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Experimental research of electromechanical and biological systems compatibility

Abstract. *Commercial frequency alternating current electromechanical energy transducers magnetic field influence on a biological system (model organism) is researched. Negative influence on the test-object (Drosophila melanogaster) of magnetic field of an induction motor with acquired parametric asymmetry and physical wear is analyzed. Phenotypic changes of a teratogenic character are revealed in the drosophila organism. The results are presented in comparison with the influence on the experimental insects of the magnetic field of healthy symmetric induction motors.*

Streszczenie. *W artykule przebadano wpływ pola magnetycznego wytwarzanego przez elektromechaniczne przetworniki energii na system biologiczny. Przeanalizowano negatywny wpływ pola magnetycznego generowanego przez silnik indukcyjny z założoną asymetrią na obiekt testowy (muszka owocowa - Drosophila melanogaster). Odkryto zmiany fenotypu o charakterze teratogenicznym w organizmie badanej muszki owocowej. Przeprowadzono analizę porównawczą wyników uzyskanych dla eksperymentalnych owadów w polu magnetycznym wytwarzanym przez symetryczne silniki indukcyjne, (**Badania eksperymentalne kompatybilności systemów elektromechanicznych i biologicznych**)*

Key words: electromagnetic compatibility, alternating current electric drive, teratogenesis, mutations.
Słowa kluczowe: kompatybilność elektromagnetyczna, elektryczne napędy prądu zmiennego, teratogenność, mutacje

Introduction

Our environment has always been influenced by electromagnetic fields (EMF). Being of natural origin, these fields present background radiation. As science and technology develop, background radiation considerably increases, so electromagnetic fields resulting from human activities significantly exceed the natural background and have become a dangerous abiotic factor lately. Every year power capacities grow in all the countries of the world, due to which anthropogenic EMF has become a significant ecologic factor with high biologic activity.

In literature there appear separate data of research of electromagnetic radiation (EMR) influence on particular living organisms: organism and population-species levels of biological systems (BS) organization [1–7]. Established standards of magnetic field induction maximum permissible levels (MPL) for a human being [8, 9], adopted by the World Health Organization (WHO), are most studied and introduced in many countries. These levels of commercial frequency are most completely taken into consideration now only in design of electrotechnical objects connected with electric energy transmission and transformation [10–14]. It is determined [2], that EMFs with induction exceeding 0.2 μT are harmful for human beings' organism. This value is accepted by WHO as a MPL. In Russia this standard value is 5 μT, and in Ukraine it has not yet been determined by law.

For electromechanical systems (EMS) of industrial enterprises, electrified transport, domestic appliances the MPLs of magnetic field induction created by them are experimentally determined [15]. However, it is done only for EMSs containing electric motors (EM) whose parameters and characteristics correspond to the published ones. Meanwhile, EM stock mostly consists of machines exploited for a long time, subjected to various stages of repair and having certain design discrepancies and parameters deviations. Any acquired defects make EM a distinct nonlinear system and result in occurrence of nonsinusoidal currents, additional electromagnetic moments, including pulsating ones. The said moments result from interaction of different time harmonics of the main magnetic field and stator and rotor currents time harmonics that occurred due to new acquired nonlinear characteristics. Complicated energy exchange processes causing occurrence of external electromagnetic fields with complex spatial pattern are generated. Undoubtedly, such fields influence on BS will be different, so, EMR MPLs are to be revised.

The purpose of the paper consists in research of pathogenic influence of commercial frequency alternating current magnetic fields generated by electromechanical systems, exploited for a long time and restored (with various deviations in the design and parameters), on biological systems (model organisms and human organism) for substantiation of electromagnetic radiation maximum permissible levels by means of creation of new express-methods using test-objects.

Material and results of the research

In the general case the magnetic field around the EMS is three-dimensional, of a complex character and, along with the magnetic induction fundamental harmonic, often it contains a great number of higher harmonic components.

