SOME ASPECTS REGARDING THE ELECTRICAL MICROMOTORS

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***Abstract* – The authors consider being very necessary to present a synthesis of the actual problems of the electrical micromotors, because the technical literature is not very reach with this area of research. Thus, there are presented the micromotors area, the types of micromotors which are known and the constructive elements of some interesting micromotors with the most important and specific aspects of the micromotors.**

Keywords: *electrical micromotor, specific elements, functions.*

1. INTRODUCTION

1.1. The notion of micromotor

In the habitual technical language there is talking about the power of the motors as small, medium and big and about micromotors. For the first notions (small, medium and big power) there are the accepted conventions regarding the lomits of the powers, there is no such a convention for the micromotor. Thus, we will present what should be the notion of micromotor. In the modern technical dictionary [1] the micromotor is presented like "an electric motor of small power, from a fraction of watt to hundreds of watts". The standard STAS 881-88 gives the powers, voltages and rated speeds for the three phased asynchronous motors from 0.06 to 200 kW, that operate in continuous mode at 50 or 60 Hz frequency. These values are in the tables from the standard. Table 1 presents the nominal power of the motors (in kW) considered by authors to be the powers of the micromotors according toSTAS 881-88. [2]

Series I [kW]	0,06	0,09	0,12	0,18	0,18	0,37	0,55

Table 1: Nominal power of the motors

1.2. The importance of the micromotors

The expansion of the automation and robotics, especially in industry but also in agriculture, medicine, transports, and home utilities determined an important increasing of the electrical equipments, especially of the electrical machines. It can be estimated the there are some billion machines of small power around the world.

The progress of the space and military techniques, of the microrobotics and microsurgery imposes a strong miniaturization having as result the apparition of the micromachines. In the technical literature there are presented the main phenomenon and forces used to realize micromachines as follow:

The forces based on the energy stored in the magnetic field, (the electromagnetic motor) and in the electric field (electrostatic motor).

The forces based on the deformation of some solid structures in the electric field (piezo-electricity, electrostriction) or in the magnetic field (magnetostriction).

The forces based on the deformation of some solid structures due to the temperature (bimetal, memory effect alloy).

The forces based on the chemical reaction (based on these there were realized the electrochemical pump).

The forces based on the hydraulic or pneumatic effects (servomotors with membrane, servomotors with piston). [3]

2. TYPES OF MICROMOTORS

The micromotors can be classified as follow:

After their mechanical structure component, there are micromotors with magnetic field and with electric field;

After the movement of the mobile part, micromotors with magnetic or electric field can be: with continuous rotation movement, with continuous translation movement, with increment movement (rotation or translation);

The control of a micromotor drive can be: the control of the current, the speed control and the control of the mechanical load position.

The main classic electrical machines have some correspondent in the micromachines area. Thus, regarding the electromagnetic torque generation and the machine operation there are micromotors with magnetic field as follow: synchronous micromotors (with permanent magnet, with variable reluctance, with hysteresis, step by step etc), direct current micromotors (classical or with electronically auto commutation, with cylindrical or disc rotor etc) asynchronous micromotors (with can or disc rotor).

At their turn, the usual micromotors with electric field can be classified as piezo-electric and electrostatic.
At the micromotors there are also applied some principles that are not used for the normal construction. .[4]

2.1. Electromagnetic micromotors

2.1.1. Alternative current micromotors

In this area there are asynchronous micromotors with cage rotor, asynchronous with can rotor, reactive asynchronous, asynchronous with hysteresis. Their advantages are the simple construction and an increasing safety.
The disadvantages are: if there is a system that needs a constant speed of rotation, the synchronous micromotors is not indicated because of the oscillation tendency of the rotor. For the portable apparatus, the alternative current motor needs a converter that affects the technical and economical parameters and a complex schema.
In these situations it is recommended to use the direct current or permanent magnet micromotors.

2.1.2. Direct current micromotors

The d.c. micromotors with static commutation are characterized by: a slide control, a high starting torque, no need of the collector, of the brush holder star, of the auxiliary poles and of the compensated winding (that reduce the volume, the mass and the necessary copper).
They can also be used at higher speeds and accelerations, are noiseless and safety and have a higher efficiency then the motors with collector, the maintenance is simple. In turn, the control needs an electronically schema which can be quite complex.
The synchronous micromotors, regarding its control, supply and the movement characterisitcs, can be: with continuous supply and movement, with impulse and incremental movement (step by step micromotors).
According with the electromechanical energy conversion, the synchronous rotation micromotors can be: µM with permanent magnets (active type) µM-MP; µM with variable reluctance (reactive) µM-RV and µM with hysteresis µM-H.
In the small and micro-power application the energetic characteristics are not de critical.
This is why, in their construction is not used the rotor winding supplied in direct current and there are used the synchronous µM with permanent magnets or without excitation (with variable reluctance) which have no brushes and slide contacts, being simple and having many advantages over the classical motors: good maintenance, high reliability, noiseless, are good for explosive and ignitable medium.
Micromotors with variable reluctance (µM-RV) have a small power factor toward the µM with excitation. The rated value of the power factor, efficiency and their dimensions are analogous with the equivalent power classic asynchronous machines.
The rated power is starting from tens of watt to tens of kW. µM-RV are some advantages regarding their construction (the absence of the excitation system from the rotor), a low price and some operation advantages: robustness, reliability (the absence of the slide contacts and of the permanent magnets etc) a easy starting in asynchronous (with an appropriate rotor construction), noiseless. .[4]

