Assessment and improvement of rationality methods of modern aircraft engines design and technological solution

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Abstract. The results of the research of modern aircraft life cycle structure are presented. The basic principle of a life cycle system creations is cost minimization requirement of whole aircraft and the components from designing to disposal. The proposed model is based on the analysis of life cycle aircraft by elementary components.

1. Introduction
The life cycle of aviation technology is a system of processes based on the technical specifications development, its operation and recycling. One of the main tasks in the development and production of aviation technique is to select an optimal design and technological solutions in order to costs minimization for the entire life cycle of the product. This approach allow possible creating of competitive models of aviation technique, because it takes into account not only development and production costs, but also the operating costs, which often have a significant value for aviation technique operator.

2. Materials and methods
The aviation technology competitiveness can be increased by the functional-cost analysis method. It is necessary to present the functional-cost analysis results as a complex indicator, for example, an indicator of functional perfection. The functional perfection is a relative complex indicator characterized by a measure of the proximity of the functions specified in the terms of reference, the functions that can be performed. A functionally perfect object is the object which functions are fully consistent with those specified in the terms of reference.

The maximum value of the functional perfection quality indicator corresponds to the optimal design and technological solution; its minimum value is an unacceptable variant of the design and technological solution, i.e. a deliberately unsuccessful solution is revealed, which is an important structural synthesis subtask.

The efficiency of aviation jet engines is determined by the quality of design. Project facilities can surpass by their parameters the best specimens only when in the design process, progressive methods are applied and the results of research, best practices, inventions and discoveries are used.

A complex solution of all tasks related to the design, production and operation of products must be carried out within the framework of constantly improving integrated automated systems.

The systems use common methods and means to solve all the design and technological problems on the basis of the use of modern information technologies that provide the opportunity to radically change the processes of design, production and operation.
The main problem in creating a functional and cost analysis complete system is the lack of methodological unity and common data formats. Methodological unity is based on a formalized design space representation and requires standard forms objects and the processes data representation and knowledge use. Currently, the company software and software tools developers are taken mainly for the creation of highly specialized object-oriented systems, as well as common standards for the data presentation and knowledge form about the product; yet, the life cycle stages are joined poorly.

The competitiveness improvement methodology combines decomposition and structuring complex technical systems projects methods, design works parallelization by elementary stages and life cycle stages, simulation of products, technological systems and structural and technological solutions with the modeling objects integrity preservation, allowing to obtain rational solutions with balanced functional, structural, technological and cost (technical and economic) parameters.

Creating of a special synthesized model process involves the sequential execution of the algorithm: certain informative features selection; most preferred instances data choice; search for optimality model structure, i.e., work on structural synthesis; model parametric synthesis with the certain technological requirements appointment; optimization of the created model.

It is necessary to provide the certain informative features selection, necessary for the life cycle cost model of the product, starting with the development work for the period, including the stage of development of the draft design and ending with the completion of the stage of improvements on the engines certification.

During a mathematical model creation, there is a desire to take into account many different factors. Analysis of these factors influence on the simulation results, performed in the development and research methods, shows that the following cases are possible:
- some factors do not affect the result or their influence is very small (while the factors themselves can be variable and constant);
- the accuracy of identifying factors and determining the values of the determining parameters is so low that their impact is comparable to the error of their determination;
- factors that have a mutual influence on each other, which leads to optimization problems of such a large dimension that if the solution can be found, the cost of the solution is comparable to the effect of finding the optimal value.

Modern aircrafts and jet engines are analyzed and evaluated by many factors and indicators which include performance and productivity, reliability and durability, cost and material consumption, efficiency, noise and many others. Most of the requirements for aviation technology are complex-formalized, interrelated and contradictory.

The complex technical system and its structural elements (units, assemblies and parts) creation begins with the definition of goals and objectives which are formulated in the terms of reference. The technical task, in the detail of goals and objectives, defines the main operational characteristics that should be provided by the designed system as a whole and its elements, as well as set limits on the parameters of the system and devices and the ranges of possible changes in the environment.

