DEVELOPMENT OF FLIGHT PARAMENTERS SIMULATION TECHNOLOGY FOR AN AIRCRAFT WITH COMPLEX CONTROL SYSTEM ON FLIGHT SIMULATORS FOR MORE PRECISE DEFINITION OF IN-SERVICE LOADS TO SOLVE THE STRENGTH STRUCTURAL AND LIFE PROBLEMS EFFECTIVELY

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Abstract: The current work highlights the issues associated with the use of the unified computer model of an aircraft for multidisciplinary design, certification, and the structural monitoring during operation. The technology of using flight simulators for definition of structural loads of an aircraft had been developed and implemented. The database structure for storing and processing information had been formed.

1 INTRODUCTION

The modern concept of aircraft development consists in integration of all component stages including the formation of the appearance and flight characteristics, design, technological preparation and production, home and international certification, marketing, tracking operation in the airlines companies with evaluation of durability on the condition and the flight safety and so on, until the completion of the service life. The basis of such integration appears the end-to-end usage of the computer technology for computer-aided design, production and management throughout the life cycle of aircraft.

The strength aircraft design requires coordinated execution of work during several years in many engineering disciplines with a large amount of computational investigations, stand and flight tests.

The usage of active control systems has led to necessity of revision of some design concepts and its reflection in the regulation documents of definition of the flight loads acting on the aircraft structure. The refinement of the existing calculation procedures became necessary due to the influence of the active control systems on the nature of maneuvers, the changing of unit loadings of the modern aircraft and the implementation of algorithms for reducing of such loads.

Integrated automatic control system (ACS) provides the solution of the stability, controllability problems along with the safety problem by the terms of strength.

At the stage of design and certification of strength the full influence of the loads of the modern integrated automatic control system is required to be taken into account while determining the extreme values of the loads.

During the design process the normalized aerodynamic and inertial loads on the aircraft are often defined ("frozen") relatively early, and the ACS architecture must be specified by this time. Then, during a long period of simulation, up to flight tests of the aircraft, the capabilities of the control system can be optimized in the solution of problems of stability and controllability.

At the same time, the ACS simplified models or the models that are not appropriate to ones treated in the problems of stability and controllability are applied.

Thus, it seems to be important to carry out multidisciplinary investigations at the main stages of the life cycle.

The new information technologies of the end-to-end support of complex high-tech products at all stages of life cycle from marketing to utilization are under creation in the last decade. These technologies are based on a standardized unique electronic data representation and collective access to such data, and allow to simplify significantly the implementation of all stages of the aviation products lifecycle and to improve the productivity.

An elaborated unified database structure of the design and certification computations using the results of flight simulation on the flight simulator is presented in the current article.

The research was carried out at an early stage of work over a passenger aircraft integrated control system development. Following had been implemented: the basic mode of the distance control system (DCS) operation, the algorithms of the elevation rudder and stabilizer control, the algorithms of the rudder, spoilers and air brakes control, flight safety enhancing features, standby operation of the DCS.

The researches of the airplane loading were performed in the normalized design cases: under the action of discrete gust and continuous turbulence, while performing various maneuvers. The design conditions of ground loads definition specified by the Aviation Regulations for transport category airplanes were considered.

The simulation of the landing with drift was held and the loads on the landing gears and its fastening points to the plane were determined.

The "flights" on the flight stands materials application methodology was developed for solving the static and fatigue strength problems.

The strength scientists participated in this activity were G. I. Turchannikov, M. M. Levchenko, V. V. Chedrik, D. V. Chemisov, V. V. Politov, A. P. Leagostaev, modeling was performed by Y. I. Didenko, V. F. Bragazin, M. G. Glubokaya.

2 A SCHEME OF THE AIRCRAFT LIFE CYCLE

Figure 1 illustrates the simplified diagram of the aircraft life cycle with computer support, defined as the integrated mathematical computer model [1].