2.2. The electrostatic micromotors

The electrostatic micromotors can be synchronous and asynchronous and usually there are known the electrostatic generators and less the motors.
The synchronous electromechanical conversion is realized used a system with electrodes which, supplied with polyphased voltages generates a rotational electric field $\overline{E}$, that action over the rotor (a dipole with an electric moment $\overline{p}$ and spin it with a synchronous speed and generates a rotational torque, given by the relationship:

$$M_e = E \cdot p \cdot \sin\psi \qquad (1.5)$$

Where Ψ is the angle between the two vectors.
The rotoric dipole can be realized by some electrodes with different polarity, from an electret or from a dielectric with induced polarity.
The achievement of an asynchronous electrostatic micromotors needs a rotor with the same number of the poles as in the armature. In rotor there is developed a polyphased electric field which slide toward the rotational electric field of the armature.

2.2.1. The Step by step electrostatic micromotor

In the electrostatic area the synchronous electromechanical conversion is preponderant. Usually it is realized with step by step micromotors which are similar with the electromagnetic motors.
In its construction, this micromotors has an armature and a rotor, like any rotational machines.
The armature is realized from the poles in position over a circular trace and fixed on an insulated support.
The rotor has a number of poles and, together with the armature poles have the role of the capacitor armature by whom the electrostatic energy is converted in mechanic energy.
This is possible by an incremental supply of the armature phases (Figure 1).

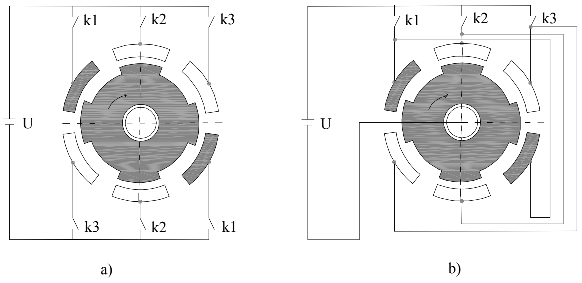

Figure 1 Schema for the incremental supply of a triphased step by step micromotor

Figure 2 shows an step by step electrostatic micromotor with a ratio 3/2 between the armature and rotor poles. For a single pair of poles (one on the armature and one on the rotor) it is observed the analogy with a plan capacitor with a mobile armature with a parallel deplacement with the two armatures (figure 2b).

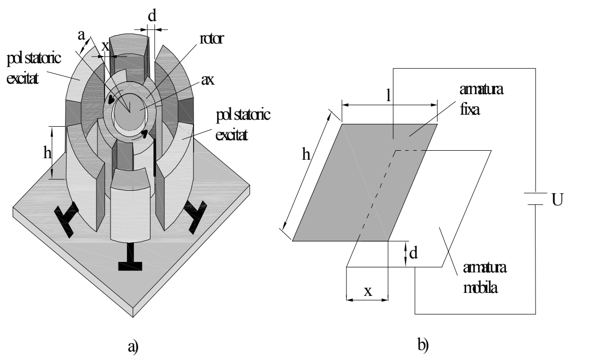

Figure 2 The electrostatic interaction between the poles of a MEPP
a) step by step electrostatic micromotor with a ratio 3/2
b) equivalent capacitor correspondent to the electrostatic coupling between poles

According to the theory of the generalized forces in the electrostatic field, the interaction force between the two coupled forces is given by the relationship:

$$F = -gradW_e = -grad\left(\frac{1}{2}CU^2\right) \qquad (1.6)$$

where F is the electrostatic force that act on the rotor, W_e is the energy stored in the electrostatic field of the two poles, U is the voltage , C is the capacity of the equivalent capacitor . It can be observed that the voltage has a very important role for the force.

2.2.2. Electrostatic micromotors with arch armature (MESA)

For the undermilimetrical electrostatic motors, the movement transmission to the drived element is a serious problem because the shaft is a fixed element and around it is moving the rotor. Thus, it is preferred for the rotor to be directed coupled with the drived element, one of the proposed solution being the arch armature micromotor (MESA).

