Development of Computer-Aided Thermal Procedures of Technical Objects

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Abstract — **The popularities of the development of design procedures and thermal design operations for the construction of a general structure of a computer-aided thermal design of technical objects with the aim of providing their thermo-physical characteristics are described.**

Index Terms — **thermal design, technical object, thermal model.**

I. INTRODUCTION

The general process of the development of technical objects (TO) can be described in stages and levels of decomposition, each of which corresponds its problems of designing of technical objects. During the solving of these problems for technical objects, the peculiarity of which demands taking into consideration thermal regimes and providing temperature stability within the process of their functioning, it is necessary to put subproblems, which form in general the process of thermal design

II. PECULIARITIES OF DESIGN PROCEDURES AND OPERATIONS DEVELOPMENT

The design procedure of the thermal design of technical objects is considered in close correlation with the design procedures of scheme and constructionally – technological levels of designing and is described separately with the aim of development of its general structure, that is used during the solving of different problems. Let's describe project operations, which are components of the project procedure (Fig. 1).

Solution of thermal design problems is closely connected to modeling and analyzing the thermal conduction [1, 2]. That's why the first project operation is modeling, the result of which is a thermal model of the technical object, the second one is receiving the additional information by using subsystems of the scheme constructional and technological design. The third operation is the analysis. The result is a temperature field of the construction or the index of temperature of the elements of the technical object.

The development of criteria and macromodels for finding scheme, constructional or technological solutions is done further. The last operation is finding the design solution.

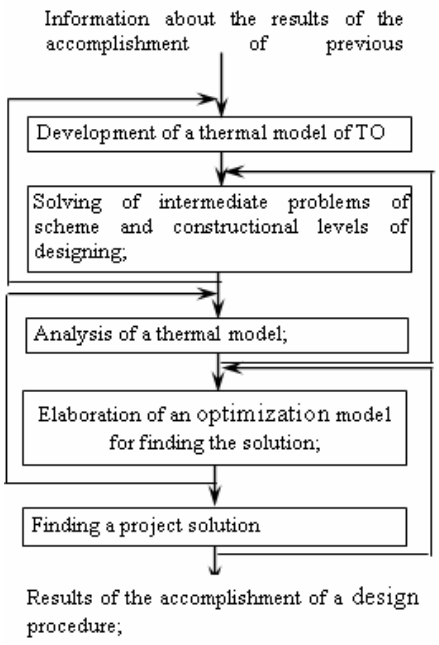

Fig. 1. Structure of heat design procedure in a continuous cycle of a TO design

The computerization of the thermal design process of technical objects claims for the development of methods which are characterized by such peculiarities:

– possibility of gaining adequate results with simultaneous simplicity of the method of problem solution;

– possibility of the computerization of the process of preparation the input data. For thermal models and design procedures;

– possibility of the improvement of received and the development of new mathematical models, algorithmic and computational models;

– quickness in finding solutions within the process if designing;

– use of various methods at all problem solving levels – from model construction to receiving design solutions.

According to system-structural approach the process of modeling and analysis of thermal conditions could be divided to such stages (Fig. 2):

1. Thermal model construction, that is an acceptance of assumption to geometrical version of technical object construction;

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2. Description of physical processes in the given geometrical model;

3. Transformation and reduction of the primary mathematical model;

4. Choice of method and convergence of mathematical model to the system or the sequence of specified functions;

5. Acquisition of function meaning;

6. Acquisition of technical object thermal condition

In each stage specified methods could be used for getting results [1]. Subject to the necessary degree of problem detailing, the presence of technical means, the organizational base and the methodical provision, either one or another method is used (Fig. 2).