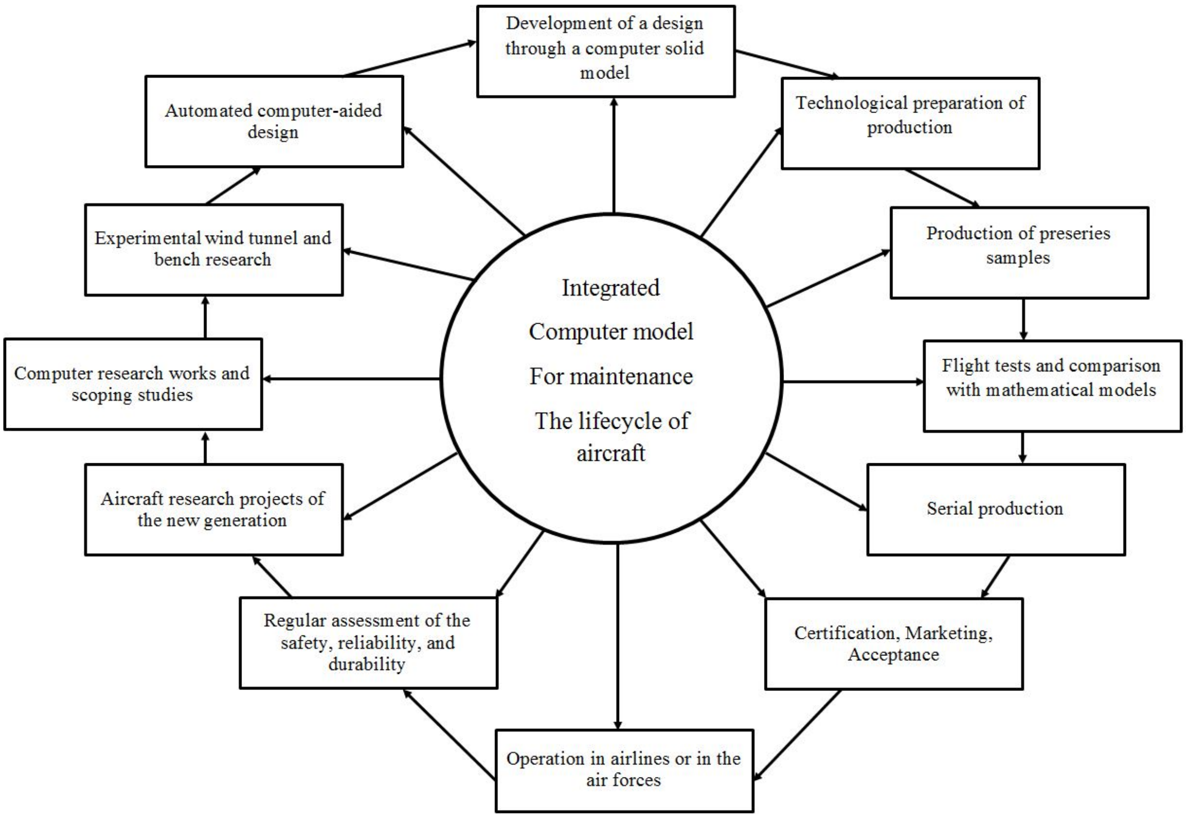

Figure 1: Simplified scheme of the aircraft lifecycle

For many years, TsAGI together with design engineering bureaus tracked the most important stages in the life cycle of aircrafts, including the stages of design, certification and operation.

At developing of the aircraft life cycle concept in the aviation branch very important is the unification of software and computer systems, including high-performance tools for information processing on the basis of modern database management systems (DBMS) that are able to integrate research findings in various scientific fields that support a unified computer model.

Figure 2 shows the general database diagram of the “PARUS-INT” software complex developed within the bounds of modern operating conditions and loading monitoring system formation at the new technical and organizational level.

The first-priority aim of this monitoring in aviation industry are safety ensuring on the static strength conditions and increasing of the air fleet life potential use efficiency by establishing a system of individual monitoring based on modern information technologies, which allows to take into account the operations characteristic of each instance and to minimize the values taken when establishing life reserves for loading dispersion.

The individual monitoring should be understood as the registration of the actual unit’s loading level of each aircraft instance in service with following processing for damageability in load factors and strength factors.

