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Film Electromechanical Motor Homogeneous Space As a Way to Ecological Technology

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V.L.Diatlov, Yu.G.Kosarev

Introduction

1. Spontaneous population growth on the Earth and man's reckless propensity to satisfy his ever increasing demands rather through accumulation of means of violence against the Nature than by harmonizing his relations with it have infringed the natural course of evolution and pushed it from the trajectory of harmonious growth of the noosphere (i.e. the sphere of reason) to a trajectory of perilous hypertrophied growth of the technosphere (Fig.1). Man thus has put himself in a situation of a crucial need to find in a short enough time (before this process has become irreversible) another way of satisfying his needs that would not require vast natural resources and be not accompanied by dangerous pollution of environment [1].

The situation is aggravated by that over the entire previous course of human history man had never been faced with a problem of such a scope and danger and, therefore, has been now caught unprepared to approach it either prognostically, or methodologically, or practically.

2. The main consumers of natural resources and main sources of environmental pollution are engineering and the power industry. And dominant is the former being the principal consumer of power. In machine building, in its turn, the leading role is played by electric machine engineering which is a major consumer of high quality materials and power, i.e. of a high-cost type of energy. (Thus by estimates, electric motors consume about 70 percent of total electric power [2]).

Since one can hardly expect whatever significant decrease in the scope of the use of machines, *the solution of the ecological crisis is directly dependent on the possibility of great (by orders) decrease in the material intensity of electric motors.*

3. According to [3] by *material intensity* is meant the consumption of material resources, i.e. of *objects of activity:* feedstock, materials, completing articles, fuel, power etc. and of *means of activity,* i.e. machines, equipment, instruments etc. needed per unit of production. For our purposes, total input of material resources **R** it is convenient to relate to the *paying work* **W** *performed by the machine over its entire lifetime.* Then material intensity **M** of all branch of machine building is :

$$M = R/W = (R_0 + \Sigma R_i)/\Sigma N_i \eta_i P_i T_i , \qquad i = 1,...,S, \qquad (1)$$

Where R_0 is the total consumption of resources per industry (construction, infrastructure etc.); R_i is consumption of resources on the i-th type of motor; N_i is the number of motors of the i-th type with the efficiency η_i , power P_i and average service life T_i;

Material intensity can be measured in physical units (which is inconvenient) or in monetary units (which is convenient but hardly practicable) per Joule. In order to evaluate the quality of a particular motor, a more simple (technical) measure is often used - its mass to power ratio, or the reciprocal - *power intensity* [W/kg].

4. Microminiaturization of products also can permit to reduce the sizes of machines and enterprises in general, to diminish the scope of construction work and power consumption and to approach the problem of pollution effluence (their amount will be lower and the sources localizable [4]).

The appearance of light and compact electric motors can substantially reduce the need of use in transportation of internal combustion engines which are the main source of air pollution. And which is all important, the passage to a new ecological designing-technological basis will lead to *the liberation of Man from the tyranny of machines* and from the need to adjust himself and environment to the callous world of primitive machines-monsters (see Fig. 1, point 5).

Therefore, the reduction of material intensity of electric motors has a key importance both for engineering as such and for ecology in general.

All this permits us to define the reduction of electric motor material intensity as a major problem of modernity.

1	Explosive population growth under a severe deficit of new places for habitation.
2	Sharply increased needs in living resources and in arms for defence of own land and for seizing somebody else's.
3	Active exploitation of natural resources by industrial methods under the conditions of ineffective resource-intensive technological base.
4	Mass production of high power, heavy machines; complicated in making, requiring specific operation conditions and able to perform only the simplest set of operations.
5	Submission of the entire human activity to the tyranny of machines. The creation of large industrial centers producing machines and a vast infrastructure to serve them. A sharp increase of power consumption and transportation flows. The allotment of vast lands to extractive industry and for other industrial needs. Withdrawal from crop rotation of many efficient kinds and types of plants uncompatible with the existing equipment. Soil erosion in the result of its hard treatment and tamping by heavy machines *etc.*
6	Collapse of conditions for the existence of living beings: violation of heat balance and the hole in the protective ozone layer of the Earth; the appearance of some morbific microorganisms against which man and other living beings are unprotected.
7	Further aggravation of ecological crisis and demise of the existing civilization.

