CONTRIBUTIONS CONCERNING THE IMPROVEMENT OF SOME SOLAR ENGINES WITH FLEXIBLE WAVE-ROTOR

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Abstract. *In this paper we present the results of the preliminary research performed by the researching team from "Ştefan cel Mare" University of Suceava, in the Laboratory of Energy Conversion, in order to obtain an engine designed for the continuous functioning of special installations (solar converters whit focusing, photovoltaic cell panels, heliostates etc.). The researches make reference to the solar engine whit flexible wave-rotor and especially to the rotor designing. There are presented a few constructive solutions which ensure a secure operation of solar engine.*
Keywords: *solar engine, flexible wave-rotor.*

1. Introduction

The solar engine whit flexible wave-rotor was developed and mentioned for the first time by Ivanov-Smolenski in 1980 [1]. The idea of the engine whit flexible wave-rotor is presented in the specialty literature in two variants: when the rotor is made under the shape of a flexible cylinder successively distorted by the forces of electromagnetic nature [1] and when the rotor is made of a solid material, which cannot be distorted, which is under the action of a intermediary flexible and distortable element made of a ferromagnetic material and gradually distorted under the action of the same forces of electromagnetic nature [7]. Further on, we shall make reference to the first constructive variant.

While in operation, the fixed coil produces a spinning magnetic field which is a bipolar magnetic field in the simplest variant. This magnetic field actuates over a ferromagnetic flexible rotor which leans on a support in a fix position. Under the action of the radial electromagnetic forces created by the spinning magnetic field, the flexible rotor distorts and takes the shape of an ellipse whit the main axis

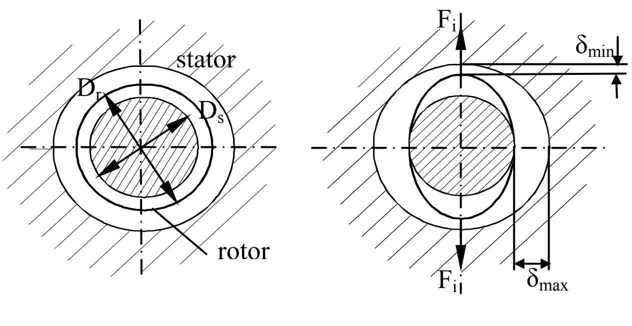


Fig. 1 The rotor configuration in repose (a); the rotor configuration while it is under the action of a pair of electromagnets (b).

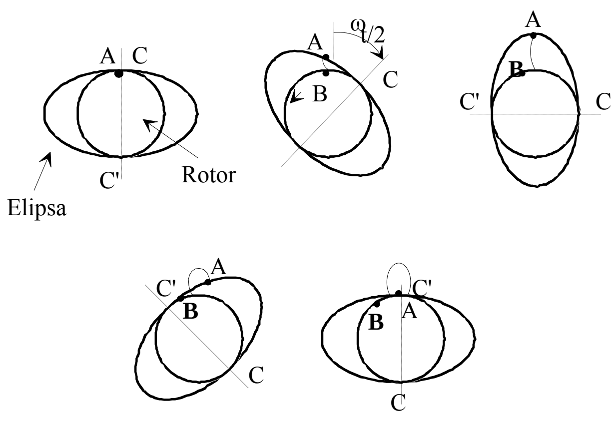


Fig. 2 The evolution of the cylinder configuration for a complete rotation

headed towards the direction of action of the electromagnetic forces (fig. 1). The evolution of the configuration of the flexible rotor distorted under the action of the spinning magnetic field is shown in fig. 2.