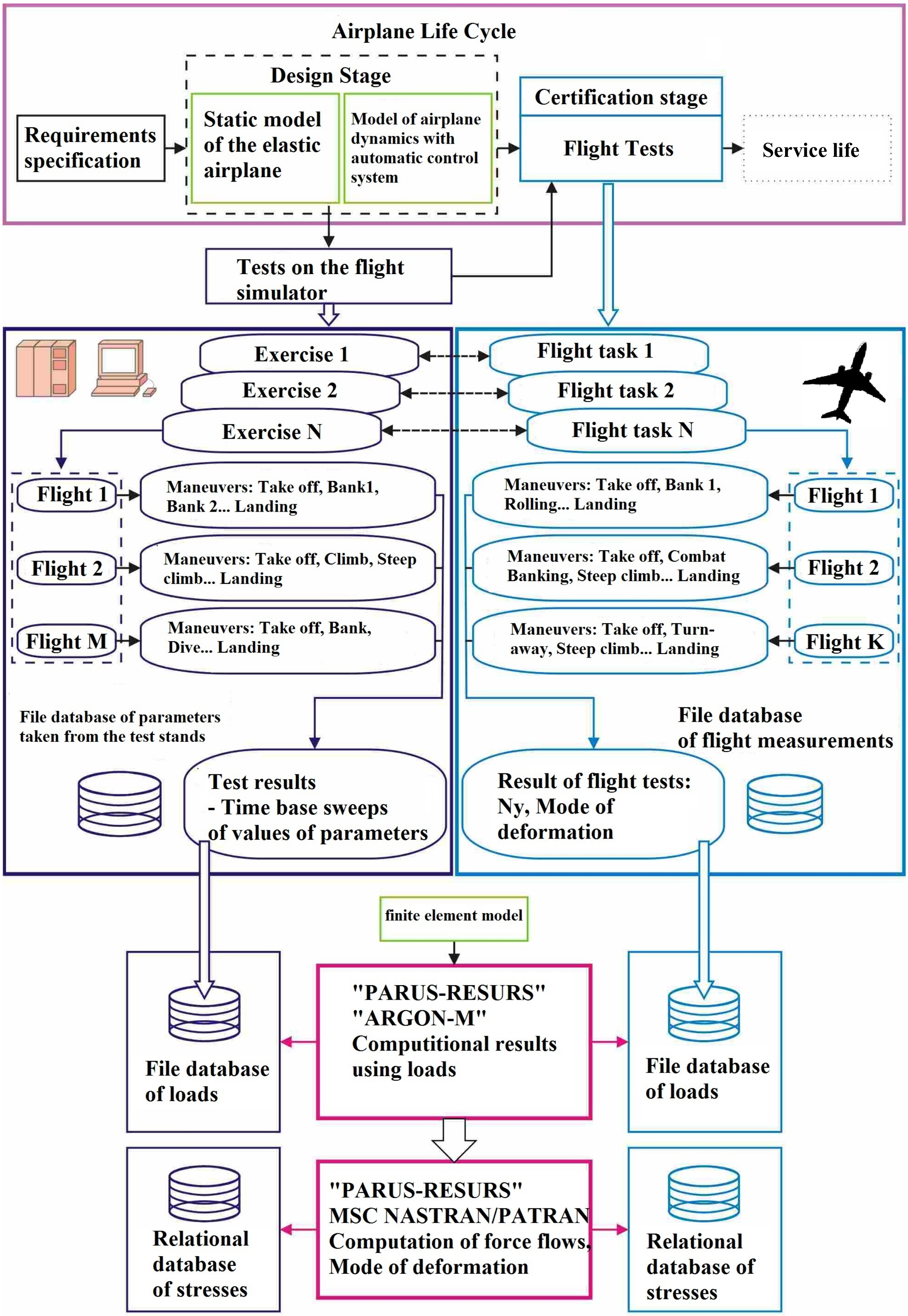

Figure 2: General scheme of software complex "PARUS-INT" database for solving static and dynamic strength and resource problems

3 INTEGRATED COMPUTER MODEL OF AN AIRCRAFT

At the design stage an integrated computer model of an aircraft is being created. The integrated computer model is considered to consist of the following main parts:

- Information computer model that represents the complete set of all flight and technical characteristics of an aircraft, steady and unsteady aerodynamics characteristics, parameters of stability and control, strength and aeroelasticity etc. This set of parameters is formed by means of computer computations and experimental bench and flight tests.

- Mathematical computer model that represents a set of mathematical formalization of physical problems (equations, problem statements), computational methods, techniques for solving of steady and unsteady problems, linearization, the method of computational grids generation etc.

- Software computer-aided tools, including algorithms, software codes proper, problem-oriented system environment and the application description.

- Statistical computer model, which is replenished by a set of statistical data during the aircraft service and includes data such as on-board equipment or unit failure, behavior features of behavior in normal and critical modes, durability estimations on the condition and other structure characteristics and aircraft behavior during long term operation.

An essential property of the aircraft integrated computer model is its “historical sweep” timeline along the stages of design, production, and service lifeof the item. At the airplane supporting process the model is being adjusted and updated receiving the data from flight tests and operation. At the first stages of the life cycle this computer model plays the role of instrumental system, a kind of generator to create a new aircraft. At the following stages it fulfiles the analysis functions of its “behavior”.

