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Diagnostics of aviation engines according to the functional characteristics using computer systems

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Abstract

Opportunities to use of computer systems for the analysis and calculations of functional characteristics of aviation engines of aircraft are investigated. The methodology of the analysis and visualization of throttle characteristics and classifications of malfunctions of modules of aviation engines with use of package Maple9 is developed. The expediency of use of computer systems for the automated analysis and visualization of functional characteristics in the aviation enterprises is proved. The brief analysis of use of the complex non-destructive testing over diagnostics aviation engines is prepared.

Keywords: diagnostics, functional characteristics, aviation engines, non-destructive testing.

Introduction

Nowadays it is common to use computer mathematics for an estimation of a technical condition of aviation engines. For engineering calculations in the operational enterprises the system Excel is used, but recently the use of computer packages was intensively developed: Maple, Matlab, Mathematica and MathCad. There are investigated opportunities of the use of computer systems in classification of malfunctions in the modules of engines. With the help of computer packages, Fisher's quadratic discriminately function with the use of the statistical data, measured in flight is solved. Ways of an estimation of classification are estimated. In experimental calculation with the help of Maple9 there are developed quadratic functions of regress for the analysis of throttle characteristics of engines and establishments of economic operating modes of the engines under the analysis of functions, temperature of gases behind the turbine, specific charge of the fuel and sliding of rotors of the aviation engines are also calculated. There are developed criteria of classification of malfunctions of engines g_x according to Fisher's discriminately quadratic function [1, 2, 3, 4, 5, 6, 7, 8, 9, 10].

The purpose of optimization of characteristics was to define (determine) and establish interrelation of change of testimonials from of depth of arising defects in modules of the engine. The following parameters have been measured: draft of the engine, frequency of rotation of a rotor under cascade of high pressure, hourly charge of fuel, specific charge of fuel, degree of increase in pressure of the compressor at low pressure, temperature of gases behind the turbine, characteristics a of degree of increase in pressure of the compressor under high pressure, a total degree of increase in pressure. The greatest diagnostic value represents the temperature of gases behind the turbine of the engine.

1. Experimental investigation

Using package Maple 9 were it is calculated numerical characteristics of aviation engines: selective average, dispersion of a sample and an average square-law deviation(rejection), and also unbiased dispersion of a sample and an average square-law deviation(rejection), and then on Fisher's quadratic discriminately function g_x [10] we carry out classification of malfunctions into the first and second class.

If $g_x > 0$, it will be a diagnostic attribute of the serviceable engine - class 1 and if $g_x <= 0$ there will be a diagnostic attribute of the serviceable engine - class 2 [9, 10, 11].

$$g_x = \frac{(x - Mx_2)^2}{Dx_2} - \frac{(x - Mx_1)^2}{Dx_1} + \ln(\frac{Dx_2}{Dx_1})$$

where Mx_i ir Dx_i - selective average and a dispersion.

The temperature of gases behind the turbine on a take-off mode of the aviation engine have been tested and investigated, the rise in temperature of gases behind the turbine has been measured. Further the method of the use of package Maple9 (Maple10) is resulted.

Results of calculation of 12 parameters g_x:

g_x: -12.322, -1.224, -8.617, -12.322, -10.431, -4.339, 6.849, 2.94, 0.232, 9.511, -1.224.

Using package Maple 9 from the analyzed temperature of gases for diagnostic attribution of 12 engines: 10 engines belong 2 - to an ohm to a class (g_x <0), and two - 1 - to an ohm to a class (g_x > 0) [11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21].

The first class of malfunctions - malfunctions in the module of the compressor of the engine, and the second class of malfunction - malfunctions in the module of the turbine of the engine.

With use of system Maple the decimal fraction of result of calculation can be carried out (be spent) with very plenty of figures after an integer. It calculations which possess very big accuracy also speak.

Using developed computer technology with the help of system Maple 9 the basic functional characteristics of aviation engines further are shown.

1.1. A technique of the analysis and visualization of the throttle characteristics of aviation engines with the use of computer package Maple9

With the use of system Maple9 on the data with the operating time of the engine, SNE 7454 hours, PPR 64 hours the technique for reception of functional characteristics. The reason of prescheduled removal - a in oil is shown.

1.1.1. The characteristics of draft of the engine from frequency of rotation of a rotor under cascade of high pressure, sliding of rotors

Further the technique of preparation of functional characteristics with use of system Maple of the aviation engine in the beginning of operation and characteristics of the same engine after occurrence of malfunction is shown.