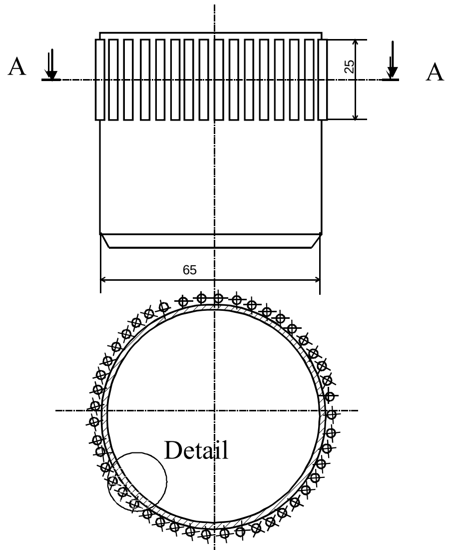
Due to the friction that appears between the flexible cylinder and the guide, there result some tangential forces that impart to the rotor a rotation sense which depends on the geometric configuration and on the sizes of the ferromagnetic cylinder and of the guide. In order to improve the functioning of the engine, the authors have made and experimented more types of flexible rotors. The interest shown by the authors for the engine is related to the prospect of using it within a system for directing after sun some solar collectors whit concentrator or some panels whit photovoltaic cells.

Contribution concerning the construction and the experimentation of some ferromagnetic flexible rotors [2, 3, 4, 9]

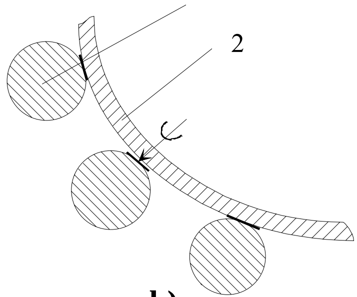
As a consequence of the experiments carried out, it has been established that the radial electromagnetic forces which activate over the flexible rotor are not always powerful enough in order to perform a secure operation. The previous observation is related to the prospect of using the photovoltaic sources when feeding the engine. In this sense, the authors have tried to optimize the engine operation under the condition of some relatively reduced electromagnetic forces, imposed by the use of photovoltaic sources.

One of the solution is shown in fig. 3. The flexible rotor is made of a thin aluminium sheet on which there are stuck, whit an adhesive, some ferromagnetic cylindrical bars whit a diameter of 2,5 mm, placed at a distance of 1-2 mm between them. Thus, it is obtained an electromagnetic armature joined with the flexible cylinder, which leads to the optimization of the magnetic coupling between the fixed coil and the rotor. The solution has the advantage that there are obtained some rotors with the flexible support made of non-magnetic materials. What remaining important is the flexibility of the support for the bar. One of the shortcomings observed is related to the relatively law reliability.

The improvment of the previous solution was



a)



b)

Fig. 3 Flexible rotor whit ferromagnetic armatures made of cylindrical bar: (a) general overview; (b) 1- aluminium-sheet cylinder; 2- ferromagnetic armatures made of cylindrical bar

possible through the modification of the way of immobilizing the bar son the flexible surface (fig.4). It was used an elastic cement having both an adhesive function and one of distancing the ferromagnetic bars.

The experimental tests have pointed out the following shortcomings: unsatisfactory behaviour at temperatures over 40 degrees, when joining the ferromagnetic bars with elastic cement becomes unsure; the assembly's elasticity is reduced because of the elastic cement.

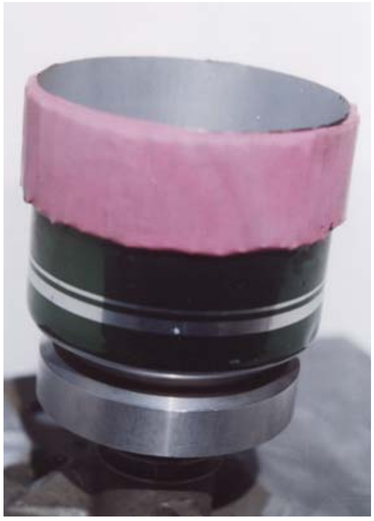
Eliminating these shortcomings has proved possible through the use of a thin, rubber band, placed over the layer of elastic cement used in order to fix and tos pace the bars from the elastic support (fig. 5a and fig. 5b).