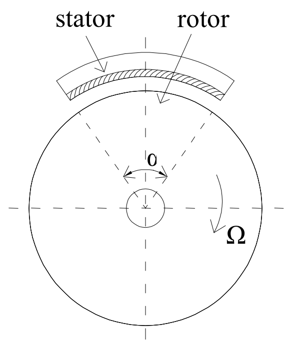

Figure 3 Linear induction motor with arch armature with radial air gap

The idea is to use as a rotor the revolving part of the drived mechanism (a fly wheel, a cylinder, crown gear etc). To realize synchronous ratations different on the 3000 rot/min multiples, the inductor covers only a part of the rotor (figure 3). Apparently, such an armature is a part from a usual induction machine armature, but actually it is the induction machine with arch armature of Fridkin. In the armature slots is realized a usual poliphased winding, with *p* pair of poles.
The micromotor version is presented in figure 4.This is build from a support shaft 1 on which spins the rotor 2 that has exteriorly a crown gear 2a wit 12 teeth. The rotor is coupled with the armature by an electrostatic field, the two parts being isolated by a radial space.
The armature has 18 electrodes in two arch segment, with a rotoric cover angle of 80^0 (the electrodes 3a, 3b, ... 3i, and the electrodes 3j, 3k, ... 3r). The two segments are placed around the rotor in opposite diametric positions. The adequately electrodes are symmetrical distribute (with the same 10^0 angle), corresponding to the rotoric teeth position, which are a real polar crown, coupled by the electric field with the armature electrodes. The 18 electrodes 3a...3r are divided in 3 sets, as follow:

- set 1, realized with electrodes 3a, 3d, 3g galvanic linked in regard to connect them at one of the supply pole and another electrodes set 3j, 3m , 3p placed in opposite diametric position regarding the first set, which are also galvanic linked for the connection to the other pole of the supply.
- set 2, realized in the same conditions from the 3b, 3e, 3h, electrodes and 3k, 3h, 3q electrodes;
- set 3 realized from 3c, 3f, 3i, electrodes and 3l, 3o, 3r electrodes.

The three sets of electrodes are successive connected to the supply. Starting from the situation presented in figure 4, the next sequence is to deexcite set 1 and excitation of the set 2, when the rotoric poles are attracted by the armature poles 3b, 3e, 3h, and 3k, 3n, 3q, which give to the rotor an angular movement with an incremental step of 10^0. Then there is disconnected the set 2 and is connected the set 3 (3c, 3f, 3i, and 3l, 3o, 3r), and the rotor turn with a new incremental step. The cycle is re-run by disconnected set 3 and reconnection of the set 1.

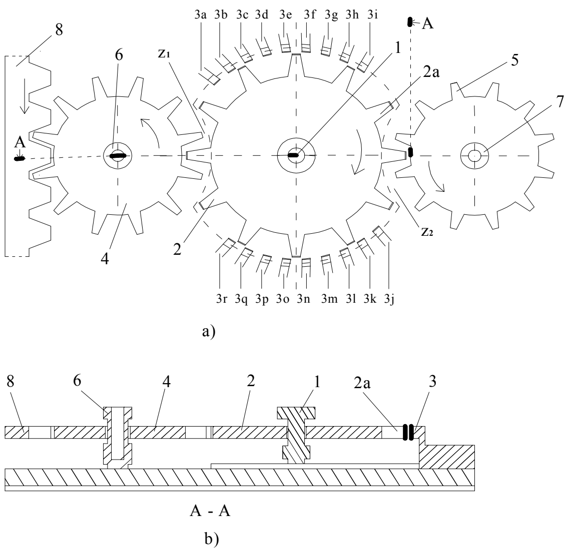

Figure 4: The electrostatic version of the motors with arch armature
a) general view b) longitudinal section

The electrodes repartition (the armature poles) on the two segments (figure 4 a) is realized so around the rotor there are created two antipodal free areas, z_1 and z_2 in which there are placed two pinions 4 and 5, in gear with the crown gear, which is also the polar crown of the rotor. The two pinions, placed each one on a fixed shaft 6 respectively 7 can be connected with other gears or with a cremaillere 8 and thus is resolved the problem of the movement transmission to the drived element. The arrows used in the figure 4 shows the movement direction of the rotor and of the intermediate elements of the drive system. The properly micromotor and the movement transmission system are realized by the same planar technology, based on the superficial trating by photolithographic methods of a polycrystalline silicon plate. Figure 4 b shows a section on a micromotor after the trace A-A indicated in figure 4 a.

Using similar analogies it were imagine: electrostatic micromotors with rolling rotor (MERR) , electrostatic induction micromotors (MEI) and others. [5]

3. CONCLUSIONS

Having into attention the necessity to develop small active forces and torques it can be say that we can realize electrical micromotors by any phenomena in which they are forces resulted from the different interaction. Thus, the micromotors variety is very large and is difficult to present all of them in this paper. The main target is to focus the experts on the nonconventional character of the obtained motor forces. It is also possible that some available micromotors to influence the construction of the small power electrical machines.

References

[1] Dicționarul elementar de tehnică modernă - energetică electrotehnică, Editura Ştiințifică şi Enciclopedică, Bucureşti

[2] Institutul Român de Standardizare, *Maşini electrice rotative (Vol. I) – Condiții generale, Mărimi caracteristice*, Editura Tehnică, Bucureşti, 1997

[3] Dan Teodorescu, *Maşini electrice – Soluții noi tendințe orientări*, Editura Facla, Timişoara, 1988

[4] Carmen Cojocaru Filipiuc, *Micromaşini electrice sincrone şi de curent continuu*, Editura „Gh. Asachi" Iaşi, 2001

[5] Dorel Cernomazu, Alecsandru Simion, Leon Mandici, *Micromotoare electrostatice*, Editura Universității Suceava, 1997