Fig. 1. The Trajectory of the Hypertrophied Growth of Technosphere.

1. Ecological Designing Technological Basis.

1. We have already mentioned the crucial need in immediate switch-over of machine building to a new (highly ecological) designing-technological basis which will be direct opposite to the present (nature ruining) one by all its essential properties (Table).

All properties given in Table, directly or indirectly, characterise the impact made by technical means on Man and Environment.

Microminiaturization in combination with *integrated-circuit technologies* allows, in a single technological process, to make within a small size an enormous number of elementary devices. This greatly decreases both consumption of materials (including high-price, scarce and toxic ones) and the needed operating areas. The decreased size of the working body of machines makes it possible to essentially increase their operational frequency and, hence, power P_i, which is very important.

Transition to the use of systems of machines allows to do without giant machines flexibly accumulate and distribute power to avoid serious failures etc.

Increased longevity, reliability and survivability of machines increases the time of their paying work T_i and decreases their material intensity.

Precision in combination with *microminiaturization* permits to create effective robotized technologies, makes complicated and cumbersome drive mechanisms unnecessary etc.

Universalization and specialization. Universal equipment is always ready for operation but the efficiency is low; specialized equipment has high efficiency but wide application involves high capital costs. Only the combination of these two qualities (achievable in case of programmed adjustability of functional properties) allows considerably decrease material intensity. This combination can be achieved by *expanding the range of machine power* and, especially, by *programmable (flexible) technologies.* Note that such technologies exercise a reforming influence on the market too, transforming the commodity market into a market of orders. (Decreased are losses of stocked commodities, no need to store tremendous reserves of finished products etc.) [11].

All the properties shown in Table,B are well compatible and all together form that designing-technological basis the transition to which can permit to decrease the hazardous effect of machines on Man and Environment by several orders.

2. Integrated-circuit Technologies in Computers

1. In looking for positive ideas able to help to create desirable properties in machine-building it makes sense to rely on the experience in the development of computing equipment where something like that has been occurring before our eyes. (Note that formula (1) can be extended to computing industry if power is measured in operations per second, work in operations and efficiency as the percentage of algorithmic operations to their total number).

The initial period in the development of the computation equipment the peak of which characterized by huge, low-power and wayward machines-monsters, series IBM 360/370 (and its analogue ES EVM) is very similar to the current state of mechanics (Table, A).

The present state of the computation equipment characterized by the dominant role of desk personal and multi-processor super-computers, in some properties already responds to what is desired (see Table, B) and in others tends to.

2. The main point which well pays off the vast costs of the development and industrial production of integrated-circuit technologies in computation equipment is a *double gain of power* achievable by combination of two factors: *increased operating frequency* and *joint operation of a large number of elementary computing devices* created in a single technological act. Potential possibilities of these two factors are different. The number of devices can be in principle whatever large while the operating frequency has quite a definite limit determined by both physical and technical factors (heat withdrawal, propagation time, noise immunity, reliability etc.)

3. Designing approaches best compatible with integrated technology, microminiaturisation and other desirable properties from Table,B in a concentrated form are expressed in the idea of computation space and systems proposed three decades back [5-7].

This idea is based on three principles: *parallelism* (computation is performed by harmonized simultaneous operation of a great number of elementary machines (elements of space); *homogeneity* (M elements of space are the same, have the same functionally complete sets of operations performed (automative and commutative) and are placed in units of the homogeneous structure of communications); *programmed adjustability of properties* (each element of space can be programmed to the performance of any operation from the available sets).