Fig. 4 Flexible rotor with ferromagnetic armatures of cylindrical bar, fixed with adhesive (practical achievement)

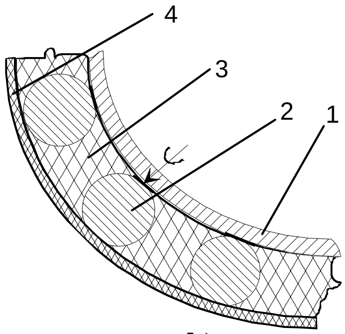
The experimental investigation have lead to the conclusion that the use of the rubber band brings a plus of elasticity, that creates some antagonist forces which reduse the action of the electromagnetic forces created by the fixel-coil assembly. We add to this, the danger of the rubber band's early destruction in the presense of vapours of petroleum products. The temperature variation, specific to the environment where the engine has to work, lead to the rubber ageing and to the engine destruction. Eliminating the mentioned shortcomings was possible due to the experimenting of the solution presented in fig. 7a and fig. 7b.

The ferromagnetic bars have in the middle area a gap which allows the mounting of a flexible bandage also made of ferromagnetic material and which allows the fixing of the bar assembly on the surface of the flexible support.

Shapin the middle part of the bars creates the possibility of sustaining the bars through the mentioned flexible band but it leads to an increase in the magnetic reluctance of the magnetic circuit. Eliminating this shortcomings as possible due to the adequate increase in the diameter of the aluminium bars and to the reduction of the flexible band's width (fig. 6).



a)



b)

Fig. 5 Flexible rotor: (a) general overview; (b) detail concerning the fixing with rubber band: 1- flexible cylinder; 2- ferromagnetic bars; 3- elastic cement; 4- rubber band. (practical achievement)

Further on, the optimisation was possible due to the use of some smooth bars (without the middle gap). In order to fix the bar son the elastic support, they were perforated axially, allowing the use of some fixing anchors made of a ferromagnetic material with identical performances with those met at the bar itself (fig. 8).

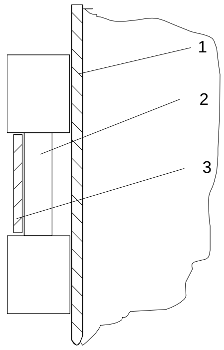


Fig. 6 Fixing the ferromagnetic armatures with flexible ferromagnetic band:
1- flexible cylinder; 2- ferromagnetic bar;
3- flexible ferromagnetic bar.

a)

b)

Fig. 7 Flexible rotor
a) general overview; b) detail.
(practical achievement)

The disadvantage of this solution is represented mainly by the spaces relatively large between the bars. The size of these spaces is accentuated by the curvilinear profile of the bar's section. All the other things shown lead to the increase of the magnetic reluctance whit the practical implications already shown.