Calculation of this field is a rather difficult problem. In most cases authors use simplified mathematical models [8, 16-18], enabling determination of occurring magnetic moments and approximate calculation of EMF induction on the object surface as well as at a certain distance from it. As an example of this calculation with the use of mathematical package FEMM [19] (Fig. 1), mathematical modeling of magnetic field at a distance of 0.1 m around an induction motor (IM) 4A71A4U3 IM of the power of 550 W with parametric asymmetry of stator windings was carried out.

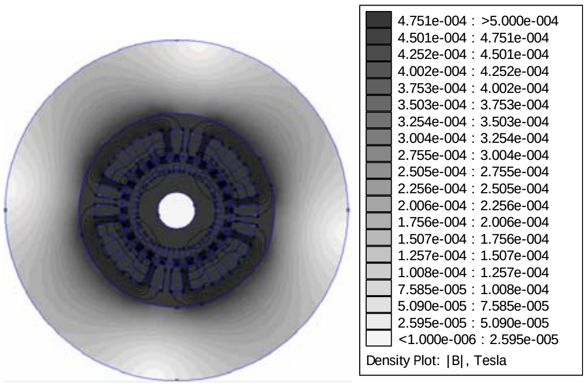

Fig. 1. Modeling of magnetic induction levels distribution around an IM with winding asymmetry

It can be seen in the figure that areas of increased values of magnetic induction exist around the asymmetric motor. Undoubtedly, their negative influence on BS in such areas will intensify. It can only be assessed experimentally.

With this purpose in view, measurement of magnetic field induction of two new identical IMs of the power of 550 kW was performed directly on the electric motor case and at different distances from its surface contour in accordance with the circuit shown in Fig. 2. One of the IMs had an artificially created parametric asymmetry. Induction levels were registered by means of EMF tester "TES 1394" with the following characteristics: measurements range 2…200 μT; measurement operating frequency 30…300 Hz; error ± 3 % in the range of 50…60 Hz.

Imitation of asymmetry was done by increasing the resistance of one IM stator phase winding. The currents asymmetry occurring in this stator phase was 4.8%.

Experimental research and measurement of the magnetic field induction were carried out at the same load torque, which was equal to 30% of the rated load torque, for symmetrical and asymmetrical IM. The shaft loading was conducted with a DC machine, operating in dynamic braking mode.

The possible negative impact of vibration on model organisms was minimized due to the IM mounting on the damper material.

The analysis of experimental research results demonstrates that, there exist distinct irregularities in the distributions of magnetic induction of magnetic field in the space around IM, and they are more distinct for the asymmetric motor. On the Fig. 3 for an example it is shown the distribution of magnetic induction at the distance of 0.1 m far from the IM surface and the tester is located at the height of 0.02 m far from the basis surface.

It is in such places of increased level of magnetic induction, around the motors, that test-objects – model organisms of the fruit fly – *Drosophila melanogaster* Meigen were located in test tubes on agar nutrient medium (Fig. 2).