Table

N	Main properties of the designing-tecnological basis	Phases of antroposphere: technospheric (A)	noospheric (B)
1	Man to Machine relation	*Tyranny of machines: degradation of Man and Environment; harm inflected as the result of frequent accidents*	*Authority of reason: total control over machines; their friendliness, safety*
2	Ecological safety Power intensity Microminiaturization	*low (by orders lower than in living beings)*	*high (comparable with natural "constructions")*
3	Dominant technology	*assembly line*	*integral*
4	Dominant way to increase productivity	*increased capacity of separate machines*	*increased capacity of systems of machines*
5	Reliability and survivability Longevity Precision Power range of machines	*limited*	*practically unlimited*
6	Combinativeness of universalization and specialization	*universalization* **or** *specialization*	*universalization* **and** *specialization*
7	Readjustment of functions and switch over to a new type of machines and technologies	*long and high-cost (apparatus)*	*fast and low-cost (programmed)*

3.Integrated-circuit Technology in Electric Machine Industry

1. The possibility of application of integrated circuit technologies in the production of electric motors largely depends on the answer to the main question: just what advantages over a single motor (comparable in size or mass) will exist in case of many micromotors of the same type. It is necessary, therefore, to answer the same question as with regard to computational equipment where as was mentioned above there is a double effect: due to increased operating frequency and due to increased number of micromachines working in parallel *each of which (at the same operating frequency) is equal in power to large machines.*

In the electric machine engineering each one of the N micromachines which has 1/N size of an ordinary machine will have 1/N of its power too (at the same frequency of their operation, of course). That is, in *electric motors the gain can be obtained only by an increase in their operating frequency.* However, since the operating frequency cannot be higher than the natural frequency and in inductive motors and in ceramic piezoelectric motors it is small, the use of integrated-circuit technology in them does not make much sense [8].

2. For a noticeable increase of the natural frequency it is necessary first of all to decrease the weight and size of the motor working body. Just this can be achieved in film electromechanics. As was shown by calculation and experiments, the *operating frequency of film motors can be raised up to 5 kH which is 100 times as high as frequencies usually used in inductive motors [9].*

Therefore, *the properties of film electric motors make it quite possible to use the integrated-circuit technology in machine building.*

3. In order the integrated-circuit type of technology be used in electric machine engineering it is necessary first to find such physical principles and designing approaches which might allow to reduce motor sizes (down to miniature ones) and at the same time increase their power intensity. As was already mentional, for these purposes inductive and ceramic piezoelectric (vibrational) motors prevailing at present in electric motor engineering (Fig. 2) are hardly suitable. At the same time it is film capacitance motors (by the way almost entirely ignored by business) which display an unique ability at miniaturization together with a high power intensity, reliability and precision [8, 9]. So just they should be counted on in the future.

4. In Fig. 2 for inductive and piezoelectric motors the values of parameters taken from concrete occurrences are shown, while for film motors (space elements) only tentative limits are indicated (1). The reason is that in film motors almost all the mass is accounted for by substrates the thickness and material of which can perceptibly vary. The concrete occurrence of the motor space element determines also the power intensity of the whole space (see point 1). Therefore, from each point of field (1) a horizontal line goes (to field (2)) whose each point corresponds to the number of space elements.

4. Motor Homogeneous Space

1. The unique quality of film motors (see Fig.2) is manifested not only in the field of low and super-low powers and sizes. They can compete with inductive and monolithic piezoelectric motors and in average and high powers. There are two mutually complementary ways to enhance their power (see Parts 2,3).