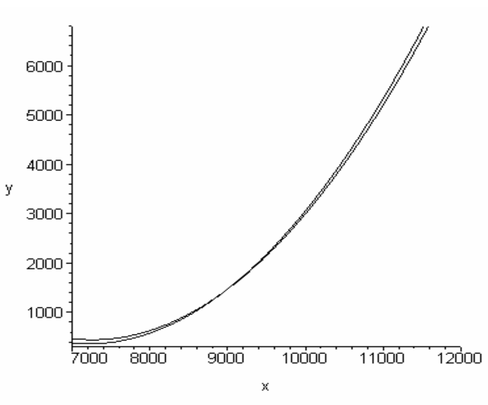

Fig. 1. **Characteristics of draft of the engine (y) depending on frequency of rotation KVD, SNE and PPR (x) (SNE - from the beginning of operation, PPR - after last repair)**

1.1.2. The characteristics of sliding of rotors

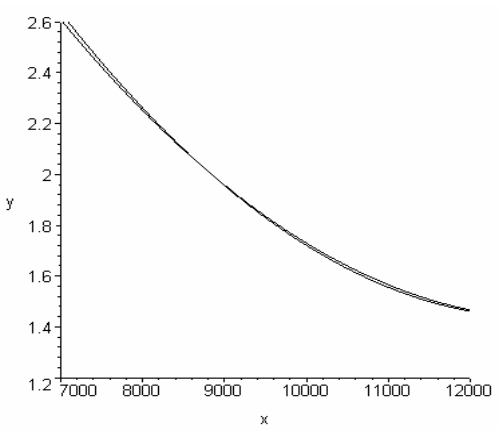

Fig. 2. **Characteristics of sliding of rotors on the draft when the engine (y) is at frequency of rotation KVD, SNE and PPR (x)**

1.1.3. The characteristics of the hourly charge of fuel

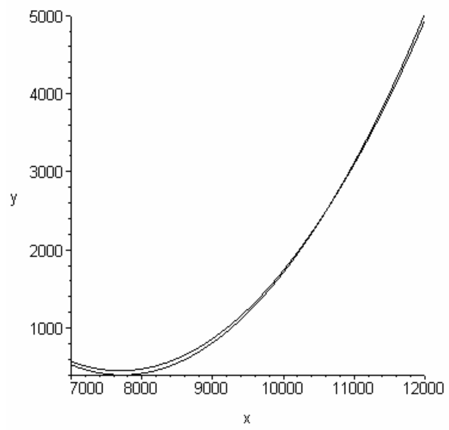

Fig. 3. **Characteristics of the hourly charge of fuel of the engine (y) on frequency at rotation KVD, SNE and PPR (x)**

1.1.4. The characteristics of the specific charge of fuel

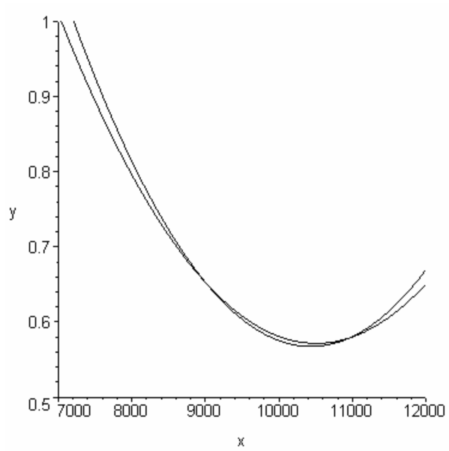

Fig. 4. **Characteristics of the specific charge of fuel of the engine (y) at frequency of rotation KVD, SNE and PPR (x)**

1.1.5. The characteristics of temperature of gases behind the turbine

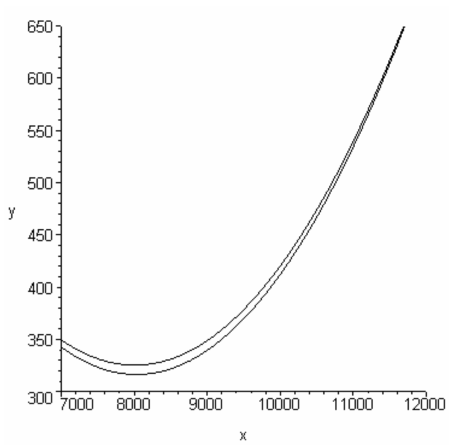

Fig. 5. **Characteristics of temperature of gases behind the turbine of the engine (y) at frequency of rotation KVD, SNE and PPR (x)**

1.1.6. The characteristics of degree of increase in pressure of the compressor at low pressure (KND)

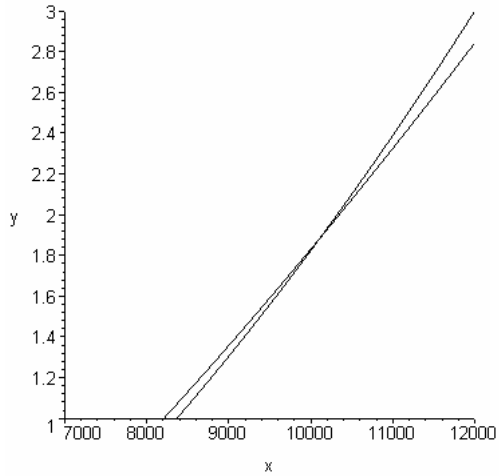

Fig. 6. **Characteristics of a degree of increase in pressure KND of the engine (y) at frequency of rotation KVD, SNE and PPR (x)**

