Methods of computer modeling and recognition of functional characteristics during the diagnosis of aviation engines

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Abstract

In Lithuania non-destructive testing and quality monitoring is used in the aviation enterprises of civil aviation, in the department of Mathematical modeling, in the Faculty of Transport engineering and in Aviation Institute of Vilnius Gediminas Technical University.

In the aviation enterprises of civil aviation and in the department of Mathematical modeling of the Vilnius Gediminas Technical University the new method of diagnosing of aviation engines under the functional characteristics, used in aviation factories, in maintenance and in design organizations has been developed.

Key words: testing, aviation, method, diagnostics, modeling.

Introduction

In Lithuania in industry, energy and transport sectors a non-destructive testing and technical diagnostics have been carried on and the results of such research have been implemented in practice. Significant theoretical and practical studies have been conducted since 1980. Civil Aviation Scientific Institute carried out diagnostic aircraft engine identification tests. This research work made a great start further to develop the aviation engine diagnostic tests according to their functional characteristics and to develop the technologies and the use of aircraft engines, according to the actual technical state [1-16]. This paper is written in order to summarize the main non-destructive testing and diagnostics tests used in Civil Aviation enterprises.

1. Aviation engine diagnostic computer technology

In the research work, using a computer system Maple8 (up to Maple12), the aviation engine test and flight data processing and analysis technology and functional characteristics of the aircraft engines has been explored. The testing and diagnostic system of an aircraft engine, linear matric calculation of the diagnostic results and their further opportunities, classification of faults of aviation engine modules, functional characteristics of simulation and visualization have been proposed, regression analysis for the aviation engines have been applied to assess and to determine the functional characteristics of the most economical modes [1-6].

The proposed technology is used in engineering calculations, for diagnostics of aviation engines, in diagnostics companies. The aim of the study was to adapt computer systems in order to analize the aviation engine (AE), automated data recording and new numerical methods for the diagnosis.

2. Objectives of the study

The following main research tasks have been formulated:

- To investigate the use of aviation engine information processing and automated diagnostic techniques.
- To prepare technology of the AV recording of automated flight data using numerical methods.
- To calculate the stamp diagnostic characteristics using numerical methods to determine the technical state of the AE.

With the help of the aircraft bort diagnostic systems it is possible:

- to explore the technical condition of evolution of aircraft engines for the use of the process;
- to diagnose the engines in due time;
- to diagnose the engine, running it for the purpose;
- to forecast the technical state in the period up to the end of the flight or to the nearest maintenance;
- to investigate the short-term and long-term failures;
- to provide the crew and technical staff with the information in the convenient way for them;
- to provide information on the damaged units for operational exchange;
- to reduce the cost of maintenance.

At present the thing is that the flight parameters are recorded, because they immediately be used in a computer for further analysis and using them in a process.

3. The basic of ideas of a method of diagnosing aviation engines under functional characteristics

Diagnosing of a condition of engines under functional characteristics provides identification of the set of dependences reflecting specific features of characteristics of the concrete engine and its modules at the initial stage of operation. Diagnosing is reduced to perform of the following operations:

- experimental deviation of base parameters, definition with the help of a linear model of physical deviations;
- gas dynamic parameters in characteristic power setting, definition of deviations critical parameters for each module, its characteristics describing change, an estimation of change of characteristics of the engine and its modules in a view of change of sliding of rotors, localization and an estimation of a degree of malfunction or damage within the limits of the module.

Methods of diagnosing of engines under functional characteristics include the following tasks:

- to predict occurrence of functional malfunctions of the engines caused by the change of geometrical characteristics of elements of a flying part;
- to define operational characteristics of engines in an aircraft;
- to distinguish a condition and a degree of malfunction of the engine and its elements.

The establishment of a source and degree of malfunction is carried out in to indirect attributes - on a degree of deformation of functional characteristics of the engine and its elements. The necessary initial information is the set of parameters, measurement of which is provided by a regular monitoring system and also structurally steady characteristics of the turbine.

Definition of characteristics of the fan of the engine with the big two contours in aircraft by results of measurement gas dynamic parameters of the input and the output of the fan is practically impracticable due to significantly radially unequal fields of pressure and temperatures behind the fan. In this connection, it is expedient to put a condition of the fan in dependence on its integrated power characteristics which can be determined with the help of a model of the engine on the basis of results of the test of the engine under a special program. This program has been developed and identification tests of engines at the stand which have been out of service for research of malfunctions during the initial moment of their occurrence are carried out. It is supposed, that the compressor has rotary shovels the directing device with the help of which it is possible to change the loading of the compressor.

