The Influence of a Magnetic Field on the Behaviour of the Quantum Mechanical Model of Matter

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Abstract— The paper presents an experimental measurement of a material inserted in various types of magnetic field. The related model accepts the time component of an electromagnetic field from the perspective of the properties of matter. The relatively moving systems were derived and tested [1], and the influence of the motion on a superposed electromagnetic field was proved to exist already at relative motion speeds. In micro- and nanoscopic objects such as the basic elements of matter, the effect of an external magnetic field on the growth and behaviour of the matter system needs to be evaluated. We tested the model based on electromagnetic field description via Maxwell's equations, and we also extended the monitored quantities to include various flux densities. Experiments were conducted with growth properties of simple biological samples in pre-set external magnetic fields.

1. INTRODUCTION

Similarly as in the first experiment [2], we tested the numerical model and carried out an experimental measurement of material heating speed; also, we designed a method for accurate verification of heating speed changes depending on the external magnetic field.

This paper proposes a very detailed analysis focused on the influence of a magnetic field upon inanimate objects. Experimental measurement of the temperature change of a copper sensor in a stationary homogeneous and gradient magnetic field was performed. Up to 10 times, the sample was cooled down to the nitrogen boiling point (-195:80±C to 77.35 K); the sample was then removed at the pre-selected time and placed in an area where it was heated to the temperature of -20±C. Using the measuring centre and 4 temperature sensors (2 sensors measuring the temperature of the sample and 2 others for the measurement of the ambient temperature), we recorded the temperature change in the sample and the required heating time. This experiment was repeated with four magnetic fields.

2. MODEL: THE ELECTROMAGNETIC FIELD AND PARTICLES

For a model with distributed parameters of the electromagnetic field, it is possible to use partial differential equations based on the theory of the electromagnetic field to formulate a coupled model with concentrated parameters (in our case, particles) [2]. The details of the model are analyzed in this paper. The forces acting on a moving electric charge in the electromagnetic field can be expressed by means of the formula

$$f_{\mathrm{e}} = \rho\left(\mathbf{E} + \mathbf{v} \times \mathbf{B}\right) \ \text{in } \Omega, \tag{1}$$

where $\mathbf{B}$ is the magnetic flux density vector in the space of a moving electrically charged particle with the volume density ρ, $\mathbf{v}$ is the mean velocity of the particle, $\mathbf{v} = \mathrm{d}\mathbf{s}/\mathrm{d}t$, $\mathbf{s}$ is the position vector from the beginning of the coordinate system o, t is the time, $\mathbf{E}$ is the electric intensity vector, and Ω is the definition region of the independent variables and functions. The properties of the area Ω are described by the mutual relationship between the intensities and inductions as defined by

$$\mathrm{rot}\mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} + \mathrm{rot}\left(\mathbf{v} \times B\right), \quad \mathrm{rot}\mathbf{H} = \mathbf{J}_{+}\frac{\partial \mathbf{D}}{\partial t} + \mathrm{rot}\left(\mathbf{v} \times \mathbf{D}\right) \tag{2}$$

$$\mathrm{div}\,\mathbf{B} = 0, \quad \mathrm{div}\,\mathbf{D} = \rho, \Omega \tag{3}$$

where $\mathbf{H}$ is the magnetic field intensity vector, $\mathbf{J}$ the current density vector, $\mathbf{D}$ the electric flux density vector. The material relations for the macroscopic part of the model are represented by the expressions

$$\mathbf{B} = \mu_0\mu_r\mathbf{H}, \quad \mathbf{D} = \varepsilon_0\varepsilon_r E, \tag{4}$$

where the indexes of the quantities of the permeabilities and permittivities r denote the quantity of the relative value and the 0 value of the quantity for vacuum. The relation between the macroscopic and the microscopic (dynamics of particles in the electromagnetic field) parts of the model is described by the relations of force action on the individual electrically charged particles in the electromagnetic field, and the effect is respected of the movement of electrically charged particles on the surrounding electromagnetic field according to [2]:

$$\mathrm{rot}\mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} + \mathrm{rot}\left(\mathbf{v}\times\mathbf{B}\right) - \frac{1}{\gamma}\mathrm{rot}\left(\rho\mathbf{v} + \mathrm{j}c\rho\mathbf{u}_t + \mathbf{J} + \frac{\gamma}{q_e}\left(\frac{m_e \mathrm{d}\mathbf{v}}{\mathrm{d}t} + l\mathbf{v} + k\int_t \mathbf{v}\mathrm{d}t\right)\right),$$

