METHOD OF COMPUTER MODELLING ACCURACY INCREASE FOR ELECTRONIC MEANS BASED ON INTERCONNECTION OF DIFFERENT PHYSICAL PROCESSES PROCEEDING

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The paper is devoted to the development of a new method for computer modelling accuracy increase in case of the circuit and designer project decisions making. The original idea of joint consideration of electric, thermal and mechanical processes mathematical models with the physical model presented in the form of the representative fragment design of electronic means construction in which these processes proceed at the same time is offered. The paper proved the availability of new ideas use of mathematical and physical models integration for the accelerated identification of internal parameters of electronic means electronic components and constructive materials at the expense of the problem reducing dimension by the offered method. The values of the identified parameters provide a significant accuracy increase of physical processes computer modelling in.

Keywords: mathematical modelling accuracy, parameters identification, electronic means, physical model, electric processes, thermal processes, mechanical processes.

One of the most important tasks in the development of electronic means (EM) is the task of providing the required reliability rates. It, in turn, is the task of providing electrical, thermal and mechanical operation modes of electroradioproducts (ERP) and construction materials. These processes are the most influencing at reliability characteristics EM, thus protection of their negative influence on equipment is the most difficult. Support of operation modes of ERP is understood as support of reasonable reserves for the above mentioned physical processes in the computer-aided design. On the currents, voltages, thermal emissions capacities, elements temperature, vibration acceleration and shock of ERP in the technical specifications (TS) are set the maximum permissible values. Also in constructional materials TS limits of their durability and the maximum allowable temperature are set.

Now thanks to broad development of a CAD at the enterprises by development of electronic equipment aim to receive their characteristics at early design stages, yet without having laboratory models and pre-production model. Powerful programs of mathematical modelling allow carrying out detailed calculations of electrical, thermal and mechanical operating modes of each radioelement. However due to the input data error the calculations of ERP operating modes in circuits and constructions materials are carried out without the required accuracy support. This cause the calculation reliability rates don't reflect the actual situation.

Test results of pre-production models at the final stages of EM design also often disagree from the results of electrical, thermal and mechanical processes. Now developers have to intuitively assign reserve coefficients to loadings of radioelements and materials, as is EM cause of failures because of exceeding of the actual values of currents, tension, temperatures and mechanical stresses over maximum permissible reference values.

One of the ways to provide reasonable reserves - increase of accuracy computer modelling of EM.

Modelling as any process due to its features, its specificity has errors. Modelling error - the difference between the true value of some quantity (received in the experiment) with the value received in modelling.

The analysis showed that in most cases the Modelling error has three elements.

1. Error of mathematical models. It is related with the detailing level of construction and is defined by the accounting level of physical process features in the circuit and construction and the accepted simplifications.

2. The error introduced by the computer use. It is related with the features of digital computing machines, i.e. with the dimension of the numbers representation and arithmetic algorithms perform the rounding numbers

3. Error of input data. It is related to that automatically in case of calculations values of physical parameters of elements models which contain in databases of modelling programs without dispersions are used.

As it was established, the third component of error makes the greatest contribution. The reason is that usually in the ERP and materials models are set nominal values of parameters. They are average statistical values for a variety of suppliers and are given in the database. However, the parameters are variations due to the technological specifics of each supplier, i.e. actual values of parameters ERP and materials differ from the nominal specified in database (see figure).

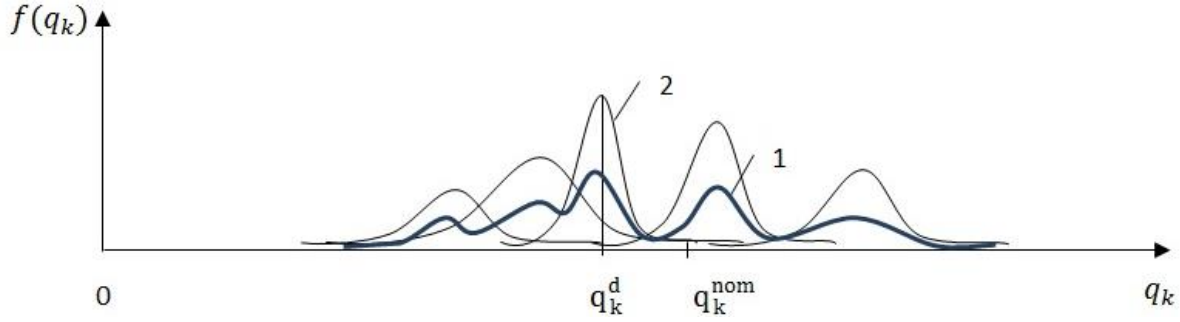

Figure. Location of parameter q_k for real ERP or the construction material of EM: q_k^{nom} – the nominal database value of k-th internal parameter as average multitude of ERP suppliers (1); q_k^d – the real value of k-th internal parameter for the law of its distribution of specific ERP supplier (2)

In this paper it is offered to receive the real values of parameters by identification. Then if in case of modelling of the EM printing node to use them instead of nominal values, it is possible to receive the considerable lowering of modelling errors.

To identify the geometrical and physical parameters of ERP and the construction materials in this paper is offered to combine mathematical modelling with physical modelling [1]. Physical modelling involves the manufacture and testing of specially-made construction fragment model. The fragment is a printed circuit board. Its size is much smaller than the original circuit board. The fragment has radioelements, parameters of which are need to identification. Can be added other elements so that the fragment has some circuit, which was a small functional unit, which could be in the experiment to start the work. The elements fastening on a fragment is the same as the fastening of these elements in the projected printed circuit board. In this case, the allocated heat flows in the functioning of this schemes will be identical flows in the original scheme. The same applies to mechanical physical processes arising when exposed to vibration.