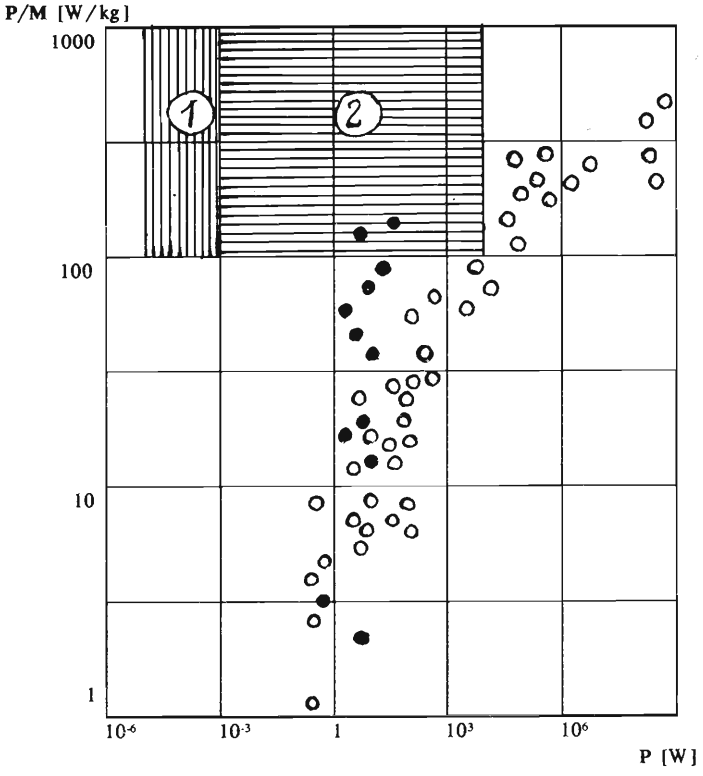

Fig.2. Power Intensities of inductive (o), piezoelectric (•) and film capacitance motors (generators). 1-elementary motors; 2-motor homogeneous space; P-power; M-mass.

The first way is to raise the operating frequency (*vibrational principle*). It is the most simple and low-cost way to increase power. And, which is very important, *power increase is then accompanied by proportional increase of power intensity.* The possibilities to enhance power in this way are restrained by natural resonance frequencies of motors and, if they are increased through miniaturization, tolerance values of power are determined by such physical factors as heat release, reliability etc. Vibrational principle is widely used in piezoelectric motors [10].

The second way is to enhance the number of devices operating concurrently within the same program (*principle of parallelism*). On its basis, it is potentially possible to obtain *whatever high increase in total power at the same value of power intensity.*

2. The principle of parallelism has been thoroughly investigated with regard of computation (see Part 2). It yields the highest effect when combined with two other principles, i.e. *homogeneity and programmed adjustability of the properties.* At the *microlevel* this has led to the idea of *homogeneous computation space* [7] and at the *macrolevel* to the idea of *homogeneous highly efficient computation systems* [5, 6].

3. Similarly we can speak of motor homogeneous space [8]. By motor space meant is a set of identical elementary motors joined into a homogeneous structure each of which possesses a number of mechanical functions, is able of being software adjusted to any of them and performs it simultaneously with all other space elements.

4. As a matter of course, in the models of film motor homogeneous space specifically purposed for commercial production strictly definite relationships among mechanical and electrical parameters should be observed and their limiting characteristics recognized [9]. Just in order to determine these relationships many years of theoretical and experimental investigations were required in the result of which a theory of electromechanical phenomena, methods and software package for engineering computations have been developed [8, 9].

5. For film capacitance motors as space elements it is very promising to use the phenomena of rolling (Fig.3) [8,9]. In a voltage feed between an immovable base covered with insulating layer and a film tab fixed to a movable platform with the film tab, the latter, under the action of electrostatic forces, is spread on the base thus displacing the platform at one step. After voltage removal, the tab, under the action of elasticity forces, "comes off", slides on the base and takes its initial position.

6. Note that this type of motors allows to achieve the same record-breaking travel accuracy of angstrom fraction order like the piezoelectric motors [10]. Such a high precision (apart from its own inestimable value) is one of paramount prerequisites for joining such motors into an aligned set of devices, i.e. a motor space (Fig. 4) [8].

7. The similarity of properties of motor and computation homogeneous space and their mutual complementarity permit us to pose a question about their joint production within the framework of the common integrated-circuit technology.

5. Specific Features of Machines Designing on the Basis of Motor Homogeneous Space.

The transition from the paradigm now dominant in machine building to the new design-technological basis will also require new approaches and solutions in the field of electric machine designing. The latter include the following.

1. *Common properties*:

 # dispersal. Low price and small sizes of the electromechanical space chips produced with the help of integrated-circuit technology justify the use, instead of a single powerful motor, of a certain (generally, quite large) number of motors working in accord. For example, instead of one large pump which has to create a high pressure at the input in order to overcome the resistance of the whole main, there appears a possibility to install many pumps along the main. Then not only the required total power but also material intensity of pipes can be reduced (due to lower pressure at the input).