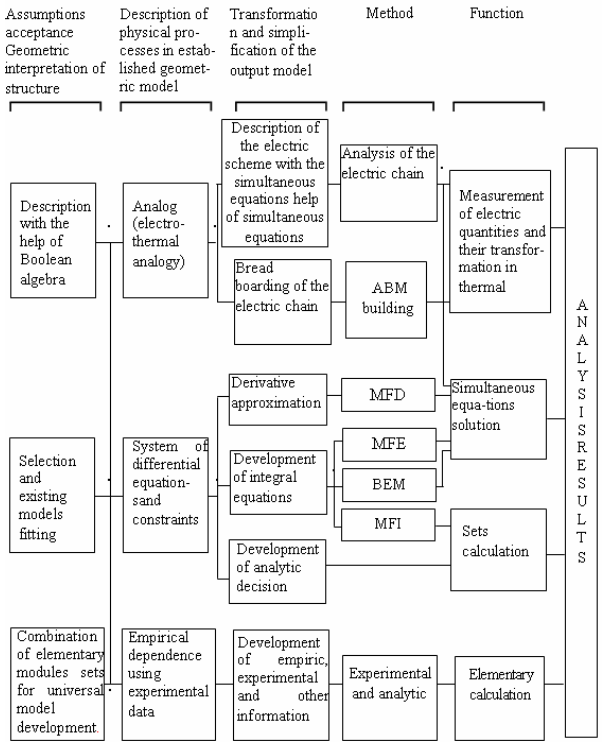

Fig. 2. Phases and methods of temperature fields models development and analysis

It may be noted that there are three basic strategies of thermal regimes analysis. They are – mathematical modeling, which is based on the use of digital computer techniques, analog methods, which are based on the electrothermal analogy and the construction of specialized analog computers (AOM) experimental-computational methods, which are widely used for the building of simple engineering methodologies that do not require complicated computer equipment, but the availability of this equipment and highly skilled engineering staff with extensive experience is expected. Advantages and disadvantages of these methods are known..

In most cases, a digital computer technique is used as the universal mean of automation under conditions of automated design methods integration into common system.

Therefore, mathematical methods are emphasised in modeling of thermal regimes. The abstract of these methods, which are divided into analytical and numerical, is given in [32]

Methods division to analytic methods and numeral methods is very relative, especially in cases of receiving analytic dependence of coordinates and time during resolving problem, while coefficients of this dependence are represented in numeral form. Results of the numeral problem solution could be approximated by analytical dependences for further processing and vice versa – results which were received in analytical form could be represented in charts of numeral meanings.

Each methods of mathematical modeling problem solution have its advantages and disadvantages. The reduction of one or another method to the universal method puts to heavy expenses for algorithm development and making calculation.

Notice cited above, as to wide possibilities of automatization and computing machinery, we suggest, according to generalization of various methods characteristics and possibilities, to construct methods which combine rational compromise between mathematical, analytical and numeral methods of mathematical model development and algorithm analysis of thermal conditions in all levels. The practices confirm a necessity of such an approach, because often during the development of new modeling methods we use one or more classic methods.

The input data for development of computer-aided thermal conditions is its qualitative and quantitative determination. The qualitative determination is a type of thermal model with a primary and limit condition. The quantities determination is a degree of necessary adequacy to the real construction and functioning conditions.

The method structure is determined by special features of procedure and by its place in the process of thermal design.

The main problem during the development of the 4th and the 5th operation consists in a solution of contradictions between such factors:

1. Maximum possible use of available software methods of optimization and increased demands of receiving results efficiency.

2. Increase of automatization process degree of receiving design solution and maximum use of developer empirical experience;

3.hugeness and complexity of thermal process mathematical models in technical objects constructions and necessity of multiple calculation.

It is recommended to use an approach, which is based on half-heuristic designing methods, to solve formulated problem [3]. Hence, we can notice such specific features of operation development:

1. Based on real designing process we should develop a set of optimization models;

2. To formalize partial problems of thermal-physic characteristic provision of technical objects based on use of existing computer-aided methods of optimum designing;

3. To develop optimality criteria's and to describe searching fields of optimal solutions;

4. To provide the possibility of designer's solution acceptance based on the generalization of analysis results computer-aided processing of thermal conditions, results of optimization problems solution.

