# CONTRIBUTION CONCERNING THE BUILDING OF SOME SOLAR-ELECTRIC ENGINES. THE SOLAR-ELECTRIC ENGINE WHIT THE ROLLING ROTOR

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**Abstract.** *In this paper there are presented the researches carried out by some authors in the area of solar engines, who want to obtain a prototype that can be used in order to operate some special equipment, such as the solar converters with concentrator, the heliostats, the photovoltaic panels etc. The researches were focused on the solar-electric engine with rolling rotor, engine characterized by reduced speed and high functioning torque. In the first part of the paper there are mentioned a few theoretical aspects concerning the operation of the solar engine with rolling rotor, continuing with the presentation of the constructive solutions devised and realized by the authors.*
**Keywords:** *solar-electric engine, rolling rotor, photovoltaic cells.*

## Theoretical consideration

Proposed by Moskvitin in 1944, the rolling-rotor motor differs from all other motors in two aspects. Firstly, the rotor core has neither a winding nor any rotations or notches on its surface. Secondly, a rotating field causes the rotor to roll on guides so that it remains eccentrically positioned inside the stator. In Moskvitin opinion [1], the stator motor, carries

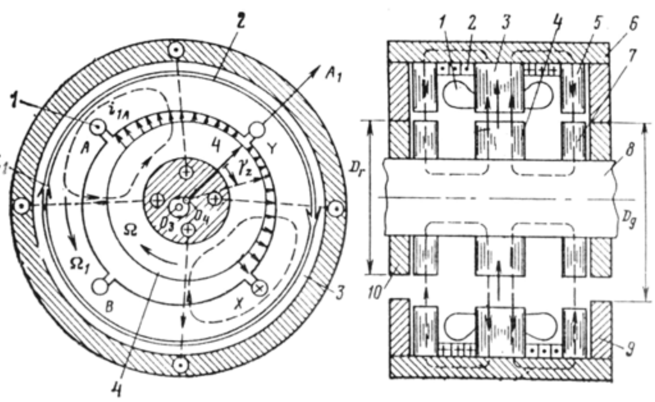


**Fig. 1 Electric engine whit rolling rotor (reproduced by [1])**

two windings, namely a heteropolar armature winding (1) and a homopolar field winding (2). Fig. 1 shows a two-phase armature winding, but it can be made three- or poly-phase as well. In any case, however, it must be a two-pole winding ($p_1$=1). The field winding consist in two symmetrically disposed coils encircling the shaft. The two-pole field set up by the armature winding has its path in the main stator (3) an rotor (4) cores. The two cores are smooth and built up of electrical-sheet steel lamination. The openings of the stator slots are so small that the effect of stator saliency on the performance of the motor may be neglected. The path for the excitation flux are provided by auxiliary stator (5) and rotor (7) cores which are likewise cylindrical and built up of electrical-sheet steel laminations. Thus, the magnetic circuit for the excitation flux has the following parts: the main gap, core 3, stator frame 6, core 5, auxiliary gap, core 7, shaft 8, and core 4. The rotor shaft mounts rollers 10. When driven by the rotating field, the rollers carry the rotor on cylindrical guides 9. The diameters of the rollers and guides, $D_r$ and $D_g$, are chosen so as to produse a sufficiently large gap eccentricity and so that the rotor core does not touch the stator core.

$$e= (\delta_{max}-\delta_{min})/2=\delta_{max}- \delta \quad (1)$$

That is, $\delta_{min} > \delta_{safe}$. Here, $\delta_{max}$, $\delta_{min}$, $\delta$ and $\delta_{safe}$ are the maximum, minimum, average (mean) and safe radial gap lengths, respectively. As is easily seen, the above requirement is satisfied when $D_g – D_r = 2e$.
The rollers and guides are made either toothed or smooth, of a special wear-resistance materials having a sufficiently high coefficient of friction.
A rolling-rotor is stated by exciting the field winding whit a direct current $i_2$ and by connecting its armature winding to a supply line at $f_1$. When excited, the field winding sets up a unipolar field in the gap, and the armature winding establishes a two-pole rotating field which travels at $\Omega_1=\omega_1= 2\pi f_1$. Fig. 1 shows the position that the rotor takes up at $i_{1A}=I_{1m}$ and $i_{1B}=0$, when the axis of the rotating armature field is aligned whit the axis of phase $A_1$. The gap is a minimum, $\delta_{min}$, on axis $A_1$, and a maximum at the diametrically opposite point, $\delta_{max}$. In travelling, the field tends to pull the rotor along. Since, however, the force of sliding friction exceeds the force of rolling friction, the rotor is moving down the guides on the rollers. After a time $T_1$, which is the period of change of current, the field axis turns through an angle $2\pi$ counter-clockwise, where it is again aligned whit axis $A_1$, the point on rotor (4) that was originally on axis $A_1$ will have turned through an angle $\gamma_z$ to take up the position marked by a dashed line. The angle $\gamma_z$ is the difference between the angles through which the minimum gap point moves on the surface of the rotor and stator, respectively, that is

