

Thermovision control, interferometry and computer modelling for increasing reliability and quality of electronic products

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Abstract

We present information on an automated system ASONIKA that is designed to maintain reliability and quality of radio-electronic equipment (REE) and to simulate physical processes in REE. Methodological aspects are considered to integrate computation and instrumental diagnostics on the basis of the software ASONIKA and measuring thermovision KRIT_T. Formation of the thermal model-norm, utilized for verification of specimens according to their thermal images and evaluation of electronic device reliability and quality under the destabilising influence is suggested. It is noted that a similar technique utilizing holographic interferometry equipment and the mechanical subsystem ASONIKA-M software will allow to generate the model-norm of devices' condition under load.

1. Introduction

The combination of thermovision systems, optical interferometric devices, acoustic sensors, etc. with computers allows to improve nondestructive testing and defectoscopy technology. Broad application of computer methods do not only concern processing to gauge the visualized primary measuring information, i. e. thermal images, interferograms, holograms, fields of mechanical strains and deformations: Changes take place in the whole process of testing on the basis of computer technology for acquisition, storing, and further utilization of experimental information. This is used, first of all, for the analysis of state and processes, as this is the most complete way to describe objects in various stationary and dynamic modes of operation. Also methods are developed to evaluate probable deviations ("defects") from the accepted normal state. In this sense we see the tendency for growing similarity on the basis of development of computer methods, instruments, and software for technical diagnostics.

2. Methodology

The general methodology is illustrated by the following architecture which contains basic modules of software design and computerized tools for testing and defectoscopy of electronic devices (Figure 3). Application at the stage of designing of the automated system for maintenance of the reliability and quality of electronic units and devices ASONIKA [1] (which consists of the software for study of electrical modes ASONIKA-Q, thermal and mechanical models ASONIKA-T and M, combined valuation of reliability and quality ASONIKA-Q) allows to develop a model for the state of an electronic unit or a product. The accuracy of the model depends on initial results of instrumental research and information stored in the ASONIKA database. The model provides a specific or combined *model - norm* on the state of the electronic product. The *model - norm* relationship characterizes a reference condition of the product and admissible kinds of deviations, caused by destabilizing factors. The software provides the comparison of a mass-produced specimen with the state defined by the *model - norm*. The specimen verification and product certification for validity in particular is made with respect to the deviation of experimental data from reference data.

Thus the software covers the whole process from the design of a new product up to testing of mass-produced specimens. Moreover, a forecast of a product behaviour during operation can be made.

3. Principles of modeling in ASONIKA

The ASONIKA software simulates various physical processes in REE in a unified way that is based on mathematical similarity in the representation of electrical, thermal and mechanical processes in REE and approximation of the space in which it exists. The analytical form of process description is reduced to the derivation of a system of algebraic and differential equations with unified parameters and arguments and its computing. The derived model is analyzed in parametric sensitivity function and, if necessary, a correction is introduced.

In order to determine the analytical form for processes description for a device, a topological model of processes in this device is developed preliminarily taking into account its design, mode and operation conditions. Such a model is represented in a kind of scheme or nondirective graphs. Extensive instructive data on modeling of processes in elementary construction units (included into database and from a large number of formalized designs and processes in REE devices) is useful for the equipment design.

Figure 2 shows the example of thermal modeling: the image of a device with a printed-circuit-board (2a) and a topological model (2b) describing a thermal process. The upper parts of the topological model correspond to heat generating and dissipating elements. Graph branches characterize heat exchange with their numbers corresponding to the type. The evaluated temperature distribution in single elements is also presented (2c).

The uniform methodology in ASONIKA permits to link together different subsystems (_E, _T, _M, _Q) and to develop some new subsystems. The new software ASONIKA_ET, _TM and _ETM takes into account mutual influence of various physical processes in a device and provides for the optimization of a model with respect to influencing factors. The subsystem ASONIKA-Q allows to estimate quality and reliability of a simulated device. The subsystem has two modules: i. e. "Stability" and "Reliability". The "Stability" module performs the evaluation of quality. It is designed to examine the influence of one or several technological or in-service destabilizing factors (e.g. scattering of technological parameters of radioelectronic elements; materials degradation; changes in cooling conditions or load character; irradiation effect). Here specimens which need no adjustments, is carried out as well. The "Reliability" module evaluates the degree of reliability of a device according to the parameter of probability of non-failure of a device in view of gradual or sudden failures [1,2].

