Intelligent system for data analysis and decision-making on test results

G.A. Saitova, A.V. Elizarova
Ufa State Aviation Technology University, Ufa, Russia

E-mail: saitova@bk.ru, elizarovaanastasia@gmail.com

Abstract. Intelligent data analysis systems are designed to minimize the efforts of a decision-maker in the process of data analysis. The article deals with the tasks of intelligent processing and analysis of data from an electronic engine control system unit during testing. An intelligent data analysis system is proposed with the subsequent decision-making on the states of the engine and the electronic control system during test flights. With the help of artificial intelligence methods, causal relationships and regularities of the parameters of a turbojet engine have been revealed.

1. Introduction

Today, the research associated with the intellectualization of data processing and analysis methods is intensively developing. Testing is one of the ways to determine the characteristics of a turbojet engine, to verify the correctness and effectiveness of design solutions, to prove that the specified requirements and requirements of the validity standards have been met.

A large number of tests are performed to identify patterns and causes of deviations and problems. The duration of the tests is directly related to the test methods, as well as to the hardware and software used to record information during the flight and analyze their materials. An effective solution to problems related to determining the necessary characteristics includes preliminary calculations, analysis of flight test materials, accompanying modeling, and a combination of these methods to obtain integral estimates [1-3].

The general block diagram of the organization of tests is shown in Fig. 1.

Therefore, the purpose of the work is to analyze data on the engine and ECS unit states during test flights, which allows us to identify the causes that affect the engine performance and reduce time costs.

Aircraft engines are equipped with a huge number of sensors that generate thousands of signals, so one of the most important problems, especially during testing, is the large amount of information that needs to be analyzed (for example, during testing, files with data in Excel format are received up to 700 pieces). Often, for a more thorough analysis of the data, it is necessary to consider each engine operating mode separately. To do this, in the general data set, it is necessary to select those that correspond to certain operating modes of the turbojet engine, and this is a rather laborious work for an expert.

Among the areas where it is possible to replace an expert are the following:
- intellectual data processing in order to find bottlenecks, etc.;
- the ability to classify difficult to formalize groups of categories;
- clustering of states with the allocation of the most similar clusters and the assignment of corresponding states to each cluster [1-2].
The relevance of this work lies in the fact that the existing methods of processing test data take a lot of time at the stage of preliminary data processing. The use of intelligent methods will automate the data processing process and speed it up. The results of data mining will be used for further informed decision-making and automation of the expert's analytical activities.

Intelligent data analysis systems (IDAS) are designed to minimize the efforts of a decision maker in the process of data analysis. Many IDAS allow not only to solve classical decision-making problems, but also are able to reveal cause-and-effect relationships, hidden regularities in the system being analyzed [3].

The proposed report is devoted to the development of an intelligent data analysis system with the subsequent decision-making on the states of the engine and the electronic control system (ECS) unit during test flights.

The scientific novelty of the work is represented by a set of methods for data mining of test results and decision-making on the causes of failure and malfunctions.

2. Development of an intelligent system for data analysis of test results
Modern gas turbine engines have reached a high level of excellence. The increased number of flights also places great demands on engine reliability.

The main tasks when testing gas turbine engines and an ECS unit during test flights:
- checking turbine components for aircraft engines;
- installation of full turbine performance characteristics in operating conditions as close as possible to real ones;
- study of the effect of the cooling flow on the turbine performance for high pressure turbines;
- detailed studies of the air flow;
- research of the fuel combustion process;
- determination of efficiency and compliance with environmental requirements;
- providing a database to improve control algorithms;
- stability of work in critical modes [3].

Each aircraft engine undergoes testing through the design, construction and manufacturing stages.

2.1. Transfer and processing of test results data
In order to speed up the data processing and analysis of test flight results, it is proposed to use an intelligent system in the existing process.

During the tests, the data from the engine are read by the ESU unit and transmitted in the form of signals to the "Carat" system. Analyzer, i.e. the data converter, which acts as an intermediary for bi-directional data transfer between the "Carat" system and the database, converts the characteristics in the form of numerical data in Excel-file format and then they go to the experts for their further analysis. The block diagram of the sequence of data transmission and processing during the test is shown in Fig. 2.

