THE MAGNETIC PROPERTIES OF MATERIALS AND NEW MILITARY APPLICATIONS OF THEM

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Abstract: *The technological development of the last decades has brought to light more and more important possibilities for improving the technologies applied in aviation. Among other things, the low-speed aircrafts can be in the near future equipped with electric engines of a totally new type. But for this, we must first establish theoretically how the direct conversion of the magnetic energy can be done and also, we have to study the properties of the magnetic materials and how they can be used in the design of a new type of a prime mover. Aviation should be one of the first areas that would benefit from the results of this research and development activity.*

Keywords: *magnetic energy, prime movers, electric engine.*

INTRODUCTION

The idea and the desire to build vehicles (including aircrafts) driven by electric (or magnetic) engince is very old. But the multitude of problems that have arisen has prevented and still hindered the large-scale development of such (electric) vehicles and if they are still realized, they have extremely high price, often inaccessible so that we do not discuss these cases. We will therefore see if there are technological solutions that can overcome this deadlock.

1. THE MAGNETIC AND THE ELECTRIC ENERGY

While it is inappropriate to review the definition of electric energy, which is widely known and used at present, we will still focus our attention on the magnetic energy, much less known and rarely directly applied: *the magnetic energy is a physical size that shows the capacity of a physically system corresponding to the magnetic circuits to store the energy consumed by the mechanical work of an electric current, but also the ability to perform a mechanical work at the transition from the given state to the reference state, its value depending only on the magnetic field strength and the permeability of the environment, i.e. the magnetic properties of the matter; also representing a potential function with the function of state function for the physical system corresponding to the magnetic circuit*.

By such a definition, we try to make a preamble of presenting the practical aspects of the use of magnetic energy in the case of prime movers, which are also applicable to motor-powered terrestrial vehicles and aircrafts.

Naturally, there are physical and mathematical instruments of calculating the magnetic energy whose determination as a self-standing notion has been mentioned before, urging physicists and engineers to pay more attention to the study and the theoretical determination of all aspects regarding this form of energy. A form of energy that, although recognized by the scientific world, is insufficiently studied and most often treated very superficially in the works of art, which at best barely consecrates a few rows.

As we can see from the bibliography research in this area, often, there are not clear and complete definitions about the magnetic energy, considering that the magnetic energy would be a sort of accessory to electricity. Nothing more fake! In spite of the indisputable complementarily of electricity and magnetism, as well as the fact that without electricity the magnetism phenomenon could not exist, the magnetic energy is, however, a separate concept, directly and strongly related to the magnetic properties of the material, but also to its size and configuration, because the magnetic material acts as *an energy storage environment*, the value of which depends on the dimensions of that "reservoir".

In the case of a bobbin, the calculation of the magnetic energy that is lost when the supply to the circuit is interrupted is done when the circuit is closed or when the source is disconnected. In order to obtain a current increase, it is necessary that the electromotive force of the source be operated in accordance with Lenz's law, ie against the self-inductive automotive voltage, because during the current increases, the electromotive voltage of the source performs a mechanical work against the self-induction and so, we can consider that the time interval due to the increase of the current through the circuit will pass an amount of electricity equal to:

$$dQ = Idt \tag{1}$$

where dt is the aforementioned time interval, and the mechanical work against the electromotive voltage of self induction is given by the expression

$$dA = -\mathrm{E}_{ind} Idt \tag{2}$$

knowing that

$$\mathrm{E}_{ind} = -\frac{d\Phi}{dt} \tag{3}$$

and obtaining

$$dA = I\frac{d\Phi}{dt}dt = Id\Phi \tag{4}$$

where we have the transformation into the magnetic energy of the energy from the source, the increase of energy being

$$dW = Id\Phi \tag{5}$$

for which, considering the Biot-Savart-Laplace Law, we have an induction that depends on the current in a linear fashion, and how-

$$\Phi = BS = LI \tag{6}$$

then it follows that,

$$dW = ILdI \tag{7}$$

but in order to obtain the total value of magnetic energy, we have to sum up practically all the elementary mechanical works transformed into magnetic energy, which we can do by integrating-