In the mathematical aircraft jet engines life cycle modeling, a hierarchy is formed with the allocation of each of the specific structural elements hierarchical levels. The composition of hierarchical levels for functional cost analysis can be limited by the following list: life cycle stages, stages, tasks (projects, tasks), project procedures and project operations.

The perspective innovative system presented by Department of the aviation industry of the Ministry of industry and trade of the Russian Federation provides nine stages. Thus, risks at introduction of new technologies significantly decrease and are assigned to the industry to a lesser extent.

The following levels in the innovative aircraft life cycle development are envisaged:
1. Potential Russian standard in aviation technology.
2. Needs analysis and the formation of the terms of reference.
3. Technical proposal.
4. Conceptual design.
5. Technical (working) project.
6. Manufacture and testing.
7. Operation.
8. Decommissioning and disposal.

When forming the life cycle stages, it is necessary to take into account the tendency to increasing of the life cycle phases number, which increases the manageability of projects and programs in the face of the external environment and the internal environment complexity. The role of various standards and decision-making procedures is increasing. The management of knowledge-intensive projects is approaching foreign approaches and standards with regard to more attention to the experimental development process support.

3. Results and discussion
3.1 System and product life cycle environment

The European Space Agency (ESA) approach described in the work [1] assumes to divide the life cycle of a space project into 7 phases. This approach does not include the stage of conceptual and scientific researches and does not emphasize a significant stage of production initiating. The approach of the Canadian Space Agency (CSA) [2], suggests five stages life cycle structure, with insufficient detailing of the life cycle on post production interval of a spacecraft [3].

Russian scientists V. Volkov and A. Orlov [4] consider the life cycle in space technology area for mass production. The proposed life cycle concept in the work [4] generally corresponds to the practice accepted in Russia [5], based on the local norms and standards.

In recent years, Russian aviation society has come to understand that aircraft life cycle consists of numerous processes, but main part of the aircraft life cycle correspond to the operation process [5, 6]. The main information data flows between the life cycle processes participants during aircraft technical operation take place exactly at technical operation stage. A wide variety of processes, elements and objects of the life cycle process leads to certain complexities in information data flows between counterparties [7].

The concept of Continuous Acquisition and Lifecycle Support (CALS) has a designation in Russia as “information support of product life cycle” (the abbreviation IPI in Russian). An integrated information environment (the abbreviation IIS in Russian) was created for interaction within the framework of the IPI (CALS) technologies. The purpose of IIS is to provide both continuous data exchange between customers, manufacturers and consumers and improving management efficiency, reducing paper workflow and maintenance costs.

Thus, the IPI (CALS) concept based on common information and ensuring uniform methods of process management and interaction between participants in the product life cycle in accordance with the requirements of international norms governing the rules of management, interaction and data exchange. In this case, the IPI (CALS) is a data warehouse located in a network computer system that covers all services and departments of the company connected with all product life cycle processes. The IIS has a unified system of rules and regulations for storage and exchange of information. These rules are used for all communication processes of product life cycle support on all life stages. The main principle of IPI (CALS) technologies is information that once originate at any life cycle stage must be stored in the IIS and after that becomes available to all participants on this and other life cycle stages (according to the priority to use the information) [8].

Consider the life cycle system requirements segmented by:
- Business Requirements define high-level targets of producer or customer (consumer). Business requirements answer the questions “why?”, “for which purpose?” etc.
- User Requirements describe targets/tasks of system. User Requirements answer the questions “who?” and “what?”
- Functional requirements define system functionality.

The main rule should be implemented in the life cycle system of aviation technique – information that once appears at any life cycle stage must be stored and can be available for all participants [9, 10]. Information should be stored centralized and have different access, modification and deletion rights.
This approach allows avoiding duplication, recoding, unauthorized data changes, avoiding errors and inaccuracies.

Thus, the life cycle system concept should be based on a single information space and ensure uniform methods of process management and participants interaction in the product life cycle in accordance with the requirements of international and local norms governing the rules of management, interaction and data exchange [11]. At the same time, the life cycle system basis is a data warehouse that exists in a network computer system covering all services and divisions of the enterprise associated with the product life cycle processes. Very important point is identity of information processes that accompany and support the life cycle system should concerning storage, exchange of information etc. This approach eliminates processes errors and reduces manpower costs, time and financial costs. The participants of information exchange process can be geographically distributed from each other and located in different cities and even countries, and the use of information can be significantly heterogeneous. For complicated systems, and the engine life cycle system is such, it is necessary to ensure the insensitivity of the system to the shortage or missing data.