$$\gamma_z = (D_g/D_r)\, 2\pi - 2\pi \quad (2)$$

As a result, the rotor turns at a speed which is a small fraction of the field velocity (and the opposite direction). As the rollers travel on the guides, they reduce the angular velocity of the rotor mechanically by a factor $D_r(D_g – D_r)$ in comparison whit the field velocity

$$\Omega = \gamma_z/T_1 = \frac{D_g - D_r}{D_r}\Omega_1 \quad (3)$$

The torque of a rolling-rotor motor can be found in a easier way, if we observe that electromagnetically it is a effect an induction-type synchronous motor whit a smooth stator and homopolar (axial) excitation. The ratio $D_r/(D_g – D_r)$, called the mechanically speed reduction ration, can be as high as 100 or even more. Owing to this, rolling-rotor motor can give very low rotational speeds, from several rpm to tens of rpm, and large torque.
A major disadvantage of rolling-rotor motors is that the centre of gravity of the rotor, $O_4$, moves round a circle whit the radius $O_4O_3$ at very high angular velocity, $\Omega_1$. This circular motion of the centre of gravity necessitates the use of suitably designed couplings to transmit rotation from the rotor to the output shaft, and also leads to vibration and noise in operation.

**Contributions concerning the realization of some experimental and prototype models of solar-electric engines with rolling rotor (SEE-RR)**

Further on, we shall present some of the results of the researches carried out by the authors in order to obtain a solar-electric engine, starting from the already known idea applied in electrical engineering: the idea of the rolling-rotor engine [2]. The solar-electric engine with

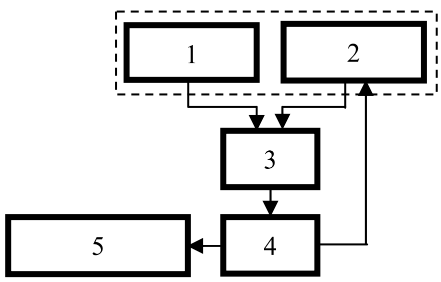



**Fig. 2 The block diagram of a solar electric engine with reduced speed**

rolling rotor is part of the category of solar electric engines with reduced speed, from where there can be obtained speeds reduced to up to a few rotations per minute, without using mechanical reducers. The block diagram afferent to a solar electric engine with reduced speed is shown in fig. 2, where the symbols are the following: 1-panel with photovoltaic cells; 2-solar-optical position transducer; 3-electronic switch; 4-synchronous motor; 5-system for orienting the solar converter after the sun.

The idea of a SEE-RR and axial electrical gap was developed within "Stefan cel Mare" University of Suceava by Professor Cernomazu Dorel and Professor Mandici Leon [3, 4, 5]. Thus, it took shape the first variant of the solar engine with rolling rotor and axial electrical gap in electromagnetic variant (fig. 3) [6]; this is built of a ferromagnetic rotor (1), under the shape of a disc, jointly fixed on a shaft (2), made of ferromagnetic material which is under the successive action of four electromagnets (2a), (2b), (2c), (2d) feed by means of some electronic driving circuits coming from a battery of photovoltaic cells (3), situated on an electrical insulated panel (4) directly exposed to solar light.

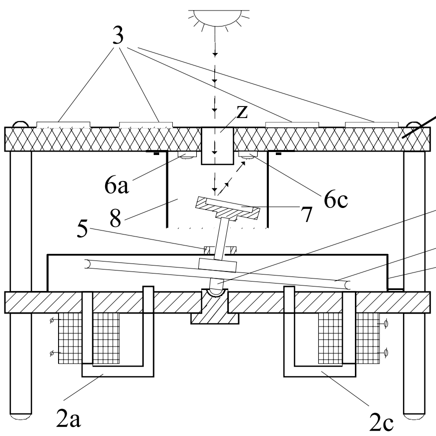



**Fig. 3 SEE-RR and axial electrical gap: longitudinal section.**

The successive drive of the electromagnets feeding circuits is made with the help of a solar-optical position transducer. For this purpose, the support plate (4) has in its center a circular hole (z), through which the solar light reaches a mirror (7), situated at the end of the rotor's shaft and which, depending on its inclination, reflects the light towards one of the photoelectrical elements (6a), (6b), (6c), (6d) situated on the opposite side of the plate (4) and protected by the daylight through a sun shade element (8) made as a tube, thus performing their successive excitation. The researches had also in view the improvement of the solar-optical position transducer, an extremely important element in the operation of the solar engine. One of the constructive solutions supposes that the solar light flux is directed through an optical line, made of a cylindrical rod of plexiglass and covered on the outside with a layer of reflecting material of foil paper [7]. The other solution supposes that the transfer of the