$$\mathrm{rot}\mathbf{H} = \gamma\mathbf{E} + \rho\mathbf{v} + \gamma\left(\mathbf{v}\times\mathbf{B}\right) + \frac{\gamma}{q_e}\left(\frac{m_e \mathrm{d}\mathbf{v}}{\mathrm{d}t} + l\mathbf{v} + k\int_t \mathbf{v}\mathrm{d}t\right) + \mathrm{j}c\rho\mathbf{u}_t + \frac{\partial \mathbf{D}}{\partial t} + \mathrm{rot}\left(\mathbf{v}\times\mathbf{D}\right). \quad (5)$$

The coupling of both models is formulated using Equation (5) and the formula

$$q_e\left(\mathbf{E} + \mathbf{v}\times\mathbf{B}\right) + \frac{q_e}{\gamma}\left(\rho\mathbf{v} + jc\rho\mathbf{u}_t - \frac{\partial\left(\varepsilon\mathbf{E}\right)}{\partial t}\right) = \frac{m_e \mathrm{d}\mathbf{v}}{\mathrm{d}t} + l\mathbf{v} + k\int_t \mathbf{v}\mathrm{d}t.$$

The effect of the behaviour of the macroscopic model describing the matter with the quantum mechanical model of elements of the system can be observed using the fluxes of quantities. The known quantities are magnetic flux ϕ, current flux I, and electric flux having the magnitude q:

$$\phi = \iint_\Gamma \mathbf{B}\cdot d\mathbf{S}, \quad I = \iint_\Gamma \mathbf{J}\cdot d\mathbf{S}, \quad q = \iint_\Gamma \mathbf{D}\cdot d\mathbf{S}, \quad (6)$$

where $\mathbf{S}$ is the vector of the oriented boundary (in a 3D model of the plane), and Γ is the boundary of the area Ω, in which the flux is evaluated. If there is a moving element of the system in the model with a scale difference expressed in orders, it is easier to describe the state and effect of the superposed electromagnetic field by expressing the time flux density $\boldsymbol{\tau}$. The time flux can be different or inhomogeneous in parts of the area Ω. It is then possible to write

$$t = \iint_\Gamma \boldsymbol{\tau}\cdot d\mathbf{S}.$$

After expanding the expression with the time flux density for the Cartesian coordinate system o, x, y, z, we have

$$\boldsymbol{\tau} = \frac{1}{v_x(t)\,dx}\mathbf{u}_x + \frac{1}{v_y(t)\,dy}\mathbf{u}_y + \frac{1}{v_z(t)\,dz}\mathbf{u}_z, \quad (7)$$

where $\mathbf{u}_x$, $\mathbf{u}_y$, $\mathbf{u}_z$ are the base vectors of the coordinate system. Time density depends on the instantaneous velocity of the particle motion $\mathbf{v}$ in the quantum mechanical model and on the element of length $d\ell$. Then, for the motion of the electrically charged particle along the element of the closed curve $d\ell$ (according to the microscopic interpretation), it is possible to write

$$\frac{\mathbf{E}}{q_\mathrm{e}}d\ell = \left(\boldsymbol{\tau}^{-1}\times\mathbf{B}\right) \text{ in } \Omega. \quad (8)$$

If an electrically charged particle moves in the magnetic field having a magnetic flux density $\mathbf{B}$, and if the dimensions of the area Ω are multiply larger than the electrically charged particle or groups of particles, it is necessary to consider the question of how the motion of the particle is influenced and what are the observable oscillation changes, namely the time flux density changes in parts of the area Ω. In the quantum-mechanical model of matter, the particles move in a nuclear structure, and their motion dynamics are changed by an external magnetic field. Thus, a simple material heating test can be carried out to demonstrate the influence of an external magnetic field on the elementary model of matter. We tested three basic variants of the state of the macroscopically interpreted distribution of the external magnetic field having a magnetic flux density $\mathbf{B}$ [2] . Using the results obtained from the first experiments [2], we designed an exact technique for measuring the temperature change in the examined copper sample, Fig. 1.