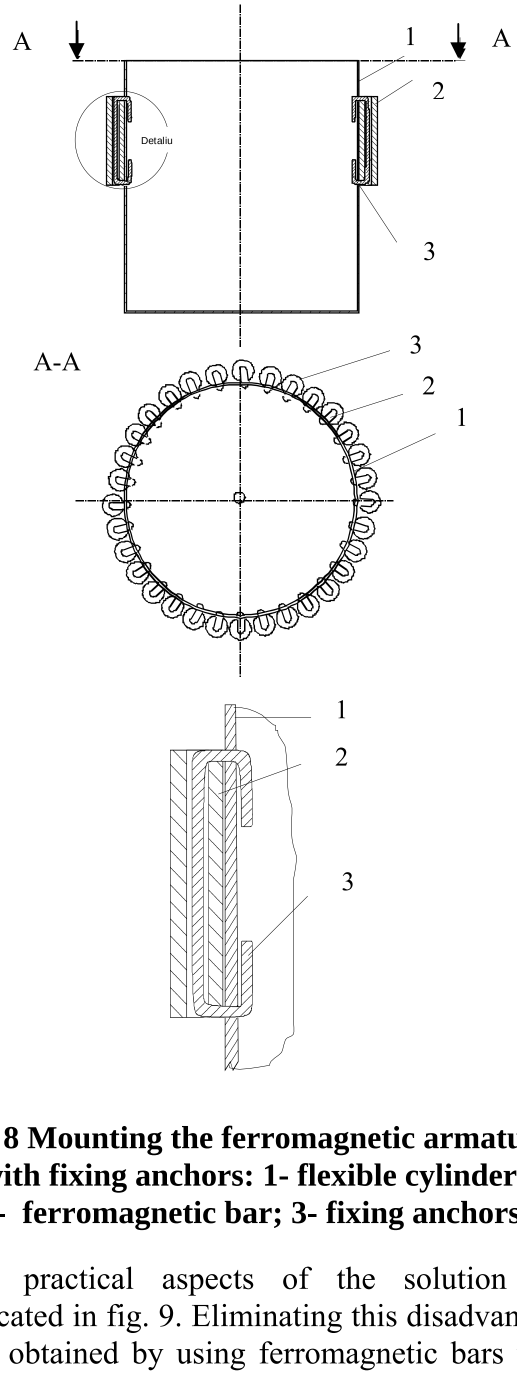


Fig. 8 Mounting the ferromagnetic armatures with fixing anchors: 1- flexible cylinder;
2- ferromagnetic bar; 3- fixing anchors.

The practical aspects of the solution are indicated in fig. 9. Eliminating this disadvantage was obtained by using ferromagnetic bars with rectangular profile (preferably right-angled) fixed on the elastic support through anchors (fig. 10).

The succession of improvements is continued through the use of the psychological technique of creation known under the name of „inversion technique”. Using the question „…why inside and not outside”, we arrive to the solution of placing the electromagnetic bars on the inner side of the elastic support (fig. 11).
All this solution of flexible rotors have used to obtain constructive solutions of solar engine with flexible wave-rotors [5,6,8].

Fig. 9 Flexible rotor with ferromagnetic armatures mounted by means of the fixing anchors (practical achievement)

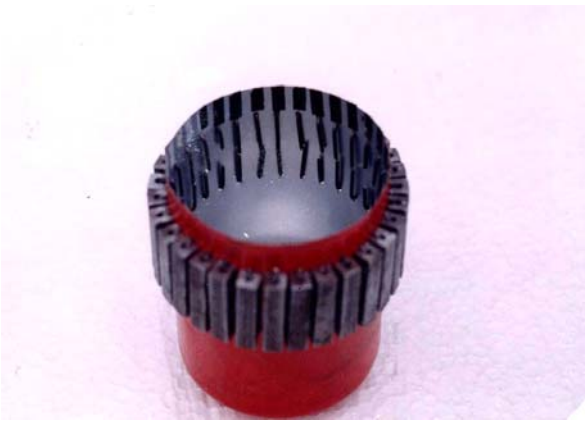


Fig. 10 Flexible rotor made of ferromagnetic armatures with rectangular section; detail concerning the aspect of the rotor’s inner surface (practical achievement)

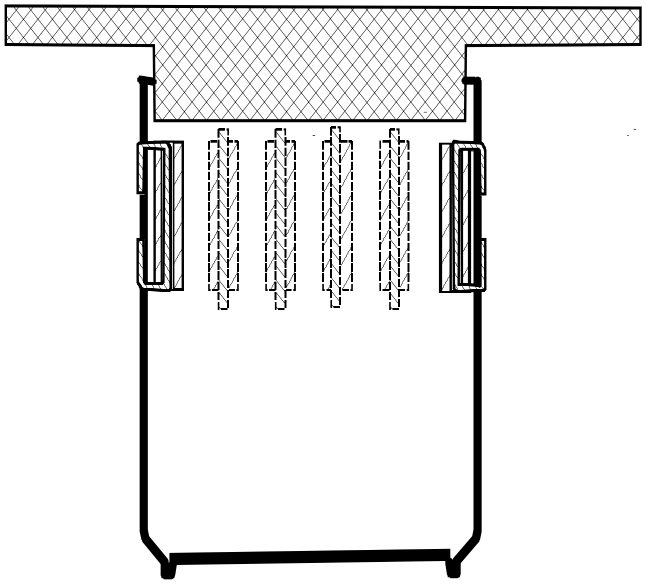


Fig. 11 Flexible rotor with ferromagnetic bars placed on the inner surface of the flexible support