 # programmed change of functional properties. A possibility of programmed monitoring of the motor space permits to switch on and off particular elements as well as flexibly change their power, direction, speed of rotors displacement with regard to stators by changing their operation frequency.

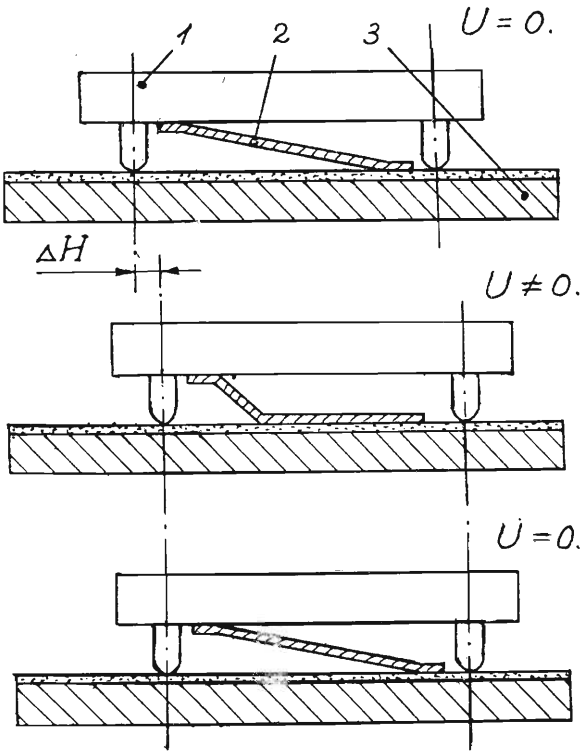

Fig.3. The Illustration of the Principle of Action of the Film Capacitance Motor. 1-movable platform; 2-film tab; 3-immovable base covered with insulating layer. U-potential difference between tab and base. ΔH-the value of displacement at one step.

#substitutability, reliability and survivability. Space homogeneity (i.e. the sameness of all its elements and the identical structure of their links) permits, without additional costs to make with the help of integrated-circuit technology such a number of space elements which is needed for safe performance of the required functions in case some elements are out of order (both during their production and operation).

#substitution of translational and discrete motion for rotary and continuous motion. So the kind of motion inherent to inductive motors is replaced by that inherent to film capacitance motors. While earlier the design approaches had to be adjusted to motors of rotation and, to convey translational motion to the object, some additional converters were needed, step motors can directly convey to the object both translational and rotary motion (for example, by placing space elements along the circle of the rotor shaft).

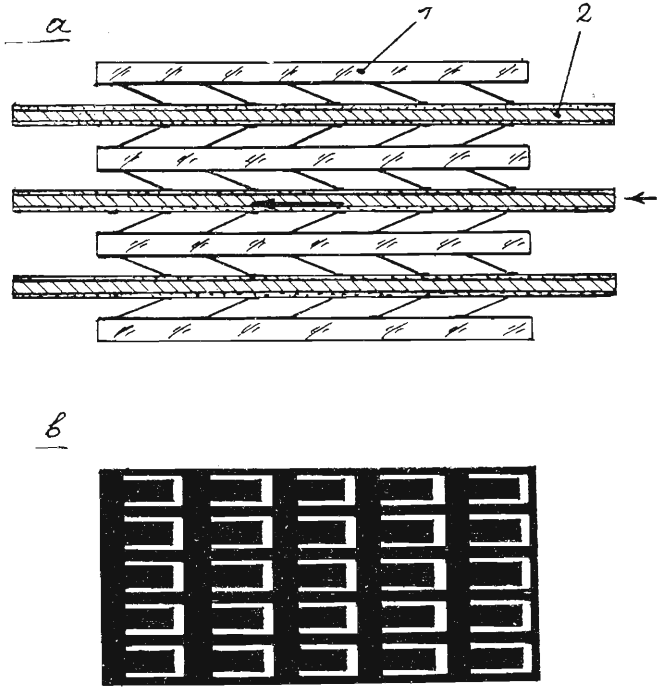

Fig. 4. An Example of Film Capacitance Motor Homogeneous Space.
a) cross-section. 1 - stator plates; 2 - rotor plates. b) Top View of the Stator Plate. direction of rotor plates movement in relation to stator plates is shown by the arrow.

using motor homogeneous space together with computational and receptor homogeneous space [8]. This very promising inquiry line is of such a universal character that it needs special discussion.