4. Aspects of integration and application of software-hardware tools

4.1. Software and equipment at tests

Let us consider integration of software-hardware tools for thermal modeling and technical diagnostics for thermovision inspection. The main tool for computer modeling was ASONIKA-T. Other subsystems ASONIKA played an auxiliary role. Diagnostics was performed with the computer measuring thermovision system KRIT_T. It uses advanced software for processing and analyzing of thermal images [3]. The thermovision KRIT_T employs a well-known and in Russia widely utilized IR camera "Raduga". It was applied for thermography of printed-circuit-cards in devices of tower and single-block design, cases of modules and microassemblies and surfaces of optoelectronic units of precision devices. A computerized thermovision microscope on the basis of AGA optics x 15 zoom was utilized for the thermography of small objects, e.g. microcircuits and other semiconductor devices, elements of non-hermetic assemblies, etc. Additionally holographic interferometry was applied in some cases to analyze mechanical strain.

4.2. ASONIKA_T: thermal models of REE

The ASONIKA_T software description is presented in detail [1]. We shall consider some features of development of thermal models for REE and problem of accuracy.

ASONIKA_T realizes computer technology of reliable thermal modeling of equipment for various purposes, design and level of integration [4]. ASONIKA_T automatically designs topological models of thermal processes and gives their numerical solution for such designs as cases and racks, cassette and tower blocks, hybrid assembly modules, printed-circuit units, microassemblies, functional cells and radiators of several types. In other cases manual design of topological models for further utilization by software is required. In both cases the ASONIKA_T advanced database is used. A user chooses the type of model, thermotechnical characteristics of materials and formalized topological sample models for elementary design units forming thermal process topology for a device. Topology development and model calculation for devices of complex design are performed step by step using the hierarchical principle, i.e. from external bearing designs (case, rack, block case) to internal parts (printed-circuit unit, module, element). Thus external thermal condition and design determine the boundary conditions for internal units. The accuracy of modeling of temperature distribution in elements and location areas of internal units depends basically on the correct choice or manual design of topological models: The problem involved is adequacy of model heat dissipation and cooling conditions, thermotechnical parameters for materials and elements to real conditions and parameters in the device. In practice the accuracy in the case of automatic monitoring of temperature in an internal unit (e.g. printed-circuit card) is usually not worse than 30 %. It attains 5 - 10 % for improved developed models [1]. In the case of manual modeling that requires some skill from a user, there is a risk of an error, and the same accuracy is attained with more effort.

The use of thermography for thermal modeling contributes to the reliability of developed models. A comparison of simulated thermal conditions with experimental results obtained by thermography on the same microcircuit was performed [4,5]. Within the temperature range of 25 - 55 °C the agreement was 3 - 5 %. To obtain this result we coupled the thermovision system to absolute temperature with an accuracy 0,2 °C by using a certified point-contact thermometer (when the contact to a surface was possible) or with an accuracy of 0,5 °C by a black body reference source (when the contact was impossible). On black surfaces the noise equivalent temperature difference (NETD) was 0.1 - 0.2 °C.

4.3. Specimen certification and defectoscopy

The thermal model developed and accepted as a norm provides an opportunity to verify mass-produced specimens for thermal conditions, in particular, for drawing up a certificate of a product. From this point of view a thermal certification system for electronic products may be described by the scheme in Figure 1. Here the comparison of real and reference fields is performed by comparison of the thermal image of a mass-produced specimen and the graphic model of surface thermal distribution, in which the admissible deviations for elements have also been introduced. If there is a reference specimen with its definite thermal normal image, it may be compared also. The comparison in the KRIT_T software is performed with built-in options for subtraction and imaging of differences from the preset reference thermal image. In this case a graphic thermal model may be used. There are also options to select elements or areas of interest from a thermal image of a multielement electronic unit surface and compare their temperatures with the preset numerical norm.

KRIT_T automatically determines the noise level in the case of comparison in the field with small temperatures. Introduced thermal images are allowed with scale gradation not below noise level.