$$W_{mag} = \int_0^I ILdt = L\int_0^I Idt \tag{8}$$

Therefore

$$W_{mag} = \frac{1}{2}LI^2 \tag{9}$$

Thus, we see that similarly to the electric field, the magnetic field is accompanied by an energy. As mentioned above, a mechanical work must be consumed for the production of this field, which, in practice, in the case of electromagnets (as used by the magnetic engine shown in the present paper), it is carried out by the current *i* that induces into the excitation coil windings a voltage *u*. It has been assumed for the above relationships that *L* inductance and magnetic permeability μ are constant throughout the process described. This gives us the validity of relationships especially for the massive magnetic cores and for air.
Considering, however, that-

$$L = \frac{n^2\mu_0\mu_r S}{l} \tag{10}$$

where *S* is the field surface of section, *l* is the length of proceeding lines of force (in the air gap), *n* the number of windings and

$$I = \frac{Hl}{n} \tag{11}$$

therefore obtaining another way to write the expression (9) namely

$$W_{mag} = \frac{1}{2}H^2\mu_0\mu_r lS[Joule]_{SI} \tag{13}$$

also for μ with constant value, and from the above expression it can easily be observed that virtually the magnetic energy is contained in the volume

$$V = l \cdot S \tag{14}$$

and from all the above, we can conclude *that the magnetic energy carrier is the magnetic field*, since in the volume V in which the field operates, there is magnetic material, its value μ_r can no longer be considered as constant, since it starts from the initial expression

$$dW = nid\Phi \tag{15}$$

above mentioned, which becomes

$$dW = HlSdB \tag{16}$$

where it ultimately results

$$W = V\int HdB \tag{17}$$

an integral that can not be calculated exactly because the intensity *H* is not an analytical function of the induction *B* but is related to it by the magnetization curve given by the hysteresis cycle. However, the intensity may be conveniently graphically determined. For example, the mechanical work required to pass the hysteresis loop can only be performed if this loop is considered to be cut into very narrow (infinitesimal) horizontal "slices" of the height *dB* and the width *H*. In this way, the above integral will represent the surface area of the hysteresis cycle, and in this case it is sufficient to measure this area in order to obtain the value of the mechanical work on the unit of volume of the magnetic core.

In applications, however, we are interested in how this magnetic energy can be converted into kinetic energy so that the (electro)magnet used can exert on a certain technical component, a force of the highest value. From this perspective, we draw particular attention to the relatively high value of the force that a (electro)magnet can develop, with low energy consume, compared to the rather poor performance of electric cars, plus the high costs and technological complications, as well as relatively high electricity consumption.

We will see the force of a classical electromagnet, and then we will try to move to the case of the electromagnet with rotating armature to get closer to the magnetic machine model to which the present work actually refers.

We assume that in front of the poles of an electromagnet there is an iron armature which is attracted to an *F* force, but the volume $V = l \cdot S$ of the air gap, which contains a part of the total magnetic field, holds in it the magnetic energy given by the relationship-

$$W_{mag} = \frac{H^2 \mu_0 lS}{2} \tag{18}$$

in the air gap we consider that $\mu_r = 1$, but knowing that $\mu_0 H = B$, we will have

$$W_{mag} = \frac{BlS}{2\mu_0} \tag{19}$$

and after applying the armature on the electromagnet poles, this part of the magnetic field and the corresponding energy cease to exist. Instead, it will be performed a mechanical work equivalent to *W* = *Fl*. As 1 Joule = Newton meter, we have

$$F = \frac{B^2 S}{2\mu_0} \text{ [Newton]}_{SI} \tag{20}$$

or

$$F = \frac{B^2 \cdot 10^{-8} \cdot S \cdot 10^{-4}}{2 \cdot 1{,}256 \cdot 10^{-6} \cdot 9{,}80665} \cong \left(\frac{B}{5000}\right)^2 S[Kgf\,]_{MKS} \tag{21}$$