Conditions for the setting of the external magnetic field were taken over from the first experiment, and they were extended with a fourth setup:

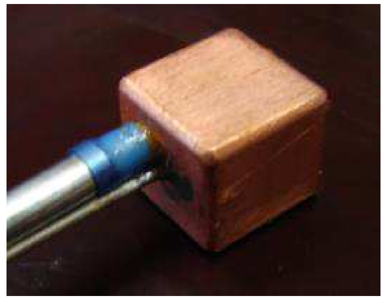

Figure 1: The measured Cu sample, $10 \times 10 \times 10$ mm.

1. The external magnetic field exhibits **low values** of magnetic flux density $\mathbf{B}$, and its distribution is homogeneous on the microscopic scale. Then we have $B = \min$, $\partial B_x/\partial x = 0$, $\partial B_y/\partial y = 0$, $\partial B_z/\partial z = 0$ in at least one direction of the coordinate system and respecting the curl character of the field.
2. The external magnetic field exhibits **higher values** of magnetic flux density $\mathbf{B}$, and its distribution is homogeneous on the microscopic scale. Then we have $B = \max$, $\partial B_x/\partial x = 0$, $\partial B_y/\partial y = 0$, $\partial B_z/\partial z = 0$ in at least one direction of the coordinate system and respecting the curl character of the field.
3. The external magnetic field is **inhomogeneous** on the macroscopic scale. Then we have $\partial B_x/\partial x \neq 0$, $\partial B_y/\partial y \neq 0$, $\partial B_z/\partial z \neq 0$, respecting the curl character of the field.
4. The external magnetic field exhibits **higher values and gradient** on the macroscopic scale. Then we have $B = \max \partial B_x/\partial x \neq 0$, $\partial B_y/\partial y \neq 0$, $\partial B_z/\partial z \neq 0$, respecting the curl character of the field.

3. NUMERICAL MODEL ANALYSIS

In accordance with [2], we used a simple analysis of the FeNdB permanent magnet blocks having the dimensions $15 \times 10 \times 40$ mm, surface magnetic flux density $B_r = 1.2$ T, and intensity $H_{co} = 850$ kA/m. During the experiment, an element evaluating the observed macroscopic behaviour of matter was inserted in the inhomogeneous magnetic field areas.

4. EXPERIMENTS

The verification of the difference in the properties of the microscopic model of matter under the pre-defined condition of the external magnetic field was performed using a copper element having the dimensions $10 \times 10 \times 10$ mm. This element was cooled down to -193°C and then heated at the ambient temperature of 20°C. The heating period was measured repeatedly, starting from -180°C and proceeding to -20°C. These limits had been chosen with respect to suppressing the systematic measurement error in the experiment; the actual experiment is shown in Fig. 2. The aim of the experiment was to repeat the previous measurement [2] and to verify its results.

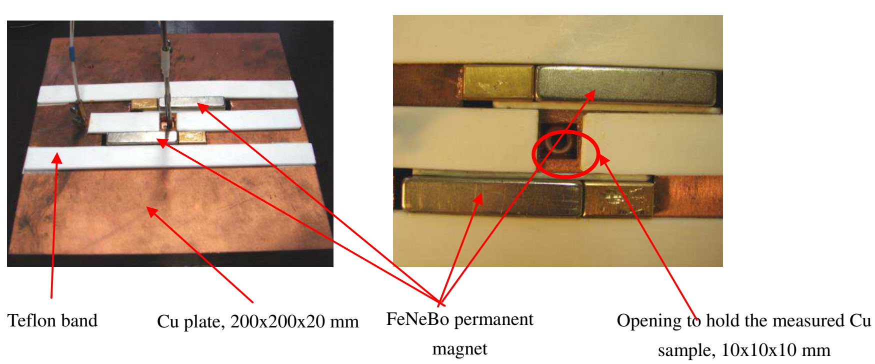

Figure 2: Detailed configuration of the experiment.

Table 1: Measured heating speed values in the examined sample.