2. *Use of designs borrowed from the living nature.* Film electric motors by their characteristics (power intensity, microminiaturization etc.) are close to the level of the living nature. This opens an opportunity to create on the basis of motor homogeneous space a number of new designs:

propellers able to flexibly change their shape (like dolphin's skin, fish tail, bird's wing, worm's body) and thereby remove the turbulence component of space (water, air, soil etc.) resistance;

artificial inner organs able to perform the same functions as heart, vessels, stomach, bowels etc. These designs can be relevant both to medicine and to different fields of engineering;

artifictal limbs may appear invaluable not only for invalids but with regard to different industrial and research processes as high-precision and convenient manipulators.

3. *Use in the field of information.* Matrix form and other properties of film motor homogeneous space (possibility to achieve high resolving power and required chromatic spectrum as well as sufficient speed of action) make them competable in the field of information display (boards , desks and control panels, television screens) with inductive motors (by cost, weight, reliability, power consumption etc.), with devices on liquid crystals (by range of operating temperatures) as well as with cathode-ray tube (by absence of harmful radiations).

4. *Precision devices:*

exclusion of intermediate drive elements owing to the possibility of planing the motor in the immediate contact with the instrument (propeller) which will permit to diminish the sizes of robots and simultaneously to improve their precision;

highly accurate displacements (mechanisms for tape transport, displacements of reading heads of disks etc.);

changed size of membrane holes (in order to change the conditions of solutions filtration, to shift the point of sodium - potassium balance etc.);

creation of optical systems with program adjustable parameters (step of diffraction grating, lens curvature etc.).

5. *Gates with remote control.* The power of fraction in film capacitance devices little depends on the rod travel length. This permits to create on their basis simple, economical and reliable remotely controllable devices for various gates, to monitor dangerous processes etc.

6. From Tyranny of Machines to Authority of Environment

1. The transition from nature-ruining machines-monsters to machines created according to laws of the nature, by their material intensity close to living organisms and capable of harmonious Man-Environment interaction will necessarily lead to a radical change of the entire present civilization.

2. Man and Environment will become free from the need to adjust themselves to machines (mechanical as well as computational).

The vicious custom to stuff ourselves from the very childhood with every new type of "machine knowledge" such as, e.g., programming will die off. No longer will it be necessary to do harm to one's health sitting before high-voltage screens. The screens with passive lighting created on the basis of film-mechanical homogeneous space will be better for eyes than books (due to image colour and size adjustability).

3. A possibility will appear to qualitatively perform mechanical work in different fields such as construction, agriculture, processing of form products, culinary, pharmacology, chemistry, genetics, medicine etc. where at present man's participation seems unavoidable and where a possibility of machine substitution has never been as much as mentioned.

There will be seeders, combines and other machines with a size and weight not exceeding that of a man and with the quality of mechanical work higher than his. There will be no need crippling the nature by raising special plants, bushes and trees suitable for machining; soil will cease degrading and being plundered by needs of industry, new roads etc.

4. The world of microrobots-insects is now little accessible to the imagination of inventors, though just such microrobots can essentially improve ecological work. With their help it is possible to control the conditions of soil, plants etc. (and that rather in each point including those currently inaccessible than according to averaged data as is the case now); actively influence the unsatisfactory local ecological situations; remove harmful insects and sustain helpful ones; pollinate plants without regard to weather etc. etc. Finally,microrobots can introduce radical changes in medicine where intracavity treatment, both therapeutical and surgical, will become common.

5. In conclusion, we can say that those grandiose changes in computational technology which have occurred due to microelectronics *are only the beginning of deep-penetrating changes in all the three major fields of the modern technology: information-technology, engineering and energy.*

7. The State of Art

1. An ever greater importance to the research in the field of micromechanics is being attached in Japan and the USA where large allocations within the national programs were made to it (in Japan 167 million dollars for 10 years, in the USA about 5 million dollars annually [11]). And, as can be understood from the available publications, the main efforts are directed to the development of microminiature motors. As to the work on the creation of structures similar to motor homogeneous space there have been no such attempts as we know of.