From the above relationships, we can easily see that an electromagnet can easily develop important forces with relatively low energy consumption. For example, we will take an electromagnet from ferromagnetic material, cut into U-shape, for which we will consider the two polar surfaces of 5 cm ^{2}, knowing its magnetization curve; if it is excited by 1000 amper-turns, for a total length of 0,5 m of force lines, we find that the electromagnet will develop a bearing force:

-for the field intensity of $H = \frac{1000 Amperi}{0{,}5 metri} = 2000 \frac{A}{m}$;

-according the magnetization curve (appllying thea graphic method) we will have a induction of about 15000 Gs;

-and having two pole faces, S = 10 cm^2 aşadar $F = \left(\frac{15000 Gs}{5000}\right) \cdot 10 cm^2 = 30 Kgf$.

From this small example, you can see how a small device with a very simple structure is able to develop important forces. However, it is a matter of adapting the classic magnetic circuits so that they can develop a continuous force on a rotating mobile element.

Practically, the example below is with 3 pairs of annular electromagnets which form a group of forces in which the electrical energy is first transformed into magnetic energy in order to subsequently convert the desired magnetic energy into kinetic energy .

2. THE MAGNETIC PRIME MOVER - A POSSIBLE SOLUTION IN LIGHT AVIATION

There is the possibility of building prime movers based on the transformation of magnetic energy into mechanical energy, with low energy consumption. These prime movers would operate in more advantageous regimes than any of the currently known electric engines. On this occasion, the authors also proposed a series of reconsiderations in the terminology used in physics and electrotechnics, pointing to the misuse or inappropriate use of sme terms. A comparative presentation between the electric/ *the magnetic motor*:

-the electric engine requires large-scale polar parts, which are very heavy; *a well-designed electromagnet must not be large in size to develop a considerable bearing force*;

- the electric engine often requires massive windings, which lead to increased weight and higher the overall costs; *a correctly designed electromagnet will match the number of turns to the current value by choosing the optimum values for the maximum bearing force*;

- in the electric engine, the magnetic field lines do not close tightly in the yokes, most often only partly within the yokes and permanently subjected to the "stretching" and "breaking" phenomena of the field lines caused by the movement of the armature in which the lines of the field should close; *the magnetic engine shows the correct way of closing the field lines*;

-in the electric engine, in order to drive the rotor it is induced by a current, this phenomenon being accompanied by large losses due to the Joule-Lenz effect and the Foucault currents, as well as due to imperfections related to the configuration of the engine parts; *the correct interaction must be the only the direct interaction between the (electro)magnets, whether it be between the opposing sign poles or the same sign; therefore, no inductor, no induced*;

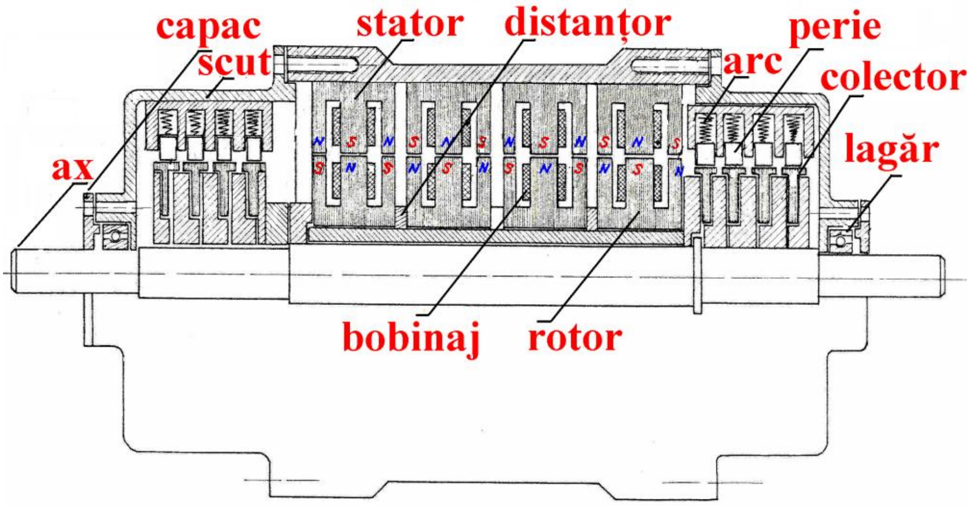

FIG.1 Magnetic prime mover with brushes.