3.2 Product life cycle system architecture sample

As it was mentioned above, the life cycle system must also meet international norms and standards beginning from classification. A world experience in classification for data structure should be used. A gas turbine engine CFM-56, which is one of the most massive (B-737, A319/320/321, etc.) can be applied for analyze. Aircraft Maintenance Manual (AMM) marks jet engine CFM-56 in aircraft structure as system “Chapter 72”. All other CFM-56 systems and subsystems have more detailed numbering. For example, item with number 72-30-00 is a high pressure compressor. The last two positions in the number 72-30-XX are used for compressor subsystems numbering. This principle is applied for all engines and aircrafts [11].

For domestic Russian engine PD-14 components it is rationally to use the same classification approach. Thus, the data structure is assumed to have one dimension in all engine elements with maximum destabilization and in other dimension the cost of a specific engine element for each life cycle stage from the Research&Design (R&D) stage to maintenance, etc.

During engines operation, this database will be filled with all life cycle stages costs. This approach allows identifying most costly systems and elements, and developing adoption decisions of new technologies and/or design changes in short time. An example of database structure is presented in the table. The real database should correspond to actual engine specification and must be detailed as much as it possible. The detailing must be done by both dimensions via components detailing and via elementary life cycle stage. The life cycle stage detailing can include procedure like oil refilling in transit flight point, etc.

| Table 1. Life cycle system architecture sample |
|-----------------------------------------------|
| Research | Design | Certification | Production implementation | Production | Service costs | … | Faults |
| 72-00-00 |        |              |                        |            |                |    |        |
| 72-00-01 |        |              |                        |            |                |    |        |
| 72-21-00 |        |              |                        |            |                |    |        |
| 72-21-01 |        |              |                        |            |                |    |        |
| ........... |        |              |                        |            |                |    |        |
| 72-62-00 |        |              |                        |            |                |    |        |
| ........... |        |              |                        |            |                |    |        |

The life cycle system should have the capability for faults recording and analysis and, of course, related operation costs. Separately, it is necessary to provide a record of faults associated with force-majeure and fault based on third parties. The costs, corresponded with third parties faults, as rule, are
covered by insurance payments. The costs, corresponded with technical malfunctions must be analyzed also separately.

Maintenance is very important and costly life cycle stage. This stage must be deep detailed and identified not only A-check, C-check, D-check, but also less complicated and less costly like Transit-check, Daily-check, Weekly-check, etc. Aircraft operator must provide Transit-check, Daily-check, Weekly-check etc and list of procedures or costs of them can significantly affect on total operational costs.

Presented above basic life cycle system data structure in life product also allows identifying components and systems, the operation costs of which are beyond the normal. Further, modification or improvements components and systems costs can be calculated in order to reduce operating costs. In any case, the decision for engine improvement and modification must be based on the life cycle stages cost.

A more complex life cycle model may be based on dynamic approach. By dynamic approach it is supposed to use one more dimension - time. Of course, the life cycle system becomes much more complicated; however, this model has some advantages. The basic model, because of its simplicity, does not allow identifying costs increase in dynamics. It, further, does not allow considering dynamical costs increase for a particular component and, therefore, does not allow identifying un-expected costs growth in certain period of engines life cycle.

The next much more complicated model is based on all costs identification for each engine separately in dynamics. This approach will allow identifying not only the costs of the above mentioned models, but also identifying these costs with reference to a specific engine, and therefore, identifying hidden production process defects at operation stage. Such models are very useful for the identification of fast production process faults and troubleshooting.

4. Conclusion
The article presents the life cycle models creation for high technology industries as well as aircraft and engine production are high technology industries. The infrastructure requirements for aircraft life cycle system are described. It is proposed to use a certain data structure (specification) – similar to international practice. The basic approach for aircraft life cycle system infrastructure is presented. The dynamic approach allows identifying un-expected costs growth and improving the functional and cost indicators.

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