Conclusions

The electrical engine with flexible rotor is a engine which develops high torques at relatively reduced speeds. Such as engine, which is promoted or used in automatic systems for directing some special-type converters after the sun, presents the advantage of eliminating the reducer from the cinematic chain.
By using the solution of ferromagnetic armatures fixed on the flexible support, it is created the possibility of using a relatively wide scale of ferromagnetic materials; within this scale there can be also included non-ferromagnetic materials and even plastic materials.
The tests carried out in the laboratory have pointed out that the flexible support made of aluminium alloys is the best solution.
The use of plastic materials is limited by the danger of the relatively fast ageing under the action of temperature and solar radiation.
Out of the constructive solution analyzed in the laboratory, it has stood out as the best solution of bars whit rectangular profile fixed on the flexible support by means of ferromagnetic anchors.

References

[1] IVANOV-SMOLENSKI, A. *Electrical machines. Rolling-rotor and flexible wave-rotor motors.* Moscow: MIR Publishers, vol. II, p. 438-444, 1980.

[2] UNGUREANU, C.; MANDICI, L.; CERNOMAZU, D. *Consideration regarding the achievement of the solar-electric engines.* In: The 2004 International World Energy System Conference - A Reliable World Energy System, University of Oradea, 17-19 May, 2004, p. 164-167, ISSN 1198-0729.

[3] LUNGU, D. *Contribuții la proiectarea, realizarea şi experimentarea unor motoare solaro-electrice de joasă viteză. Contribuții la realizarea unor modele experimentale - proiect de diplomă.* Suceava: Universitatea "Ştefan cel Mare", Facultatea de Inginerie Electrică, 2003.

[4] UNGUREANU C. *Contribuții teoretice şi experimentale privind realizarea şi experimentarea unor motoare electrice solare.* Referat III, în cadrul programului de pregătire pentru doctorat. Conducător ştiințific: prof. dr. ing. Dorel Cernomazu, Universitatea ''Ştefan cel Mare'' Suceava, Facultatea de Inginerie Electrică, 2002.

[5] CERNOMAZU, D.; UNGUREANU, C.; SIMION, A. *Motor solar*, Cerere de brevet de invenție, nr. A/01291 din 14.10.2002, O.S.I.M. Bucureşti.

[6] CERNOMAZU, D.; UNGUREANU, C.; LEONTE, P.; SIMION, A. *Motor solar*, Cerere de brevet de invenție, nr. A/01344 din 31.10.2002, O.S.I.M. Bucureşti.

[7] MUNEAKI I.; HAMAGUCHI, J.; SHIRASUKA, K.; HORI, T. *A new friction-types piezoelectric motor utilizing mechanism of the strain wave gearing*. În: IEEE Transactions on Industrial Electronics, vol. 39, No. 1, february, 1992, p. 30-35.

[8] UNGUREANU, C.; LEONTE, P.; CERNOMAZU, D.; SIMION A.; MANDICI, L. *Motor solar*, Cerere de brevet de invenție, nr.A/01461 din 14.11.2002, O.S.I.M. Bucureşti.

[9] UNGUREANU C. *Stadiul actual al cercetărilor privind motoarele şi micromotoarele solare.* Referat II, în cadrul programului de pregătire pentru doctorat. Conducător ştiințific: prof. dr. ing. Dorel Cernomazu, Universitatea "Ştefan cel Mare" Suceava, Facultatea de Inginerie Electrică, 2002.