Chapter 2. The Nature of Motive Forces

Contents

1. Computation and Measurement of Magnetic Field

Let us consider now a cylindrical magnet shown on Fig. 1. Let us denote:

x, y, z – coordinates, measured in millimeters
B - residual induction of the magnet,
μ - absolute magnetic permeability of the air,
h - height of the magnet, measured in millimeters,
R - magnet's radius, measured in millimeters,
By, Bx – radial and axial components of induction,
Hy, Hx – radial and axial components of permeability
σ - distribution function of magnetic charges density along the face plane.

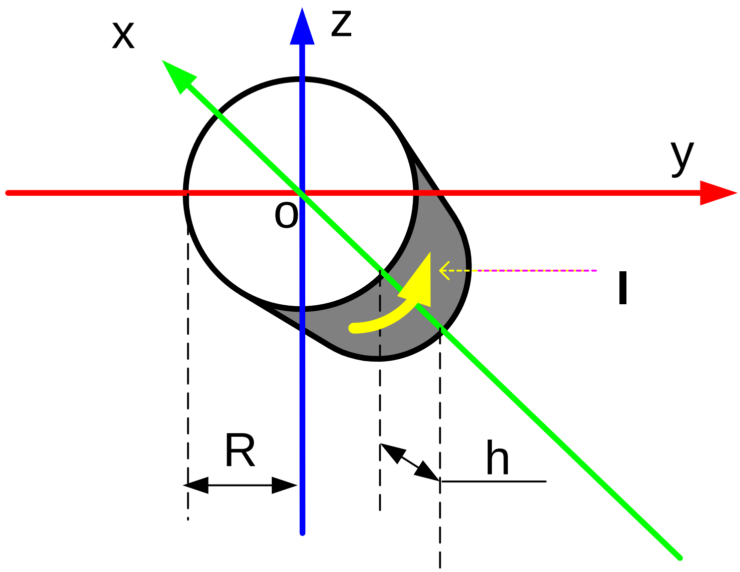

Fig. 1.

A cylindrical permanent magnet with axial magnetization direction may be considered a one-layer solenoid with infinitely thin winding, geometrically corresponding the lateral surface of the magnet, through which a magnetizing current I is flowing.

The value and the direction of the magnetic induction vector $\overline{dB}$ in arbitrary point of the magnetic field generated in vacuum (or air) by a conductor element of the length dl with current I, may be found with the aid of Bio – Savar – Laplace law. As the problem is axially symmetrical, we have to find only the components of the magnetic induction vector B_{xy} in the point $(x, y, 0)$. This projects includes a program for calculation of radial $B_y(x, y)$ and axial $B_x(x, y)$ components of permanent magnet's magnetic induction.

The radial and axial components of permeability may be found by formulas

$$H_x(x, y) = B_x(x, y)/\mu, \tag{20}$$

$$H_y(x, y) = B_y(x, y)/\mu, \tag{21}$$

For testing the given program of the magnetic field calculation, an experiment was performed; it is described in Supplement 2. The results of this experiment and computations show that the intensities of magnetic field close to the face-plane may be approximated by functions of the form

$$H_x(x, y = \text{const}) \equiv \text{Cos}(\chi x), \qquad (22)$$

$$H_y(x, y = \text{const}) \equiv \text{Sin}(\chi x), \qquad (23)$$

$$H_x(x = \text{const}, y) \equiv [1 + \text{Cos}(\gamma y)], \qquad (24)$$

$$H_y(x = \text{const}, y) \equiv \text{Sin}(\gamma y), \qquad (25)$$

where γ, χ are constant coefficients. Here it is important to note that the magnetic intensity components change periodically along the magnet axis x, i.e. longitudal intensity oscillations may be observed – see (22, 23). They are observed experimentally, but do not follow from Bio – Savar – Laplace formula for equivalent solenoid. In this fact lies the principal difference between magnetic field of solenoid and magnetic field of permanent magnet. We shall return to this question further.

2. Magnetic Charges of Permanent Magnet

It is known that Havyside was the first to introduce magnetic charges and magnetic currents to Maxwell's electrodynamics [5, 6]. A review of supposed properties of electromagnetic systems involving the hypothetical magnetic charges is presented in monographs [7, 8]. The fact, that a long magnet's pole mathematically may be identical to magnetic charge, has been marked, for instance, in [9].