The degree of given contradictions solving is marked by general demands accomplishment.

Now, when special designing features, the analysis of thermal conditions and technical objects designing are defined, let's look at the 2nd procedure operation of thermal designing.

As a result of procedure accomplishment we should receive not only input data which is describing energy, topological, constructional characteristic of thermal objects (TO), but also possible change limits, variants of components placement, the design grouping. Judging from features of further procedures development we should receive the maximum quantity of information. Such an approach let us reduce the quantity of access to mathematical model of thermal field. So that during the 2nd operation accomplishment we can form the input data which meets conceptual object model and includes data which is necessary for achieving the goal. The mathematical model should meet demand of adaptation and invariance to the input data.

III. The Structure Of Process And Automated System Of Technical Objects Thermal Design

The diversity of thermal design problems, which are realized in the form of procedures, the need for flexibility in the structure of the process, ensuring the relationship with design procedures and circuit design and process design at the level of input, output data and mathematical models of the formalization process involves thermal design based on a systematic approach in the form of set-theoretic relation. Automation of thermal design provides the development of automated systems, concrete realization of the logical structure of the process, models, algorithms and programs. Implementation of thermal design in the form of an automated system which is used independently or in an environment of integrated computer aided design is carried out by developing its key components that meet generally accepted components of CAD and general conceptual framework construction, operation, and maintenance systems. Thus, there are two categories - system in the form of a formal description of the thermal design and automated system, where the process occurs. The first system - a process of thermal design, which consists of the design procedures, operations, models, methods, and converts the input data in the results (Fig. 3).

The second system - organizational technical system for implementing thermal design in a computer-aided drafting of technical objects.

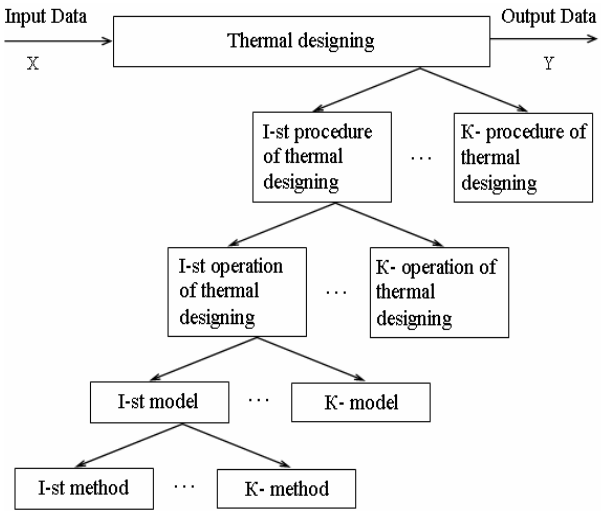

Fig.3. Hierarchical structure of thermal designing process.

Here the formal structure of the thermal design process is described. It is represented as a set:

$$M = \{X, Y, P, Q\} \quad (1)$$

Where: X – set of descriptions of the input object design; Y – set of input data (a set of design decisions made based on analysis of thermal characteristics; P – set of design procedures of thermal design; Q – the set of communication systems.

Set of the original description of the object served as:

$$X =< Xcx, Xk, Xtex, Xct, Xtep, Xf > \quad (2)$$

where Xcx – the circuit data, which include input and output circuit design; $Xк$ – Design data; $Xtex$ – Technological data; Xct – Structural parameters; $Xtep$ - Thermal characteristics; Xf – Functional parameters;

$$Y =< Ycx, Yk, Ytee > \quad (3)$$

where: Ycx – the result of the thermal design of circuit stage; Y_K – The result of the design phase of the design; $Ytee$ – The result of technological development, Yi, $i \in \{cx, k, tee\}$

And the decision, based on an analysis of temperature field and thermal characteristics of technical objects Y_a

$$Yi \subseteq Ya \bigcap Y_j^p \quad \Big| \quad j \in \{cx, k, tee\} \quad (4)$$

where Y_j^p – the result of the circuit feasibility, design or technological design.