- the electric engine, once the induction is made, induces the phenomenon of self-induction, which leads to other losses, and as soon as the magnetic flux registers variations and the parts move, there is the phenomenon of hysteresis and the action of the counter-electromagnetic forces caused in large part by the application of the Law of Lenz; *an appropriate design of a pair of electromagnets placed on the stator and rotor using a fixed magnetic field configuration interacts through the force lines without inducing induction phenomena in the magnetic core or the occurrence of phenomena occurring in the power electrical machine*;

-in the case of an electric engine, the actual drive of the mobile component (the rotor) is mainly due to the Lenz force which, due to the circuit losses, is much weaker than the direct magnetic interaction; *a magnet engine, takes over the magnet interaction model and adapts it to a magnetic circuit of ring or circular configuration*;

-in the electric engines, for the continuous drive of the rotor, the electrical machines require complex switching, which raises technological problems, including cost problems, not removed in latest years by the various improvements; *a pair of annular electromagnets can perform sequential polarity changes by means of a rudimentary switching apparatus*;

-there is known that the electric machines have great technological problems when they have to vary the speed and the power regime; requiring sometimes the existence of saturation regimes and the application of high frequencies in the feed circuit; *a magnetic motor, does not require any of this, ranging in high speed (from 500 to 15,000 rpm) but keeping the power supply parameters unchanged, and still in direct current*;

-the known electric machines require high energy consume because they do not judiciously use the magnetic properties of the ferromagnetic material; emphasizing the quantity, not the quality and making waste of magnetic core and copper winding; a magnetic engine for the same developed power has much smaller dimensions and much smaller quantities of Fe-Si material and copper;

-the electric power engines use electricity to convert it into mechanical energy or vice versa; this process is indirect (except in the case of electrostatic engines or other types of engines which use the electric fields) and is accompanied by large losses, so that, a poor yield; a magnetic engine will directly convert the magnetic energy into mechanical energy at a better efficiency.

So we can identify the differences between the electric and magnetic engine:

-in terms of applied phenomena (***operating principle***), the electric motor uses the magnetic induction between (at least) an inductor and (at least) an induced and therefore, the electromagnetic interaction established as a result of the application of the self induction phenomena, the appearance of the Lenz Force and Laplace Force, amid the general phenomena of hysteresis and the action of the Foucault currents, while *the magnetic motor uses the simple interaction between magnetic fields formed around (electro) magnets*;

-from the point of view of ***the magnetic field configuration***, in the electric engine the field lines suffer a series of alterations due to the imperfection of the magnetic circuit which fails to close well the field lines, breaking them both because of the defective configuration and especially because of the use of the rotary magnetic field, while the magnetic motor does not have any rotary magnetic field but a fixed configuration of the magnetic field as tightly closed and interacting only at the level of the air gap, eliminating the induction phenomena within the magnetic cores;

-regarding ***the configuration of the pole pieces***, the electric engine has a wide variety of possible geometries, at which the poles are visible, shielded, drowned, etc., characterized by a wide variety of magnetic spectra they can create; in the magnetic motor for driving a rotor, the polar parts are annular, with small semicircular (not radial!) excitation coils;

- in terms of ***structure and composition***, the electric engine must be formed at least by a stator and a rotor, one of which has the inductor function, the other one to be induced; besides these, there are also the auxiliary components necessary to assemble the main components or to ensure their operation; whereas the magnetic motor is only compulsorily made of pairs of annular (electro)magnets, which can either be divided into the stator and the rotor, or both of them as stator components, but separated by an air gap in which a non-winding rotor is disposed;

-according ***the principle applied to the drive***, the electric motor is generally based on the Lenz Force; while the magnetic motor applies the interaction between magnetic fields of the opposite sign or the same sign, that can be exerted directly between (electro)magnets or on a reactive discoidal Fe-Si element, placed in the air gap between the electromagnets provided with sequential polarity change.