2. In this country the research in film mechanics has been made since the 1960s in a specially set up Laboratory of Film Electromechanics within the Department of Computation Technology at the Institute of Mathematics (Siberian Branch of the Academy of Sciences of the USSR) which from the very beginning was oriented at the creation of means of electromechanics capable of the effective interaction with computational homogeneous space [5-7]. For this reason, in the activity of the members of this laboratory there existed (sometimes without recognition) orientation at the creation of structures which, like computational homogeneous space, would have structural homogeneity programme adjustability of properties and ability to ensure parallel operation of a large number of devices.

3. This has been manifested mainly in the tendency to envisage the devices created more like elements of a homogeneous motor space than as something separate and self contained. Since this approach is more general and it includes the creation of single micromotors as its part, it can be justified to state that the future in motor engineering belongs just to this line and that the creation of motor homogeneous space will inevitably come close to the development of two other homogeneous space, i.e. computational and receptor, to form eventually a common line of the creation of a more complex homogeneous space - a *robotron one.*(The problem of the use of motor homogeneous space in robot engineering needs a special consideration which is planned by these authors as the theme of their next publication).

4. *Therefore, the state of research, designing and technological developments allows to start the creating compact, ecological automated lines for integrated-circuit production of film electromotors and thereby to set up an effective and highly ecological basis under the biggest environment ruining force, i.e. under machine building. All this inspire us with a hope that the impending ecological disaster can be averted.*

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Abstract

Discussed is the unique combination of film capacitance motors: their far higher (by orders) than in inductive motors power intensity; their universal quality, i.e. by changing operating frequency and the number of motors to achieve power range from micro- to kilowatts; simplicity of design, possibility of microminiaturization, reliability, precision (angstrom precision of step). All this will make it possible for electric machine building to come closer to biological systems by material intensity; to use integrated-circuit technology; create homogeneous program-adjustable motor space and to combine them with computational and receptor homogeneous space; produce high-precision, high-effective robots. It is stated that the level of research and design-technological developments permits to start creating compact, ecological automated lines for integrated-circuit production of electric motors and there by to put the machine building which is the main killer of the Nature on a new highly ecological technological basis.

The supposed audience in a wide circle of specialists in electromechanics, robot and computational technology, ecology etc.

РЕФЕРАТ

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В.Л.Дятлов, Ю.Г.Косарев.- Пленочные электромеханические моторные среды как путь к экологич-ной технологии.- Новосибирск, 1991.- 14 с.- (препринт / АН СССР. Сиб. отд- ние. Ин-т математики, N 26).

Обсуждается уникальность сочетания свойств пленочных емкостных двигателей: их на порядки большая энергоемкость, чем у индуктивных двигателей; универсальность - возможность путем измененияработочей частоты и числа двигателей достигать величин мощностей от микро- до киловатт; простота конструкции, возможность микроминиатюризации, надежность, прецизиозность (ангстремная точность шага).Все это позволит электромашиностроению приблизиться по материалоемкости к биологическим системам; применить интегральную технологию; создать однородные, программно настраиваемые моторные среды и сочетать их с вычислительными и рецепторными средами; изготавливать высокоточные, высокоэффективные роботы. Утверждается, что состояние научных и конструкторско-технологических разработок позволяет приступить к созданию компактных, экологичных автоматизированных линий для интегрального производства электродвигателей и тем самым перевести машиностроение (являющееся одним из главных губителей Природы) на новый высокоэкологичный технический базис.

Работа предназначается для широкого круга специалистов по электромеханике, робото- и вычислительной технике, экологии и т.п.

Библиогр. 11. Ил. 4. Табл. 1.

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FILM ELECTROMECHANICAL MOTOR HOMOGENEOUS SPACE AS A WAY TO ECOLOGICAL TECHNOLOGY

Препринт N 26

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