We shall describe a set of design procedures:

$$P = P_T \bigcup P_P \quad (5)$$

where P_T – the theoretical basis of building design procedures; P_P – realization of a theoretical basis in specific kinds of CAD.

$$P_T = \bigcup_{ki=1}^{n1} Pnn_{k1}; \quad Pnn = \bigcup_{k2=1}^{n2} Pno_{k2};$$

$$Pno = \bigcup_{k3=1}^{n3} Mo_{k3} \; ; \; Mo = \bigcup_{k4=1}^{n4} Ma_{k4} \; ; \quad (6)$$

Thus P_T served as a hierarchical structure in which: P_{nn} – The design process; P_{no} – Project operation; M_o – Object model design; M_a – Methods of analysis and decision making,

$$Pp \subseteq < O, M_T, L, I, P_r, M_a, T >, \quad (7)$$

where O – organizational, M_T – Methodological, L – Linguistic, I – Informational, P_r – software, M_a – mathematical, T – technical support for CAD.

The set of relations is the union of three subsets:

$$Q = Q_Z \cup Q_V \cup Q_M, \quad (8)$$

where Q_z – the external relations of thermal design with integrated CAD technical subjects; Q_V – Internal links between design procedures; Q_M – Direct contact with circuit procedures, design, process design at the level of mathematical models (e.g., problem solving analysis and optimization schemes of technical object formed macromodel that allows to carry out the calculation of local overheating of the elements in order to access the source temperature characteristics.

Finally, describe the structure of M, note that its four main components are in the functional dependence, thus forming a formal system thermal design

$$S : Y = F(X), \quad (9)$$

where $F \subseteq P \times Q$.

Consider the practical implementation of a formal system S as the organizational and technical, which makes it possible to make thermal design of technical objects. One of the main requirements for an automatic system thermal design is its adaptability to the real process of developing devices and which, in turn, use software-implemented mathematical models and methods for specific tasks to perform procedures and results of the overall process.

Based on this section of functional automated system for following components:

1) program-methodical complex, which consists of a processor, preprocessor and post processor, interface information and monitor;

2) hardware (servers, workstations, devices, document text and graphic information);

3) organizational support, which brings together users of the system design and specific conditions.

Processor contains program-implemented mathematical models: used to analyze thermal characteristics of technical objects, making decisions, forming macromodels thermal characteristics of technical systems for object circuit, design and technological design, focused on a wide range of tasks; adaptation to decision specific tasks using the input data, which are received on the input of the processor. The processor implements the mathematical system.

Preprocessor system implements the following functions: formation of the information model for the processor based on the analysis type of problem that is solved, automated construction of thermal models is based on a conceptual model of the object and design in accordance with the stages and phases of design, content and modification of local database systems heat design, ensuring links with systematy circuitry, design and technological design; addition of other autonomous systems software packages and calculation of thermal modes of components and component technical objects.

Posprotsesor system thermal design implements the following functions: interpretation of graphic design as a one-two-and three-dimensional features on your workstation or device documentation, visualization and documentation in tabular form the results of design.

Information interface acts as a local database system and serves to store and exchange between components of the system thermal design as input data that describe the object of design, and intermediate and final results of the design. Because information is data exchange interface with the components of an integrated CAD technical objects.

Preprocessor, postprocessor, the information interface implementing information support system.

Monitor system thermal design is realized using the standard operating systems and allows interactively or in batch mode to challenge the system components in any order.

This approach enables you to organize your system with a software operating environment of workstations and work in a computer network (a server) is using the machine-oriented language for writing special programs. This increases the efficiency of installing the system thermal design on the platform of any type.

IV. Conclusion

A detail consideration of designing procedure development features and thermal designing operations let us develop the computer-aided thermal designing structure, to choose necessary methods, to develop appropriate models and methods of thermal conditions analysis of technical objects, furthermore decision acceptance with the aim of providing their thermal-physic characteristics.

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