Measurement	Time Difference/s			
	1. No Field	2. Gradient Field	3. Homogeneous	4. HomoGrad Field
1	36,64928955	34,48015863	37,71446887	22,82040233
2	38,06576586	36,4855295	41,62355197	28,36592113
3	39,7085593	39,54154481	38,67162785	29,79942564
4	41,18051012	37,88963473	40,20475581	31,49956476
5	42,77172513	38,57823307	38,4903284	33,26028898
6	41,03824944	38,49898872	38,1925093	33,13491397
7	44,16877291	39,23681201	38,91989879	34,11134567
8	45,44665016	38,8054958	37,31208691	33,56003627
9	42,74964147	38,70252762	39,09137363	34,34513303
10	45,26375993	44,30902191	41,99884713	34,38462373
Mean Value	41,70429239	38,65279468	39,22221903	31,21078131
Standard Deviation	2,801316176	2,36366684	1,495505043	3,482702384
Decrease in %	0	−7.317	−5.6	−24.4

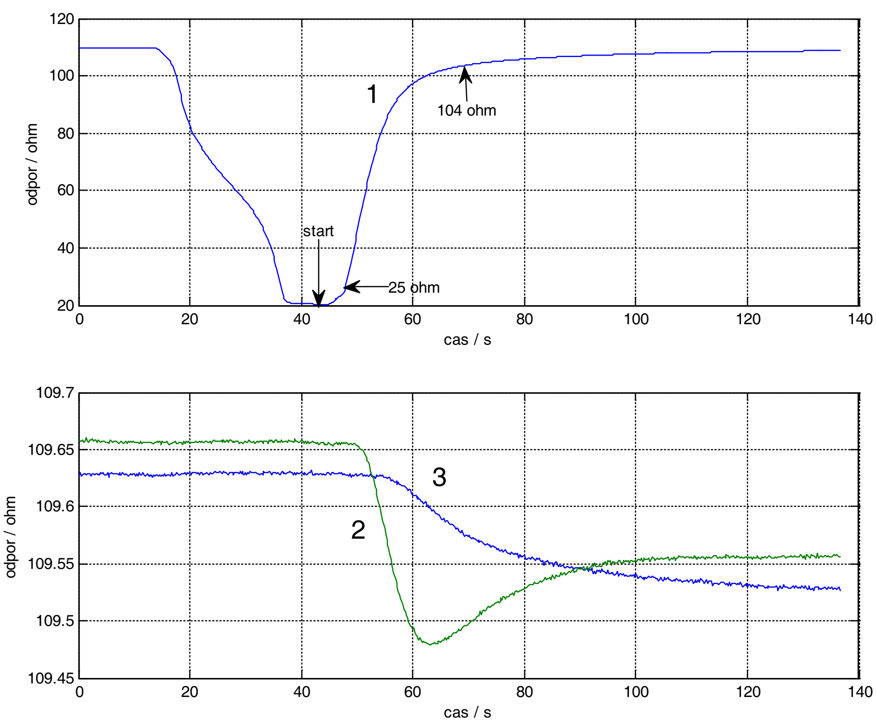

Figure 3: Examples of temperature waveforms during one measurement cycle (the 2nd series of experiments): 1 — Cu cube; 2 — temperature of the Cu block between the magnets at the distance of 60 mm from the centres of the magnets; 3 — temperature of the Cu block at a point located 60 mm (and in a perpendicular direction) from the central section between the magnets.

5. RESULTS OF THE EXPERIMENTS

It follows from the conducted experiments that, in a strong magnetic field with a high gradient character of the magnetic flux density **B**, $\mathrm{d}B/dx$;200 Tm^{-1} is the lowest density of the time flux τ. A higher value of the time flux density $\boldsymbol{\tau}$ can be found in a magnetic homogeneous field with a low magnetic flux density **B**, B;2 µT (setting 1, section 2), and the highest value is detected in a homogeneous magnetic field with the magnitude of the Earth's field $-B$;50 µT. (setting 2, section 2). Table 1 contains the values resulting from the tests. The temperature was detected by a Pt sensor, type PT 100.

The waveforms of the measured temperatures are shown in Fig. 3.

6. CONCLUSION

Repeated measurement has shown that the heating time is shorter than in the first experiments [1]; this condition was achieved via changing the entire measurement task. However, the relative ratio of the heating time is comparable to the previous experiments [2], mainly due to the various magnetic field configurations (1 to 4). Significantly, the HomoGrad configuration (4) exhibits the most distinctive reduction of the time necessary to heat the Cu cube: the total time is only 31.2 ms. All measurements for different settings of the external magnetic field are outside the range of measurement inaccuracy tolerance; thus, it can be proved that the external magnetic field changes the dynamics of the model of matter, and if time density is applied as a quantity, it can be stated that the density of time changes its value in individual cases.

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