The decision on the validity of a specimen (Figure 1) is made according to a preset criterion of the type "valid / invalid" or "valid / implicit defect / invalid". The verification of a group of specimens is performed in a similar way in other cases, too. It is possible to determine technological scattering of specimen parameters, analyze some defects in specimens, etc.

4.4. Optimization, quality, reliability

In addition to the main module ASONIKA_T designed for thermal modeling, other subsystems of ASONIKA can be used, thereby expanding the field where the method can be applied. The opportunities may be seen clearly from the scheme in Figure 4. Once an authentic thermal *model* - norm is created under conditions and modes accessible for thermography, we can extend this model to situations when there is no access. There are additional options: ASONIKA_ET - allows to optimize the output parameter of the device electrical mode when thermal conditions change; ASONIKA_MT - allows for optimization of thermal conditions stipulated by mechanical effects such as vibration; ASONIKA_ETM - takes into account both of these influences. *Table 1* indicates some examples of different ASONIKA tools and thermography.

Table 1. Examples of thermal modeling using thermovision inspection and software

N	Condition for software model-norm	New conditions for corrections of model	Software
1	Thermovision control under normal ambient conditions	Operation temperature, which is not supplied by thermovision inspection	ASONIKA_T
2	Non-hermetic micro-assembly without a cover	Covered hermetically sealed microassembly	ASONIKA_T
3	Mutual influence of electrical and thermal modes is discounted	Taking into account mutual influence of electrical and thermal modes with optimizing the electrical mode of operation	ASONIKA_ET with data transfer from ASONIKA_E and _T
4	Mechanical process (vibration) effect on heating is not taken into account	Influence of vibration on thermal conditions taken into account	ASONIKA_MT with data transfer from ASONIKA_M and _T
5	Thermal imaging of specimens for comparison with the norm	Technological scattering of temperatures taken into account to estimate validity of technology	ASONIKA_K with data transfer from ASONIKA_T

This article cannot describe details of particular techniques for different problems within the methodology of application of ASONIKA tools and thermovision inspection.

4.5. Other applications

Similar systems based on precise computerized holographic interferometers and ASONIKA_M software are under development now. They are designed for the analysis and certification of electronics parts as well as optical and mechanical devices taking into account mechanical strain and deformation caused different kinds of mechanical loads: i.e. vibrations, impacts, etc.

5. Conclusion

The development the thermal modeling on the basis of ASONIKA platform with advanced thermovision system as a software-hardware combination opens new horizons for design and nondestructive control for increasing quality and reliability of electronic devices.

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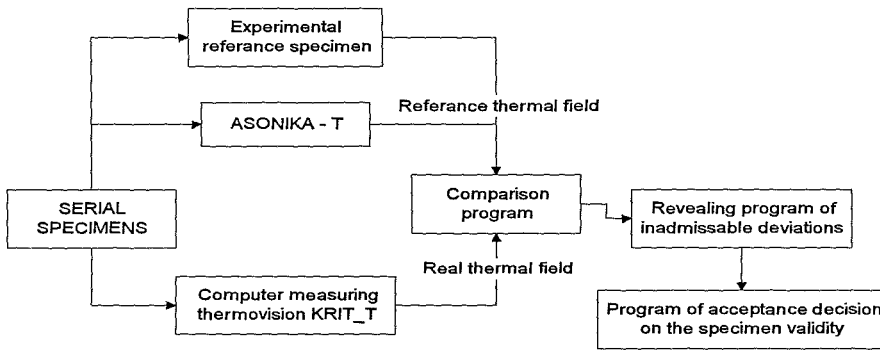


