$$\Phi_0 \sigma_a = -\kappa \frac{dT}{dR} 4\pi R^2, \quad (6)$$

we have

$$T_w - T_o = \frac{\Phi_0 \sigma_a}{4\pi r \kappa} \quad (7)$$

Here, Φ_0 is the light flux density, σ_a is cross-section of the light absorption, κ is the thermal conductivity of the gas ; R is integration variable.

Thus, from eq. (7) and eq. (5) we have :

$$\Delta T = \frac{\Phi_0 \sigma_a}{4\pi r \kappa}(\gamma_2 - \gamma_1), \quad (8)$$

and

$$F = \frac{\sigma p}{T_o} \frac{\Phi_0 \sigma_a}{8\pi r \kappa}(\gamma_2 - \gamma_1) \quad (9)$$

Let

$$\gamma = \xi \gamma_o, \quad (10)$$

where γ_o is the standard accomodation coefficient for the concrete gas-solid par ; ξ is some inhomogeneity coefficient of the particle poles. Then,

$$\gamma_2 - \gamma_1 = (\xi_2 - \xi_1)\gamma_o. \quad (11)$$

The substitution (9)-(11) into (1) results in

$$x = \vartheta \zeta \frac{\gamma_o}{\kappa \eta} \quad (12)$$

Here

$$\vartheta = \sigma \sigma_a (\xi_2 - \xi_1)/(48\pi^2 r^2), \quad (12a)$$

and

$$\zeta = p \Phi_0 \tau / T_o, \quad (12b)$$

are independent from the gas property but determined by the properties of the particle and the mode of the installation operation respectively.

For two different gases (other conditions being equal) we have

$$\begin{aligned} x_1 &= \vartheta \zeta \gamma_{01}/(\kappa_1 \eta_1) \\ x_2 &= \vartheta \zeta \gamma_{02}/(\kappa_2 \eta_2) \end{aligned} \quad (13)$$

Hence

$$x_1/x_2 = \gamma_{01}\kappa_2\eta_2/(\gamma_{02}\kappa_1\eta_1) \tag{14}$$

b. F is the electromagnetic force.

Then,

$$F = GH \tag{15}$$

Here H is the magnetic field intensity, G is the magnetic charge (magnetic monopole) of the particle.

Thus, the amplitude of the oscillation of the particle is (see eq.(1)) :

$$x = GH\tau/6\pi\eta r = \nu/\eta. \tag{16}$$

For two different gases (other conditions being equal) whe obtain :

$$x_1/x_2 = \eta_2/\eta_1. \tag{17}$$

In terms of the ensemble average :

$$\langle x\rangle_1/\langle x\rangle_2 = \gamma_{01}\kappa_2\eta_2/(\gamma_{02}\kappa_1\eta_1), \tag{14a}$$

$$\langle x\rangle_1/\langle x\rangle_2 = \eta_2/\eta_1. \tag{17a}$$

The transition to the ensemble average is a correct one ; the dispersion of the run of the measurements, $\langle x\rangle_i$, is equal to the statistic dispersion when the experimental conditions are invariable ones [2, 24].

Eqs. (14a) and (17a) were examined by the experiment.

In this experiment we use following gases :

1. Hydrogen ; $\gamma_{01} = 0.09$ [10], $\kappa_1 = 13.80\ 10^{-4}$ W/cm.^{o}C, $\eta_1 = 9.5\ 10^{-5}$ g/cm.sec [9].
2. Air ; $\gamma_{02} = 0.66$ [10], $\kappa_2 = 2.4\ 10^{-4}$ W/cm.^{o}C, $\eta_2 = 18.1\ 10^{-5}$ g/cm.sec [9].

Thus, from eq. (14a) we obtain :

$$\langle x\rangle_1/\langle x\rangle_2 = 0.045, \tag{18}$$

and from eq. (17a) :

$$\langle x\rangle_1/\langle x\rangle_2 = 1.905. \tag{19}$$

It is clear, the theoretical expectation lead to the essential different results.

A description of the experimental procedure is as follows. An airtight chamber is evacuated and is then filled with a working gas (hydrogen or air) up to atmospheric pressure. Aerosols are obtained when the solution "dusts" an electromagnetic current interrupter spark contacts. The gas (air) together with aerosols is injected through a capillary to working chamber. The electrospark sputtering of an iron in a pure hydrogen results in the non-ferromagnetic aerosols production. Perhaps, it is caused by high solubility of hydrogen in iron [4]. A He-Ne laser is used to illuminate the particles with about 5 mW and the beam is focused on the field view of a microscope. The light flow density in the focus is about 5 W/cm^2.

In order to exclude the possibility of instrumental error, multiple periodic changes were made between the hydrogen and air gases and new adjustements were made to the apparatus with every experimental run. Thus, on the whole about 500 tracks were photographed and processed and on the basis of the obtained oscillation amplitudes of the particles, x, were calculated following ensemble average values :

$$\langle x\rangle_1 = 29.6 \pm 3\ ;\ \langle x\rangle_2 = 18.8 \pm 2\ \text{(rel.units)}\ ,$$

whence

$$\frac{\langle x\rangle_1}{\langle x\rangle_2} = 1.57 \pm 0.3. \tag{20}$$

The comparaison of the eqs. (18), (19) and (20) among themselves shows uniquely that the *dilemma* monopole-magneto photophoresis is solved in favour of magnetic monopoles. Some divergences between the theoretical expectation and the experimental data ($\sim 20\%$) may be caused by an air dilution of the hydrogen when the aerosols are injected into chamber [9].

3. Conclusions

i. The model of the magneto-photophoresis with a radiometric force is non-correct because one is contradicted by the experiment.

ii. The results reported here are further evidence of the magnetic monopole existence in ferromagnetic aerosol particles.

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