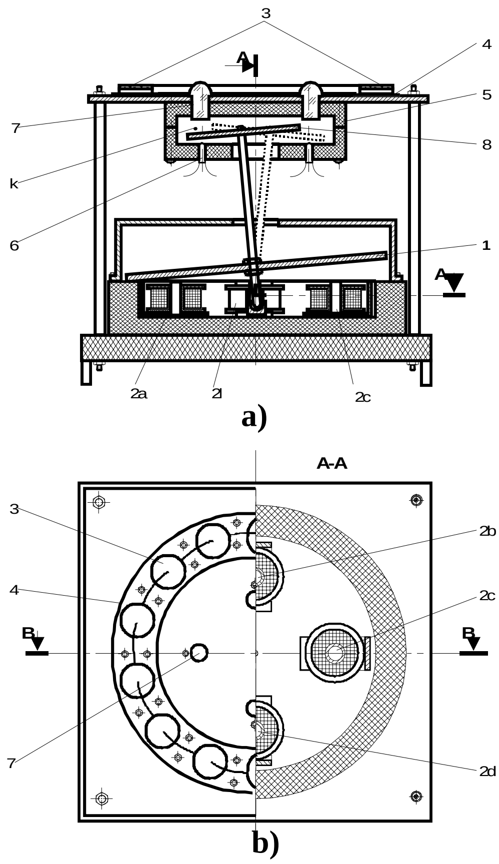
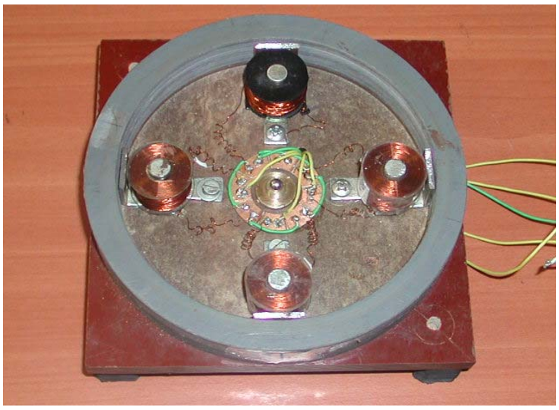



**Fig. 4 SEE-RR under a shape of a disc: a) longitudinal section; b) steps section.**

solar light flux to the mentioned photoelectrical elements is done through an optical fiber [8].

The experimental researches carried out by the authors have lead to the solution shown in fig. 4 [9], which has proved to be the simplest and safest solution. This variant is realized on the basis of the solution of the electric engine with rolling rotor under the shape of a disc, being mainly constituted of a rolling rotor under the shape of a disc (1), made of ferromagnetic material, which is under the successive action of four electromagnets, (2a), (2b), (2c), (2d), feed through some electronic drive circuits not shown in the figure, from a battery of photovoltaic cells (3), fixed on an electrically insulated panel (4) and directly exposed to solar radiation. The control of feeding the electromagnets, already mentioned, is made through a solar-optical position transducer mainly made of several optical-switching modules, each made of a short optical line (7) and a photoelectric element (6), mounted coaxially on a support (5) and having between them a gap (k) where a shutter disc drifts (8), fixed at the end of the shaft of the engine's rotor. The practical building of the stator can be seen in fig. 5a, and in fig. 5b there can be seen the SEE with the rotor and the solar-optical position transducer already mounted and ready for operation. In the secondary plane (fig. 5b), can be observed how solar-optical position transducer work. Can be seen the solar light flux (white spot) used to impress the photoelectric elements which give the successive drive of the electromagnets.



