The idea of complex multi-channel integrated automated system unification for testing structural elements of rocket and space technology made of composite materials into their development and manufacturing technological cycle

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Abstract. The concept of integration of an integrated multi-channel integrated automated system for testing elements of rocket-space technology made of composite materials into a single information space of the entire enterprise has been developed. When building the architecture of the automation system, the integration of the automated system of technological preparation of tests is provided. A unified mathematical model of the test object, test facility and loading systems, and the collection and processing of test results was taken as the basis for modeling the technological process of testing.

Modern rocket and space technology is increasingly used high-strength composite materials. Experimental autonomous testing of these products requires the reconstruction of a full range of thermal and operational effects of axial and shears forces, torsional and bending moments and thermal flows in real time. This is possible with the full automation of the entire process of loading, measurement, collection and processing of test results [1-4]. A variety of items and sizes makes it necessary to constantly operate a sufficient number of test stands and tooling, at the same time it is necessary to conduct various tests.

Up to date, the automation of the testing was limited to the local system, allowing for separate booth to play some path of power and thermal loads, to conduct the collection and processing of measurement results, displacements, temperatures and effort. The basic principles of modernization of the experimental base of large enterprises are given in the works [3]-[7]. However, studying the technical and software control systems were not considered the issues of integration into the common information space of the automated system of technological preparation of tests. In addition, the models of automation of the experimental test base should take into account the specifics of composite materials and in the construction of the architecture of the automation system based on a single mathematical model: MM test object - MM test facility - MM stressing system, collection and processing of test results.

Let us consider some features of a complex multi-channel integrated automated testing system idea development. The complexity of the automated system is determined not only by the multifactorial loads that must be simulated during testing. Most developers of rocket and space technology structures made of composite materials, including JSC “CRISM”, combine experimental testing of newly created and routine tests of serial products. Taking into account a fairly wide range of products, it is necessary
to create a single information space covering all test and experimental facilities, and integrated into the general information field of the institute. The test facility should be integrated into science and production. The multichannel system is due to a set of effects that must be reproduced during testing. As a rule, these are axial loads, bending and torques, shear forces, local heating, and internal and external portions of pneumatic-hydraulic pressure.

The results of the development of the architectural and functional structure of the multi-channel integrated automated test system and the concept of its integration are illustrated in Figure 1. The three-level structure with the organization of automated control systems of the test center, technological preparation of tests, united by the local computer network of the information exchange system with the control information-measuring system of the test area, integrating data from local automated technological complexes and allowing to increase their number in the development of basic solutions was chosen.

![Diagram of the integrated system](image)

**Figure 1.** The idea of the integrated system of complex automation of heat-static tests of rocket and space technology elements made of polymeric composite materials in JSC “CRISM”
The structure of such a local automated technological complex includes operating members (hydraulic cylinders, heaters), sensor equipment (force, pressure, temperature, deformation, displacement), converters (hydraulic valves with electrical control, thyristor regulators of sensor signals), subsystems of power and thermal stressing, data collection and recording, hydraulic stressing.

Figure 2. Functional scheme of the local automated technological complex

TS - trial subject, 4 groups of hydraulic cylinders (HC), ATC - axial tension-compression, M – torque, N - bending moment, SF - shearing force, 3 groups of overpressure P1, P2, P3; 3 zones of heating T1, T2, T3.

The functional scheme of the local automated technological complex is shown in Figure 3. Local automated technological complex of a single facility can be operated in an autonomous mode, providing independent loading through four channels of force and three channels of pressure and heating in real time.

The control information-measuring system (Figure 3) provides storage of control programs of tests, security system with subsystem of situational analysis of pre-emergency incidents and subsystem of prevention of unauthorized access to databases. In the works [1], [2], [8] the results of the development of mathematical models of the test object taking into account the characteristics of composite materials, facility equipment, stressing systems, control, collection, processing and
archiving of test results, which together represent a mathematical model of the system. This mathematical model allows not only to automate the testing process in real time, but also to calculate the stressing conditions and other parameters of the process.

Using obtained in the first equation of the dynamics of the facility, hydraulic actuators, mathematical model of the test object, we establish the connection between the control signal and the actual stress condition of the object.

Strongly pronounced nonlinearity of this process is taken into account by the choice of the model of the corresponding regulator. In the work [8] there is a similar mathematical model of heat control. It is a unified mathematical model.

An important link in the multi-channel integrated automated system is an automated system of technological preparation of tests. At a present time, as a rule, each person has a computer and makes a paper version of the test agenda on it.

It is necessary to create an automated workplace on the basis of this PC. The integration of all process engineers’ automated workplaces into a single network allows providing automation of the
process of creating software-techniques and converting them into a machine version, as well as the process of its approval and affirmation. For this purpose the appropriate automated workplaces should be located both in the customer's representative office and at the enterprise management. The functional scheme of the automated system of technological tests preparation is given in Figure 4.

Using the software product T-FLEX DOCS of the "Top Systems" company, the automated system of technological preparation of tests solves the following tasks:
- automation of technical document management (organization of storage of equipment documentation and other related documentation, in the preparation of the product for testing);
- automation of technological preparation of product tests (preparation of technological maps, route maps, operational maps, sketch maps, technological passports, loading maps);
- support of versioning of documents;
- support of multi-level access rights system;
- collecting and processing information from test facilities on the course and product tests results;
- providing tools and equipment for product test results analyzing;
- automation progress and test reports;
- archive documentation and test reports of products automation. The system of information interaction of functional subsystems of the multichannel integrated automated testing system is based on dedicated servers of management and data storage.

Central information and computer complex of the information interaction system is built on the basis of two servers that provide management of the multichannel integrated automated testing system and organization of long-term data accumulation, mathematical, including statistical, processing of the accumulated information and its reservation and its further use in mathematical modeling of processes.

Software and methodological support and a local automated technological complex with a control information and measuring system, and a central information and computer complex with information exchange systems, an automated control system of the test center and an automated system of technological preparation of tests should form a single information space, which should be integrated into a single information field of the entire enterprise. For this purpose the basic information models for the local automated technological complex, and for administrative and management systems should be accepted.

![Figure 4. Functional scheme of the automated system of technological tests' preparation](image-url)
Conclusions
The concept of creation of the complex multichannel system of tests allowing to automate completely process of experimental working off of rocket and space equipment made of polymeric composite materials and integrated with the automated control system of the enterprise in the multilevel composition form with the organization of data on local networks and construction of system of information exchange on the basis of basic information models applied both for automation of technical process of tests, and for administrative and managing systems and subsystems is presented.

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