On the basis of the above, one of the authors has already proposed the adoption of the term „*the magnetic field motor in a polar alternating stationary field*", being a technical system using the magnetic energy the carrier of which is the magnetic field, by which magnetic attraction forces are applied and simultaneous and synchronous with repulsion forces within the circumference of a circular mobile device. The magnetic prime mover is a modular system, consisting of pairs arranged and running on the same shaft. Each stator-rotor pair can operate independently and has its own sequential switch-gear. Each pair is separate from the others in mechanical and electrical terms. It is the situation that when a pair fails, the others continue to work.

CONCLUSIONS

Following the analysis of the possibilities of direct use of magnetic energy in power machinery, the following conclusions were drawn:

-although the electromagnet is defined as a temporary magnet intended to transform the electric energy into mechanical energy through the magnetic energy, we can state that under certain conditions (magnetic interactions only between magnetic fields) the electromagnet allows ***the direct transformation of magnetic energy into mechanical energy***;

-the magnetic materials (with good magnetic permeability) also allow ***the storage of energy*** but also its amplification due to the magnetic qualities of the material used; that is why the magnetic induction of a given current becomes much higher when it is exerted on an environment with good magnetic properties; this gives rise to the possibility for prime movers to develop big forces;

-given the ability of the magnetic material to store the electric energy at high values and within a relatively small volume, its ability to transfer energy in the form of mechanical energy results in higher efficiency values than the transfer of electric energy to mechanical energy (made in the "electrostatic" motors or the engines which apply the Laplace or Lenz forces - as is the case of the most current electric motors);

-the above mentioned facts require the introduction of a clear distinction in typologies, between the electric prime movers and the magnetic prime movers, just as the magnetic energy is separately defined and introduced in the known typology; the energy forms (mechanical, thermal, nuclear, electric, chemical, magnetic) correspond each to a specific prime mover, therefore the magnetic energy must correspond to the magnetic prime mover; so that, the electromagnet is not a simple intermediate in the transformation between electrical and mechanical energy, because by the intervention of its magnetic properties and corresponding its dimensions (volume, the area of the section traversed by the magnetic force lines, etc.) it has the ability to amplify a received energy; regarding these aspects, we consider that the real energy transfer is actually applied between the magnetic and the mechanical energy, so it is necessary to introduce in the typology the concept of *the magnetic prime mover*;

-regarding the applications in the field of engines, it is appropriate to abandon the inductor-induced pair and generally, the principle of induction; we also consider erroneous to apply at the engines the Force of Lenz, because it (along with the phenomenon of induction) gives rise to negative effects such as the occurrence of counter-electromotive forces, the Foucault currents etc .;

-it is also appropriate to use the direct magnetic interaction between the force lines of two concentric annular (electro)magnets each having only two notches, they have semi-circular polar parts forming circular arcs describing angles of 165^{0};

-the annular configuration of (electromagnets) and the existence of each of them only two notches (correspondingly only two polar pieces, one on each half-circumference) makes the area of the active section of the pole pieces the maximum (describing in total an angle of 330^0 of the total 360^0 of the circle) and the magnetic flux is therefore very high; at the same time, the magnitude of the magnetic interaction is greatest, being achieved at almost the entire circumference of the circle;

-an optimal magnetic circuit, is the one that closes the field lines very well and does not allow the interference of parasitic fields or the occurrence of magnetic spectrum distortions, as is the case of the rotary magnetic field and generally the case of today induction motors.

Therefore, the optimal magnetic circuit is that which uses a stable (immobile) magnetic spectrum, well-closed in the configuration of the pole and yoke. According to the above, it results the possibility of creating prime movers with performances beyond all the known and applied prime movers.

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