The change of a condition of the fan as a result of accumulation of damages will cause the change of all kinematic parameters and, in particular, sliding of rotors. Estimations of the change of power characteristics of the fan are carried out on the basis of comparison of results of the engine test in initial and considered conditions on a mode on which frequencies of rotation of the fan and an available degree of downturn of pressure are identical.

Further possible computerized technologies of diagnosing of aviation engines on the set of parameters are considered.

4. Linear diagnostic matrix (LDM) modelling and calculation using the computer systems and technology issues

Aviation engines may be described by a linear equations system. The matrix A is on the left side, and the matrix B on the right side of the equations. Each equation consists of parameters products consisting of columns and rows of certain factors. Coefficients, which are not in the equations, are set to zero. The solution of equations system is a matrix *C*, which is given by:

$$[C] = [A]^{-1}.[B]$$

$$\mathbf{B\,Y = A\,X},$$

where A and B - are the actual impact parameters of the matrix of coefficients:

$$A = \begin{matrix} a_{11} & a_{21} & \dots & a_{m1} \\ a_{12} & a_{22} & \dots & a_{m2} \\ \dots & \dots & \dots & \dots \\ a_{1n} & a_{2n} & \dots & a_{mn} \end{matrix} \qquad B = \begin{matrix} b_{11} & b_{21} & \dots & b_{n1} \\ b_{12} & b_{22} & \dots & b_{n2} \\ \dots & \dots & \dots & \dots \\ b_{1n} & b_{2n} & \dots & b_{nn} \end{matrix}$$

$$X = \begin{matrix} x_1 \\ x_2 \\ \dots \\ x_n \end{matrix} \qquad Y = \begin{matrix} y_1 \\ y_2 \\ \dots \\ y_n \end{matrix}$$

X and *Y* - are small deviations of actually calculated parameters vectors. The results of this research and application were published in the works [1-6]. The main problem is that inaccurate calculation of the actual parameters of the AE increases the measurement errors. The problem is that the parameters are required for accurate measurement and evaluation of the metrological characteristics.

In each engine all parameters are measured in the same mode and use the same operating conditions which remain unchanged as long as the air and gas tract of the engine does not crash. It is therefore appropriate to use the diagnostic features of certain parameters and parameters deviations. From the survey data it was found that this method requires further research of the diagnostic features related to metrological and accuracy issues. This method, therefore, is almost not used by aviation companies, as the accuracy of indications obtained, can not be used for diagnosis of AE.

5. Aviation engine functional characteristics of the modelling, computing and imaging technology using Maple

Maple 12 has been used for regression analysis of the system of aviation engines and to assess the functional characteristics in order to determine the most economical

operating modes. Since the AV functional characteristics usually correspond to a square function, therefore the square regression analysis method has been applied. Comparisons were made between sound - and the rotten K1 - K2 relative to the engine fuel consumption - and Cr rotor speed frequency square regression function equation, calculated by the least-squares method using the system Maple12 (Fig.1).

The functional characteristics of the Maple 12 simulation model are the following:

> **with(stats):**
> r1:=rhs(fit[leastsquare[[x,y],y=a*x^2+b*x+c]]
([[7292,9745,9950,10200,10600,10850,11495],[1.041,0.5
74,0.573,0.573,0.577,0.582,0.604]]));evalf(%);
r1: = 0.472397823010x^2 –
0.0009884773518x+5.735301799
> r2:=rhs(fit[leastsquare[[x,y],y=a*x^2+b*x+c]]
([[7164,9800,10000,10250,10650,10900,11496],[1.113,0.
628,0.618,0.608,0.602,0.603,0.621]]));evalf(%);
r2:=0.4103148132x^2-0.0008783855802x+5.299478890
> plot([r1,r2],x=7000..12000,y=0.5..1,
style=[line,line,point],color=black);

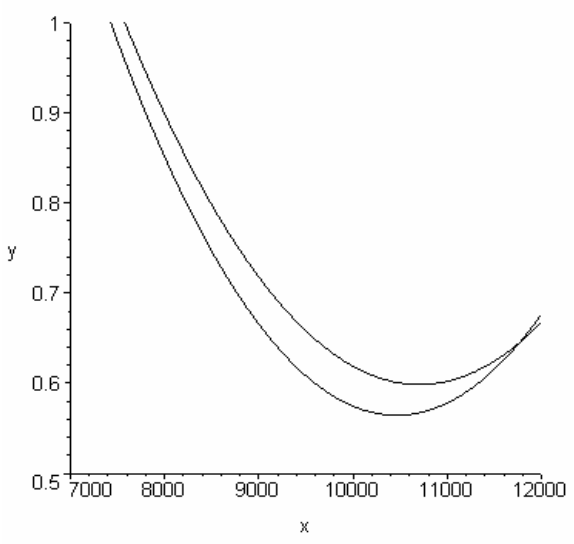

Fig. 1. **Square regression equation graph**

The relative fuel consumption graphs of the engine D-30, which was tested on the bench filings increased oil content are shown in Fig. 1. From the graph it is seen that in this case the diagnostic feature is the relative the increase of the fuel cost and slip characteristics of change (Fig. 2). Therefore, the relative fuel consumption functional characteristics were analyzed.