Thus, we will have the representative fragments specially selected from all printing circuit board reflecting flow of the main physical processes. In this paper it is offered to realize identification on the basis of complexification of supposed construction fragment physical model of EM with mathematical models of electrical, thermal and mechanical processes proceeding in this fragment.

To identify the real values of the parameters q_k^d of ERP and the construction materials of the designed printed circuit board created its mathematical model (electrical, thermal and mechanical), based on the created fragment model of construction EM (physical model). The defining characteristics y^d, received in the result of optimization should come as close as possible to defining characteristics y^{isp}, obtained in the result of measurements in the same control points.

It is offered the following sequence of parameters identification.

1. Preparation input data for identification, which includes electric circuit and design drawings of the projected electronic mean, the modelling program of electrical, thermal and mechanical processes.

2. Compiling models parameters list of the mentioned above processes, are to be identified. The list includes parameters, the values of which are not in the technical conditions issued by the manufacturer (for example, the internal thermal resistance), or depending on the type of installation (for example, stray capacitance mounting, heat resistance mounting, cylindrical rigidity of the printed circuit board with regard located on the printed circuit board ERP). Frequently the list is great. This is because when modelling EM mathematical models tend to have a higher dimension.

3. The choice of significant values from pre-compiled list (in p. 2) to identify by using the sensitivity function. I.e. the designer to reduce the dimension of the optimization problem can reduce the number of identifiable parameters, leaving only the most significant. Then in the process of identification will be determined only real values for only these parameters and the values of the remaining internal parameters will be equal to the nominal.

The selection of significant parameters is suggested by the values of the relative functions of parametric sensitivity [2] output characteristics EM included in the optimization criterion, to change each internal parameter printed circuit board:

$$S_{q_k}^{y_j} = A_{q_k}^{y_j} \times \frac{q_k^{nom}}{y_j^{nom}} = \frac{\partial y_j}{\partial q_k} \frac{q_k^{nom}}{y_j^{nom}},$$

where $A_{q_k}^{y_j}$ – absolute function of parametric sensitivity of the j-th output characteristics to a change in the k-th parameter;

q_k^{nom} – nominal value of the k-th parameter;

y_j^{nom} – nominal value of the j-th output characteristics;

∂y_j – differential (or a very small increment) the values of the j-th output characteristics;

∂q_k – differential (or a very small increment) the value of the k-th parameter.

4. The choice of optimization method, which depends on the properties of modelling programs for electrical, thermal and mechanical processes [3]. These programs in the process of optimization are used several times, and they should not delay the optimization process

5. The creation of a physical model, namely making the required number of fragments of printed circuit boards. Fragment is made of the same material as the board of the projected printed circuit board. For placement is taken one element for which you want to identify parameters. The simplest functional circuit make of them. The electrical signals (power and functional signals) connect the derived part of the construction of EM printed circuit board. This causes a flowing of interrelated electrical and thermal processes in it. Fragment can also be fixed on a shaker, in case of need, the identification of mechanical parameters. Measured define (output) features in a pre-selected control points that are available for installation of the sensors

6. At the same time the mathematical modelling of the circuit fragment and construction on a computer for obtaining the same defining characteristics. It is important to

notice that a natural connection between the electrical, thermal and mechanical processes in the physical model of a fragment played when modelling simultaneously three programs electrical, thermal and mechanical modelling, related front-end programs-converters [4]

7. Measured and calculated defining characteristics are transmitted to the optimization program. The goal of the program: by automatic change of the identifiable parameters in the mathematical model on a computer achieve the minimum deviations of the calculated values from the defining characteristics of their measured values. On the range of changes of the identifiable parameters in the program is subject to restrictions, definite by physical meaning of the tasks. In the basis of the optimization criterion is used quadratic minimum criterion:

$$\min_{q^{mod}} H_i = \left(\frac{y_i^{mod} - y_i^{isp}}{y_i^{isp}} \right)^2, \ \forall H_i < \varepsilon,$$

where $\mathbf{y}^{isp} = f(\mathbf{q}^{isp})$ – vector of measured defining characteristics;

$\mathbf{y}^{mod} = f(q^{mod})$ – vector of defining characteristics obtained in the result of the modelling;

i – number of the defining characteristics;

$\mathbf{q}^{mod}$ – vector of identifiable parameters of the fragment model of the printed circuit board;

ε – small number set by designer, depends on the required degree of characteristics coincidence.

8. The obtained values of the parameters at the end of the optimization process are accepted as the final values of the identifiable parameters.

For practical realization of the identification in this paper offers a special program complex of identifying parameters of EM, the development of which was carried out by the author with the orientation to application of automated system for reliability and quality equipment ensuring ASONIKA developed in the Scientific school «ASONIKA» MIEM NRU HSE. [5].

In conclusion, proposed in this paper combined using of physical model with mathematical (interconnected electricity, thermal and mechanical models) allows to identify coefficients of temperature influence on electric parameters of ERP and the mechanical parameters of the board material. This helps you more accurately determine the load ERP and materials and, accordingly, more accurately calculate necessary parameters of reliability in mathematical modelling of projected EM.

The developed identification algorithm with the subsystems included in the system ASONIKA, form a holistic approach to the modelling accuracy increase and make more informed project decisions.

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