Fig. 1. Thermal certification scheme for electronic products

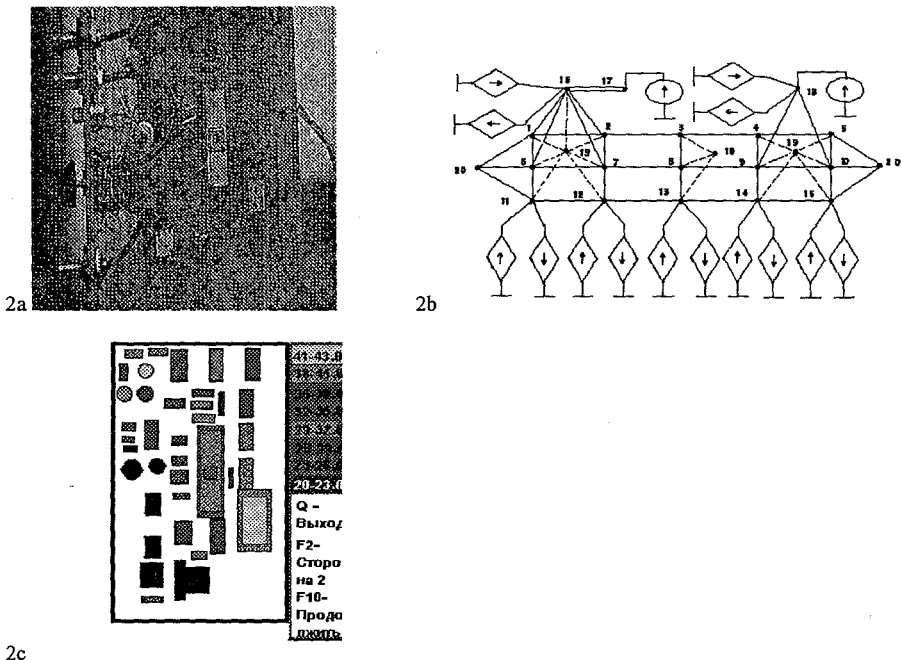


Fig. 2. Example of thermal modeling of an electronic device

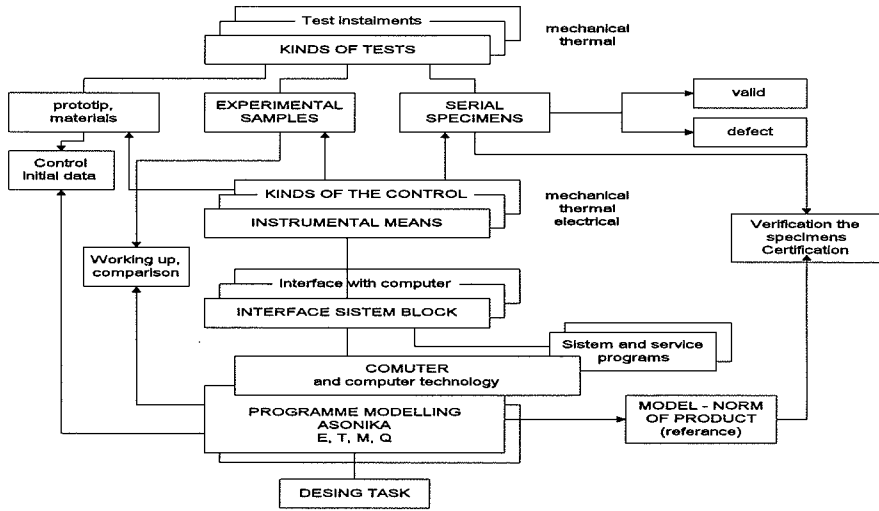


Fig. 3. Architecture software-instrumental means for nondestructive control and defectoscopy electronic units and devices

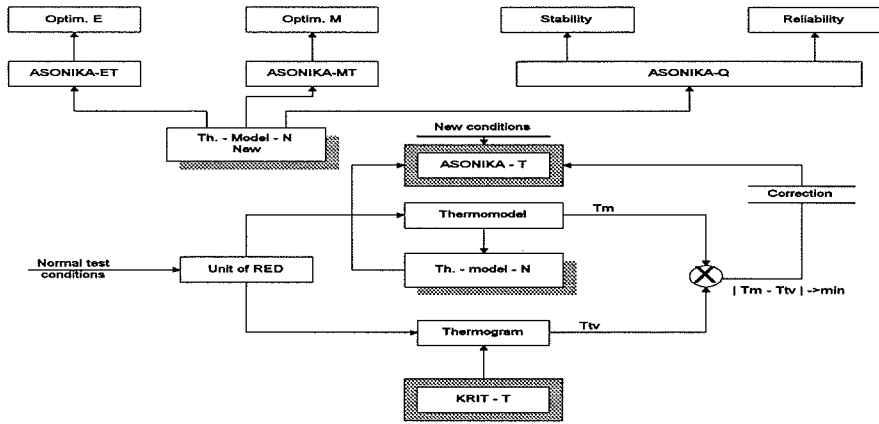


Fig. 4. Complex circuit of serial products reliability designing