4 THE USEAGE OF INTEGRATED COMPUTER MODEL OF AIRCRAFT FOR SOLVING STATIC STRENGTH AND SERVICE LIFE PROBLEMS AT THE DESIGN AND CERTIFICATION STAGES

The integrated computer model represents a rather full “initial” information volume of flight characteristics of an airplane. It is being formed on the basis of calculation using mathematical models, software tools and experimental researches in wind tunnels, on the strength stands and dynamics simulation stands. At the stage of full-scale model flight tests the airframe structure flight characteristics checking is being done, the integrated computer model is being refined with the usage of identification methods and is being amplified with information obtained under real conditions.

The elaboration of the better structure of calculated and experimental data included in the information model of a particular aircraft and the development works providing of connection of the calculation results with the experimental ones are important at the creation of the aircraft integrated computer model of an aircraft. Having received large volume of result information after the previous years experimental studies, TsAGI is currently implementing these developments on a series of aircrafts.

At the design, development and certification of an aircraft, experimental researches relevant to the current requirements on the problems of aeroelasticity, static strength, on the static and dynamic loading cases, as well as the requirements for aircraft long-term service strength are held. Computational studies on these problems of strength are performed using various software systems to solve the certification issues.

In “PARUS-INT” software complex, described in the paper [2], the strength calculations are carried out by means of the stress-strain state (SSS) computation programs, which are implemented using finite element method (FEM).

Loads are determined on the base of experimental and/or calculated data. It is important to establish the conformity of these fixed loads to those ones that can occur in operation.

In the strength analysis the calculation methods applies at the design and certification of airframe are of most value in dynamic loading conditions, such as atmospheric turbulence influence, the loading during the running on the ground, etc.

Software development for static and dynamic strength, and service life problems solving is the first step in arrangement of the individual monitoring. As shown in the figure 2, the collection of the flight parameters initial data is performed throughout the life cycle of the aircraft from the design stage to the withdrawal.

At the design phase, when there is no material structure, a flight simulator where experienced pilots perform exercises, composed on the base of predictable operation, is the data source in the proposed approach. The flight simulator software includes a static elastic aircraft model and a model of the flight dynamics with the automatic control system. Time realizations of the virtual flights parameter including altitude, Mach number, load factor at the aircraft center of gravity, angular acceleration, the position in the associated coordinate system, are recorded and brought into the database of the bench tests by parameters.

The simulation results are used directly for solving static strength problems (method of simulation limiting parameters) and the life resource (computation of damageability in load factors on the basis of time realization of the vertical load factor increment at the aircraft center of gravity). These results are involved in problems of the dynamic strength indirectly, after the conversion into the loads.

At the virtual flights performance the expected loads on the components of the aircraft are determined on the ground of the structural models in “PARUS-RESURS” or “ARGON-M” software. “ARGON-M” is a modified version of “ARGON” software complex, specialized in batch processing of large amounts of data. In both cases the output results are the time realizations of force factors (shearing forces, torques and bending moments) in the sections of units accumulated in the loads database file. The force factors damageability caused by the force factors is determined by these realizations.

For calculation of the stress-strain state these loads are applied to the structure finite element model by means of “PARUS-RESURS” or “MSC NASTRAN/PATRAN” software. The stresses database allowing to determine the damageability in applied stresses is being formed from these computational results.

The developers can decide by the results of tests on the flight simulator about the necessity of the automatic control system adjustment.

The storage and the processing of the flight data at the certification stage are similar. In addition, if the test object has the appropriate hardware, the measurement of the moments and stresses can be completed on the real physical structure.

In the database terms the time realizations resulting from flight simulators tests and test flights are described by hierarchical data model and a relational data model is formed in conjunction with data of the loads and stresses.

The accumulation and the following processing of the flight parameters measurements results described above as applied to each specific instance of the airplane is the solution of the individual monitoring problem. Modern software and hardware tools allow to solve it in near real-time (deformed state calculation during the maintenance work on the airplane). This approach is particular important for advanced airplanes made of composite materials with integrated fiber optic sensors.

5 DEVELOPMENT OF LOADS AND STRESSES DATABASES IN THE LOAD-BEARING ELEMENTS AND CRITICAL AREAS OF AIRCRAFT STRUCTURE

Database of loads was specially designed and intended for storage and processing of time realizations of flight parameters, control deviations, control actions and external influences, loadings acting in various sections of the aircraft units. The basis for the software implementation is a relational database management system Microsoft SQL Server 2012.

The database of stresses in the loads-bearing elements and in critical areas of the structure, obtained by time and frequency, is used for structured storage of forces and stresses data in the elements imported from the output files of the FEM system (such as *.f06 files for MSC NASTRAN).