Fig. 2. Block diagram of data transmission and processing of an existing process

In order to speed up the data processing and analysis of test flight results, it is proposed to use an intelligent system in the existing process. The data converter is designed to transform the data coming to it at the input, and, depending on the type of transformation, unloads the converted data into one or more receiver objects. After the Analyzer (converter), the obtained data in the form of Excel files undergoes preliminary intellectual analysis. After that, the test data on the functioning of the engine are identified by the neural network and a decision is made on the nature of the disturbances. The block diagram of data transmission and processing of a proposed process is shown in Fig. 3.

Fig. 3. Block diagram of data transmission and processing of a proposed process

2.2. Algorithm for analysing engine test data
The algorithm for analysing engine test data is shown in Fig. 4.

Stage 1 involves the choice of methods of analysis.

At stage 2, a component analysis is carried out. This includes collecting data from engine tests. The sample is an Excel-files, each file is one test of the engine. Next, Excel-files are processed for cluster analysis in order to build scatter diagrams. If the desired result is not achieved, return to the first stage and choose another research method.
Stage 3 - cluster analysis based on selected clusters and extracted rules from component analysis. If the desired result is not achieved, return to the first stage or select other clusters at the second stage. At stage 4, a decision tree is built in order to check the correlation of objects to clusters. If the desired result is not achieved, return to the first stage and choose another research method. Stage 5 - implementation of the neural network - training the network for data recognition based on the specified input and output parameters. Stage 6 is the final stage, where the results are analyzed using a reference model of engine operation.

2.3. Developing a data mining model
To develop a data analysis model for the operation of a turbojet engine, it is necessary to create a knowledge base, which will be the results of component, cluster analysis and the construction of decision trees.

A structural diagram of the implementation of a data analysis system based on a database and a knowledge base is shown in Fig. 5.
The initial sample of data taken from the ECS unit is stored in the ECS database. The generated knowledge with the help of the methods of principal components, cluster analysis and decision tree is transferred to the inference system, which performs logical inference and forms the rules, according to which a decision is made on the compliance of the technical specifications and automatic control system with the required engine parameters [4]. In order to speed up the data processing, preliminary intelligent data processing is introduced and a neural network model of the engine functioning during test flights is being developed. To implement a neural network, a method of creating and training a neural network using program code was chosen, since this will allow entering data from pre-recorded files without manual configuration. Neural network parameters are set automatically.

Conclusions
In the work, the analysis of the subject area was carried out, the structuring of the testing process, as well as the data processing process was carried out. An algorithm for the data processing automation process has been developed, which is designed to reduce the time spent at the stage of preliminary processing of data on the turbojet engine states during test flights due to the automation of work.

The scientific novelty of the research lies in the combined use of intelligent methods that allow preliminary analysis of test data and determine whether the state of the engine is close to the reference model or not.

This work was supported by the Russian Fund for Basic Research grants 18-08-00702a, 18-08-01299a.

References
[1] Grigoriev V.V Gishvarov A.S 2009 Ispytaniya aviationsionnykh dvigateley (Testing of aircraft engines) (Moscow: Mashinostroenie) p 504
[2] Gurevich O. S 2010 Sistemy avtomaticheskogo upravleniya aviationsionnymi gazoturbinnymi dvigateleyami (Automatic control systems for aircraft gas turbine engines) (Moscow: Torus Press) p 264
[3] Makarov I.M 2006 Iskusstvennyy intellekt i intellektual'nyye sistemy upravleniya (Artificial intelligence and intelligent control systems) (Department of Inform. Technologies and Computers, RAS systems) p 333
[4] Saitova G.A Elizarova A.V 2019 Design and testing of the turbojet engine reference model. Proceedings of the International Scientific and Technical Conference (Samara: Publishing House of the Samara Scientific Center of the Russian Academy of Sciences) pp 628-632