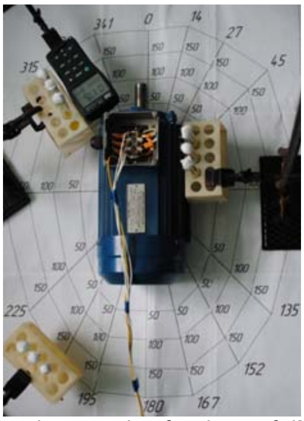

Fig. 2. Experimental research of values of IM magnetic field induction

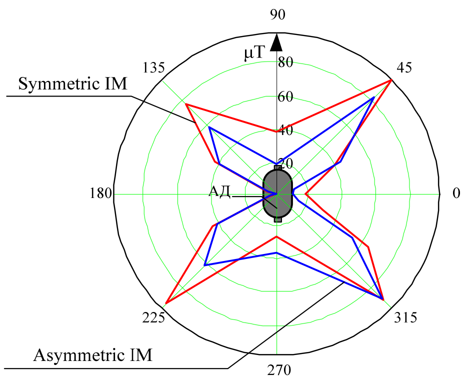

Fig. 3. Distribution of values of magnetic induction around the IM

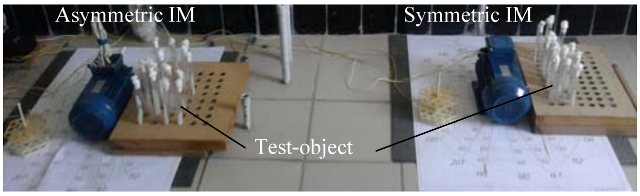

Fig. 4. Location of test-objects around the IM

Use of drosophila flies as the test-object is caused not only by their life cycle, convenient for the experiment (from 10 days at T = 25°C), but also by adequate responsiveness of these insects to the negative influence of EMR. Cameral research was performed in such a way that one of the two drosophila experimental lines was situated near an asymmetric IM and the other one – near a symmetric IM. All the model organisms were under constant effect of IM EMR at different stages of metamorphosis of three generations of the test-object (about a month). Meanwhile all phenotypic variations mainly caused by teratogenic mutations in each of the observed generations were registered.

The results of observation of the activity of drosophilae located in EMF with induction under MPL (4 μT) and induction four times as high as this level (20μT) during the first hour after turning on the IM are shown in Fig. 5. While the flies' activity hardly changed under the effect of induction of 4 μT, those that were affected by induction of 20 μT demonstrated considerable decay of activity down to fading after 20 – 30 min. Besides, this process was more rapid for the individuals situated near the asymmetric IM.

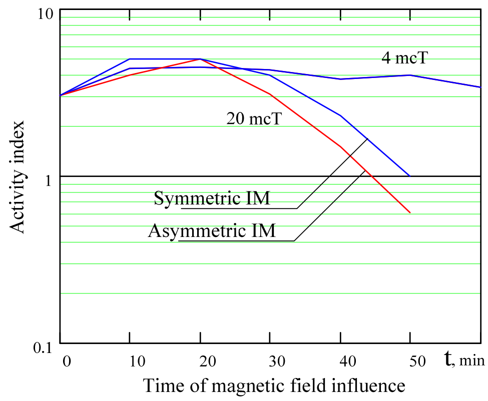

Fig. 5. Test-object activity dependence on magnetic induction value

Research of the dynamics of frequency of drosophila teratology occurrence was performed by means of registration of phenotypic variations and calculation of healthy (norm) and mutant (pathology) flies in each generation (table 1). After appearance of larvae the old insects were relocated in order to prevent them from crossing with the first generation flies born and grown under the influence of EMR.

During the research four phenotypic forms of mutagenic teratologies of the first generation hybrids were registered (F1): 1) apterous individuals; 2) apteroid individuals; 3) with deformed abdomen; 4) with disproportional parts of the body (table 2). According to a multi-factor classification the revealed anomalies refer to induced, exogenous, somatic, pathologic, monogenic mutations.

As a result of the performed research, it was found out that 74.7% of the first generation flies F_1 are healthy and 25.6% have deviations in their development, which corresponds to Mendel's second law (autosomal domination at monohybrid crossing).

For the second generation F_2 it was determined, that

21.3 % of insects have disproportional parts of the body. 3.5 %, 6.5 % and 8.0 % of apterous individuals, apteroid insects and specimens with deformed abdomen, respectively, were registered.

A specific feature of the third generation drosophilae F_3 consisted in a small number of apterous, apteroid individuals, and insects with deformed abdomens against a background of dominance of healthy flies (58.9 %) and specimens with disproportional parts of the body (41.1 %).

Thus, a preliminary analysis of the results of experimental research makes it possible to come to the conclusion about increase of mutations frequency in each of the following test-object generations subjected to EMR influence.