By differentiating the regression equation the Maple equation is obtained from which the argument, of the relative fuel consumption is minimum values determined. When *x* is equal to 2.494285714, then the fuel consumption is economical.

Using parameters of the Boeing-737-500 aircraft engines CFM-56-3 the testing results of engines were published in [1-6]. Since the function was used to obtain only three measurement points, the regression equations were linear. This method is further studied in aviation engine tests, using automated flight data.

The performance of motor rotor is always easily measured and characteristics of rotor slip, are modelled what is shown in Fig. 2. This characteristic is particularly informative for AE shaft bearings and initial analysis of faults and identification of their diagnostic features.

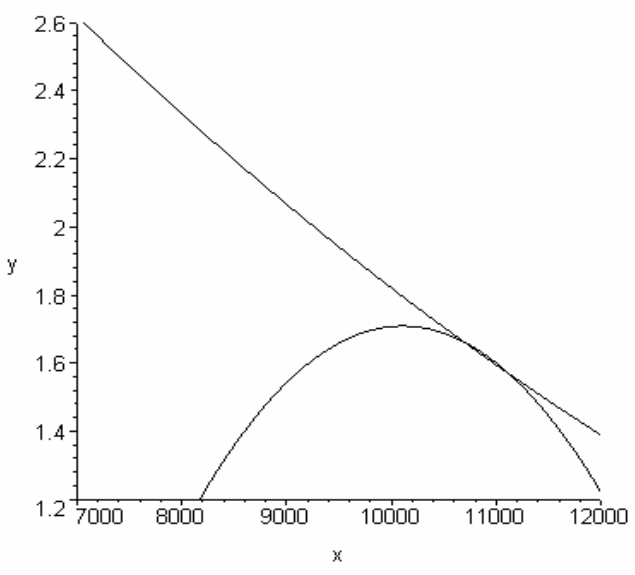

Fig. 2. **Rotor slip characteristic**

6. Classification of faults of aviation engine units

Classification of faults of aviation engine modules is particularly relevant and necessary to all aviation companies, designing and operating engines. The author proposed to classify the faults of AE using the Fisher discrimination function. This method is for detecting faults of the AE modules (compressor, turbine, etc.). This method is still to be used in aviation companies operating on the following main reasons:

• Currently the maintained AE resource and the reliability are high and the failures of the AE modules are very rare, so usually no need for companies to analyze the faults in the AE modules;

• Development of the fault classification technology AE engine modules needs to use the potential faults in the modules, which have not occurred yet. Therefore, in the absence of faults, the diagnosis model is inadequate.

This method will be particularly relevant to companies operating a large number of AE and when there is a need to increase resource of the AE.

The author in his work in general has not received the required support of Lithuanian aviation companies, therefore the research will be continued in other parts of the world, which produce aircraft engines and where there is a large number of operating companies.

In the aviation enterprises of civil aircraft and in the Department of Mathematical Modeling of Vilnius Gediminas Technical University the new method of diagnosing of aviation engines under the functional characteristics used in aviation factories, used maintenance and in design the organization has been developed and methods of modeling of vehicles have been investigated.

Conclusions

1. Computer systems were adapted to calculate and to diagnose the technical state of aviation engine data, derived from the automatic registration.

2. The diagnostic linear matrix and the diagnostic features of the method were investigated.

3. Aviation engine failure classification based on the adapted square regression analysis least squares method as a functional characteristic of the various modes of application of computer systems was proposed.

4. The most economical UA operating mode and fault classification method using a computer system Maple were proposed.

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V. Valavičius

Diagnostiniai kompiuteriniai aviacinių variklių funkcinių charakteristikų modeliavimo ir atpažinimo metodai

Reziumė

Vilniaus Gedimino technikos universitete Matematinio modeliavimo katedroje sukurtas naujas civilinių orlaivių aviacinių variklių diagnostikos pagal funkcines charakteristikas metodas, kuris naudojamas aviacijos gamyklose, priežiūros ir projektavimo organizacijose. Analizuojamos pagrindinės sukurtosios kompiuterinės technologijos aviacijos varikliams diagnozuoti. Pasiūlyti greiti ir tikslūs skaičiavimo ir vizualizavimo taikant paketą Maple 12 metodai. Pasiūlyta, kaip spręsti pagrindines aviacijos variklių diagnozavimo ir tobulinimo problemas.

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