It should be mentioned that one timeline realization of the primary data of flight parameters generates more than one time realization of force factors. For example, for one unit of the airplane such as wing, the database contains information about the loading of its right and left consoles by three force factors, while each console is divided into several sections.

The organization of data storage in the database based on the usage of hierarchical data model: the separation by the objects (aircraft) and flight modes.

Information storage of the flight parameters, control actions and loadings relating to the execution of single maneuver on one airplane is described by the relational model. All the elements of the structure are defined on a physical level (table level) and are valid for all programs that perform operations with the database, including the tools for developing and maintaining the database.

The user interface of the database shown in the figure 3 allows to handle both separate maneuvers and combinations, to build relative dependence of flight parameters, force factors and stresses subject to limitations both as function and as its argument. Constrains are used particularly for “delamination” of timeline realizations of the force factors by the Mach number while determining their dependencies from the flight parameters and the control deviation, as well as in determining the airframe static strength with the limiting maneuvering parameters.

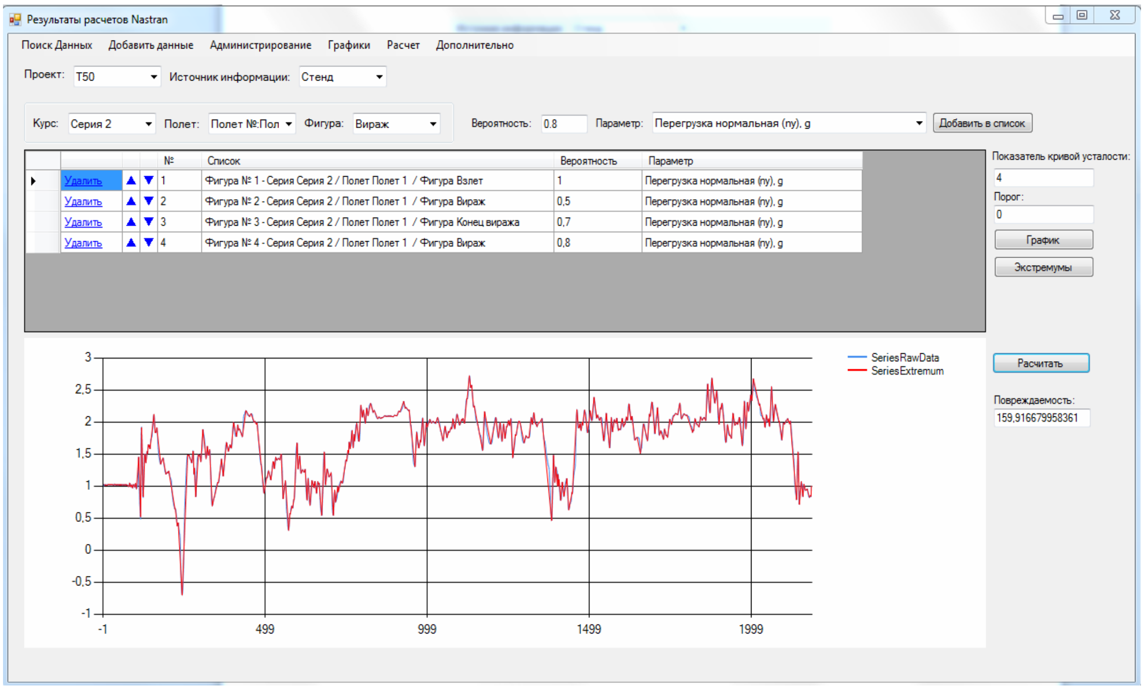

Figure 3: The user interface of the database

There is a capability of reduction of maneuvers performed in a different time intervals to a single time interval and also the capability of identifying the extreme values from the time realizations. Presentation of the parameter time realization in a form of a pair of extremes is useful if it is required to examine the mutual position of the points describing a number of realizations, and some conventional envelope.

When performing the data processing described above, there is a capability to save the graphs and tables used in their construction in a file.

To determine the service life of the structure in loads factors, force factors and stresses, there is a capability in the database to process the time realizations of the parameters using the method of the complete cycles.

7 CONCLUSIONS

The technology of using of the flight simulators for solving the static strength and structure service life problems described in this paper allows to account for the real characteristics of the integrated automatic control system for definition of aircraft loading. Such approach permits to track the influence of changes made in the ACS at the perfection stage on a flight simulator on loading and to carry out final refinements at the flight tests stage of the full-scale object.

Similar information processing on the flight parameters, registered in service life, is a solution of an urgent task of the single item structure's current state monitoring.

8 REFERENCES

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9 COPYRIGHT STATEMENT