Table 1. Comparative dynamics of teratologies in three generations of the test-object under the influence of EMR of a symmetric and asymmetric IM

Symmetric IM		Asymmetric IM	
First generation hybrids (F_1)			
Norm – 68.3 %, pathology – 31.7 %		Norm – 75.0 %, pathology – 25.0 %	
apterous individuals	-	apterous individuals	3.7 %
apteroid individuals	1.4 %	apteroid individuals	7.0 %
deformed abdomen	2.1 %	deformed abdomen	7.5 %
disproportional parts of the body	28.2 %	disproportional parts of the body	6.8 %
Second generation hybrids (F_2)			
Norm – 65.1 %, pathology – 34.9 %		Norm – 60.7 %, pathology – 39.3 %	
apterous individuals	0.8 %	apterous individuals	3.5 %
apteroid individuals	-	apteroid individuals	6.5 %
deformed abdomen	4.7 %	deformed abdomen	8.0 %
disproportional parts of the body	29.4 %	disproportional parts of the body	21.3 %
Third generation hybrids (F_3)			
Norm – 64.0%, pathology – 36.0%		Norm – 59.0%, pathology – 41.0 %	
apterous individuals	-	apterous individuals	-
apteroid individuals	-	apteroid individuals	-
deformed abdomen	-	deformed abdomen	-
disproportional parts of the body	36.0 %	disproportional parts of the body	41.0 %

Table 2. Normal and anomalous drosophilae phenotype

Norm	Anomaly			
	apterous individuals	apteroid individuals	deformed abdomen	disproportional parts of the body
				

Table 3. The number of individuals in three generations of drosophilae under the influence of EMR of a symmetric and an asymmetric IM

Generation	Control, number of individuals	Number of individuals and percent (%) of control	
		symmetric IM	asymmetric IM
F_1	49	45 (91.8)	43 (87.8)
F_2	994	860 (86.5)	758 (76.3)
F_3	989	816 (82.5)	742 (75.0)

Apart from apparent mutagenic influence on the model organism, EMR also makes negative impact on its reproduction. It is certified by decrease of the number of test-object individuals in the lineage by 8.2-25.0% in comparison with the control line of drosophilae not subjected to the impact of IM EMR. The number of individuals in generation F1, received from one initial couple of drosophilae is 49 for control line of drosophilae. In the experimental lines of flies, grown under the influence of EMR of symmetric and asymmetric IM, 45 and 43 individuals were obtained, respectively. Then 20 couples of parental flies were selected from every line of generation F1. After that 994, 860 and 758 filial individuals were obtained in the second generation F2 in each of three lines: control, under the impact of symmetric IM EMR and under the impact of asymmetric IM EMR, respectively (table 2). In a similar way 989, 816 and 742 individuals of generation F3 were obtained from 20 parental couples of generation F2, respectively (table 3).

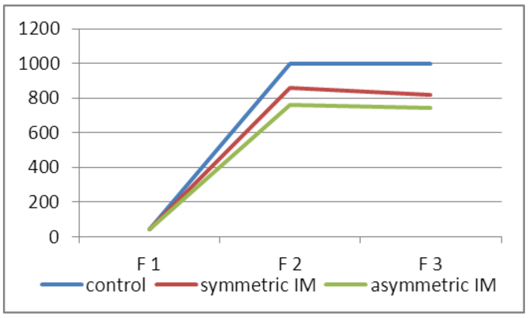

Fig. 6. Dynamics of drosophilae number under the influence of EMR in comparison with control

Thus, the most pronounced decline in fertility is in three generations of drosophilae under the influence of EMR of an asymmetric IM compared with a symmetric IM and the control line of the test-object (Fig. 6).

Conclusions

Presence of induction motor electromagnetic radiation negative influence on activity, inheritance and fertility of model organisms Drosophila melanogaster Meigen has been proved. Moreover, it has been determined that electromagnetic radiation of an asymmetric induction motor provides a more baneful impact on the test-object in comparison with the electromagnetic radiation of a symmetric induction motor.

A thesis about the necessity of assessment of worn and/or restored electromechanical systems negative influence on biological systems has been substantiated.

Further research of the influence on biological systems of electromagnetic radiation of electromechanical systems with energy converters will enable scientific substantiation of their maximum permissible levels for different levels of biological systems structural and functional organization, and will also allow working out recommendations as to repair, use and expediency of further operation of electromechanical systems and energy converters according to the criterion of their negative impact on the environment and maintenance staff.

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