**a)**

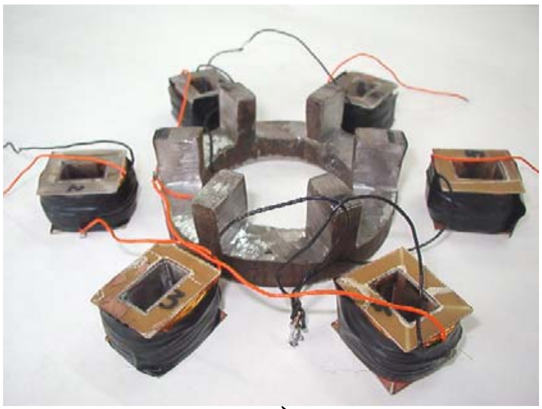
**b)**

**Fig. 5 SEE-RR and axial electrical gap: a) the stator motor; b) generale overview (practical achievement)**

The next variant of a solar electric engine with rolling rotor differs from the previously mentioned one from the point of view of the stator's geometry. This one is no longer made of four electromagnetic actuators successively feed from the power unit and positioned as in fig. 5a, but it is made of a built-up electromagnetic core, made of laminated core discs, where there have been made notches in order to mount the maximum number of electromagnetic actuators. Their number was calculated taking into account the dimensions of the electromagnet's coil, resulted after a preliminary calculus so that it can absorb from the power unit a very reduced current, under the conditions of the development of a very high electromagnetic attractive force. The geometry of the stator's core, before mounting the actuators, can be observed in fig. 6a. The stator of the solar-electric engine, equipped with the electromagnetic actuators, separated by the engine's case, and its rotor, are presented in fig. 6b; in fig. 6c there can be seen the final shape of the stator of the solar-electric engine with rolling rotor.

The reasons that have lead to choosing the stator's shape and that of the material used in building the stator are justified through the viewpoint of obtaining a large attractive force and a high responding time of the electromagnetic actuator. At the same time, by choosing this geometric shape for the stator's magnetic circuit, it results a much better use of the gap between the electromagnetic actuators over the whole circumference (fig.5a), wishing at the same time to bring the stator of the SEE to

a shape very close to that of the stator of a conventional electric engine.
The common ways of accelerating the operation of the electromagnetic actuators is mainly based on measures of constructive kind: the magnetic circuit made of laminated core discs; the use of ferromagnetic materials with great resistivity; reducing the rotor's mass.



**a)**

**b)**

**c)**

**Fig. 6 SEE-RR and axial electrical gap (practical achievement)**

Thus, can be increased the actuator's inductance, the attractive force increases, but this increase leads to the reduction of the responding time.
On the other side, the increase in inductance leads to the decrease in the current, which reduces force, resulting in the end in the increase of the responding time. Because of this, there has to be reached the best inductance for which the responding time is minimum.
The problem is the creation of an attractive force of the rotor by the stator, so that the rotor remains permanently in point-like contact with the stator and the application point of this force moves continuously on the periphery of the stator. If the stator is smooth, made of ferromagnetic material (massive or laminated), and the stator is also smooth, with a spinning field with a very dense distribution within the electrical gap, then the attractive magnetic forces accomplish the required conditions. Because the stator has notches, the stator-rotor contact being not perfect, there are approximately accomplished, the conditions required through the use of a rolling way, separately by the rotor and the stator, with a very smooth surface and which allows the eccentric rotation of the rotor within the stator. The stator-rotor electrical gap varies between a minimum-limited admitted inferior mechanical value in order not to create the stator-rotor contact, and a maximum value which results from the condition of imposed speed. The rolling way presents certain elastic non-deflecting properties, attenuating the noises and increasing friction in order to eliminate the possibility of sliding (skidding).

## Conclusions

The electric solar motors with reduced speed represent the best suited solution for building some systems for orienting after sun the panels with photovoltaic cells, the heliostats and the solar collectors with concentrator. This conclusion is related to the simplicity and safety in exploitation that SEE with reduced speed offers. In the event of a SEE-RR, the attention of the authors was concentrated on the electromagnetic actuators that it is made of. Finding the best solution for the electromagnetic actuators used in producing the solar-electric engines with rolling rotor studied by the authors, is conditioned both by the performances of the photocells included in the photovoltaic source and by the constructive characteristics of the electromagnet that constitutes the main element of an actuator and from which it is requested to absorb a very reduced current from the power unit, under the conditions of the development of a very high electromagnetic attractive force. Starting from these two requests, the authors have found the best solution for the electromagnet, taking into account, obviously, the case's dimensions and the current sizes of the existing winding conductor.

The engine with rolling rotor has a relatively simple construction. Its qualities make it stand out at operations at reduced speed instead of the classical gear motors. Its functioning duration is much longer than that of the servomotor-reducer sets used in various applications. The starting current is reduced, the power unit allowing a great number of commutations within a certain time. In what the efficiency is concerned, there are two optimums that have to be harmonized: an optimum at the level of the photovoltaic source and an optimum at the level of the engine itself. In the future, it is necessary a study concerning the insertion processes met when switching the sections of the stator winding through photovoltaic cells, and solutions concerning the optimization of the magnetic circuit of the solar-electric engine by using the method of the finite element.

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