It is known that electric induction D, created by electric charges on a certain surface may be identified with density ρ of electrical charge distribution on this surface, i.e.

$$\rho = D. \qquad (1)$$

In the same way, magnetic induction B, crated by magnetic charges on a certain surface may be identified with density ρ of magnetic charge distribution on this surface, i.e.

$$\sigma = B. \qquad (2)$$

Thus, a pole - face plane of a long magnet may be considered as a source of magnetic charges, distributed with density (2). The distribution function of magnetic charges density on the face plane of the cylindrical magnet is

$$\sigma(y) = B_x(y) \qquad (9)$$

or

$$\sigma(y) = \mu H_x(y). \qquad (10)$$

Taking into account (1.24), we get

$$\sigma(y) \cong (1 + \mathrm{Cos}(\gamma y)). \qquad (11a)$$

or

$$\sigma(y) \cong (3 - \mathrm{Ch}(\gamma' y)). \qquad (11в)$$

3. Maxwell's Equations for Permanent Magnet

Above we have assumed that magnetic charges are distributed non-uniformly in a certain volume V, adjoining the face plane, and this volume has a constant thickness Practically the thickness of this volume is very small – it is equal to the size of magnetic domain's pole. We shall assume that it is equal to zero. Then the density distribution of magnetic charges along the magnet axis my be described by a function takes on value 1 for zero value of the argument $x = 0$ (on the magnet face plane) , and for all other points $x \neq 0$ is equal to zero. We shall call this function a truncated Dirac function and denote as $\lambda'(x)$.

Taking into account the above said, the formula (11) and the magnet's axis symmetry, we may assume that density distribution of magnetic charges on the face plane has the following form:

$$\sigma(x, y, z) = \sigma_o \cdot (1 + \mathrm{Cos}(\gamma y)) \cdot (1 + \mathrm{Cos}(\gamma z)) \cdot \lambda'(x). \qquad (1a)$$

$$\sigma(x, y, z) = \sigma_o \cdot (3 - \mathrm{Ch}(\gamma' y)) \cdot (3 - \mathrm{Ch}(\gamma' z)) \cdot \lambda'(x). \qquad (1в)$$

In this project we are considering Maxwell's equations system with magnetic charges (see Appendix1) and the solution method of this system with given magnetic charges density distribution function (see Appendix 3) This method is valid also for the case, when the charges are distributed according to function (1).

In the project using this method it is shown that for that given function the Maxwell's equations system solution for permanent magnet has the following form

$$H_x = h_x \mathrm{Cos}(\gamma y)\mathrm{Cos}(\gamma z)\mathrm{Cos}(\chi x), \qquad (2)$$

$$H_y = h_y \mathrm{Sin}(\gamma y)\mathrm{Cos}(\gamma z)\mathrm{Sin}(\chi x), \qquad (3)$$

$$H_z = h_z \mathrm{Cos}(\gamma y)\mathrm{Sin}(\gamma z)\mathrm{Sin}(\chi x), \qquad (4)$$

where $h_x,\ h_y,\ h_z$ - are constant coefficients, which are determined from the following equations (which follow from Maxwell's equations)

$$\chi \approx \gamma\sqrt{2}\,, \tag{5}$$

$$h_x = \sigma_o / \mu\,, \tag{6}$$

$$h_z = h_y\,, \tag{7}$$

$$h_y = -h_x\, \gamma / \chi\,. \tag{8}$$

Formulas (2-4) show that the magnet's field is a longitudinal magnetic wave. In this magnetic wave because of a jump in distribution density of charges along the ox axis (the charge exists on the face plane, but is absent outside the face plane), there appears a magnetic field in the form of stationary longitudinal magnetic wave with a component H_x, depending of x, and its change is not monotonous, but periodical.

4. Interaction Forces of Permanent Magnets

Let us consider for example the construction shown on Fig. 4, where two cylindrical magnets are able to draw together so that their face planes remain parallel. The density of attractive force of the face plane of magnet A –the A pole, to the face plane of magnet B –the B pole is determined as

$$p(y) = \sigma(y) H_y(y - r)\,, \tag{13}$$

where

y - the distance of a given point A from the center of this pole,

$\sigma(y)$ - the magnetic charge density on the pole A in the given point,

r - distance between the poles A and B,

$H_y(y-r)$ - the intensity of magnetic field, created by pole B in the given point of pole A.

The integral of density (13) with respect to the pole's area A is the value of attractive force

$$F = \oint_S \sigma(y) H_y(y - r) dy\,, \tag{14}$$

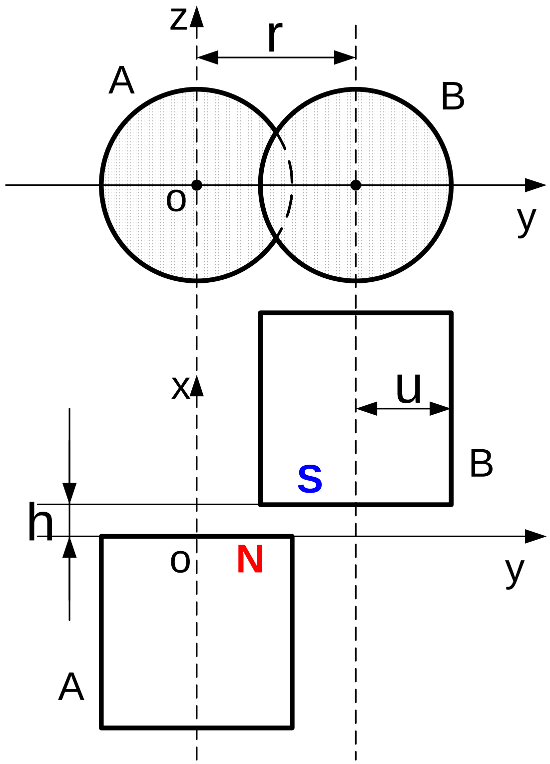

Fig. 4.

In this formula the density $\sigma(y)$ of magnetic charge on pole A and intensity $H_y(y-r)$ of the magnetic field created by pole B on the pole A, are determined in the way described in previous sections. In such way the interaction force of the two permanent poles face planes is calculated. In our project we present a program for computation of such force for arbitrary orientation of the face planes relative to each other .

When permanent magnets move relative to each other, the vector of their interaction force changes its direction. The average force along the trajectory as a rule is equal to zero. In other words, these forces in the average do not perform any work. However there exist such trajectories where average force along the trajectory is not equal to zero, and consequently, it performs work. We shall call such trajectories – "efficient" trajectories. The source of energy for performing work on these trajectories will be considered further.

In this project we shall examine in detail the Searl's construction and the equivalent construction of Roshchin-Godin. We shall prove that in these construction the permanent magnets move along efficient trajectories (under certain constructive conditions). We shall examine also the Reed's construction, and prove the same fact for it also.

> Thus, the interaction of permanent magnets serves as the source of motive forces.

> In this project we present some more constructions in which the efficient trajectories are being realized – efficient, or working constructions.

5. The Dynamics of Working Constructions

In such constructions the "working" effect begins to show at a certain minimal rotation speed ω_1 and at once appears the rotation force F_m, creating acceleration. When the speed grows, the friction force F_t grows proportionally to speed.:

$$F_t = F_{to} + k\omega .$$

The process is described by the equation

$$F_m - F_t = J\frac{d\omega}{dt},$$

where J - the moment of inertia. Thus,

$$F_m - \left(F_{to} + k\omega\right) = J\frac{d\omega}{dt}$$

or

$$J\frac{d\omega}{dt} + k\omega = F_m - F_{to} .$$

The solution of this equation is as follows:

$$\omega = \omega_o\left(1 - e^{-qt}\right), \quad q = \frac{k}{J}, \quad \omega_o = \frac{F_m - F_{to}}{k} .$$

Therefore, the motor speeds up to the speed ω_o and keeps this speed constant – see Fig. 5.

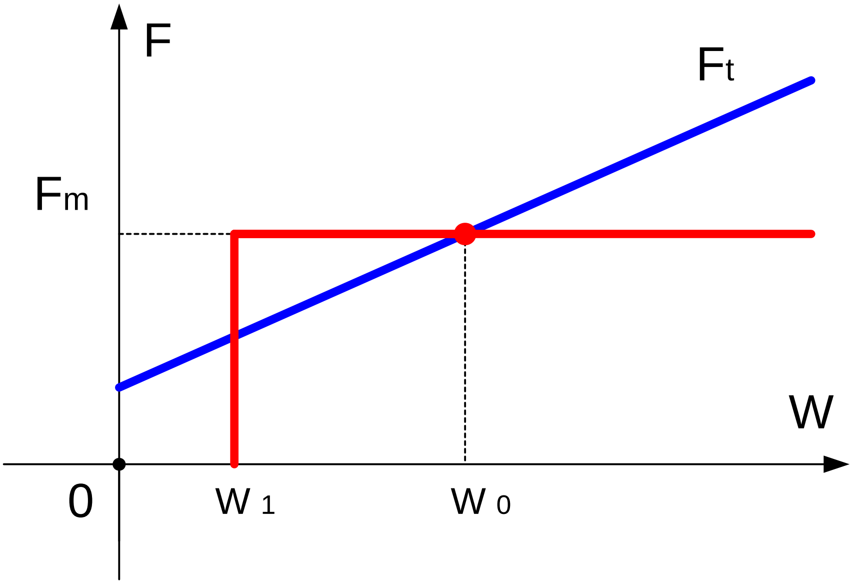

Fig. 5.