1.1.7. The characteristics a of degree of increase in pressure of the compressor under high pressure (KVD)

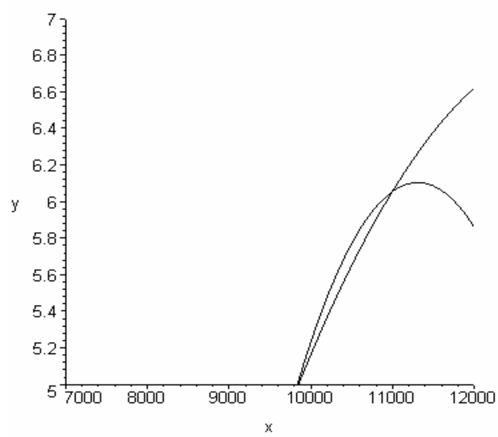

Fig. 7. **Characteristics of a degree of increase in pressure KND of the engine (y) at frequency of rotation KVD, SNE and PPR (x)**

1.1.8. The characteristics of a total degree of increase in pressure

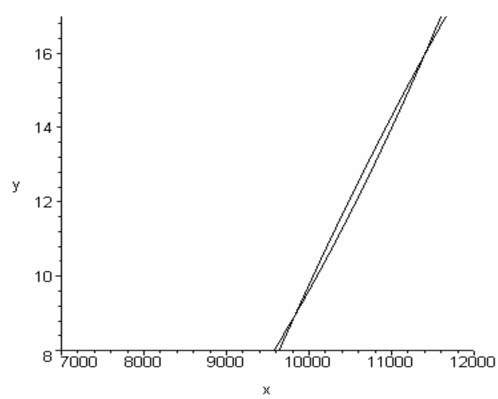

Fig. 8. **Characteristics of a total degree of increase in pressure of the engine (y) at frequency of rotation KVD, SNE and PPR (x)**

2. The basic results on the use of computer systems for construction of throttle characteristics of engines and the analysis of profitability of engines

The greatest use for the analysis of throttle characteristics of engines was received with package Maple9 (Maple10). At tests of aviation engines it is convenient to use square-law regression the analysis of package Maple9 in its system Stats.

Throttle characteristics – dependency on the draft, the specific charge of fuel, the hours charge of fuel, temperatures of gases behind the turbine and sliding of lee rotors of engines as functional dependences on frequencies of rotation of rotors of engines at revolutions of small gas up to the maximal revolutions of a take-off mode have been investigated. Computer systems are convenient for using for the analysis of characteristics of engines the with in the parameters registered automatically in flight.

2.1. Dependence the temperature of gases behind the turbine of the engine of the aircraft Boeing 737-500 on the frequency of the second cascade

Example when there was no malfunction (Fig. 2.1.):

> with (stats):Digits: = 3;

Warning, these names have been redefined: anova, describe, fit, importdata, random, statevalf, statplots, transform

Digits: = 3

> r1: = rhs (fit [leastsquare [[x, y], y=a*x^2+b*x+c]] ([[81.4,86.5,91.6], [705,746,791]])); evalf (%);

$$r1 := 0.00393x^2 + 10.3x - 175.$$

> r2: = rhs (fit [leastsquare [[x, y], y=a*x^2+b*x+c]] ([[81.4,86.5,91.6], [729,771,819]])); evalf (%);

$$r1 := -0.114x^2 + 17.1x - 150.$$

> plot ([r1, r2], x=81.. 92, y=700.. 1100,

> style = [line, line, point], color=black);

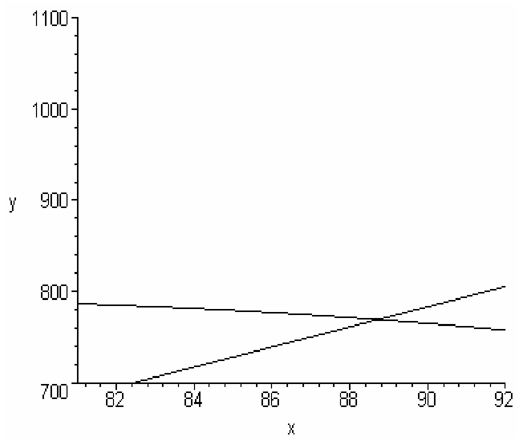

Fig. 2.1. **Dependence of the temperature of gases behind the turbine of the engine of the aircraft (y) on frequency of the second cascade when there was no malfunction (x)**

> with (stats):

Warning: these names have been redefined: anova, describe, fit, importdata, random, statevalf, statplots, transform

> r1: = rhs (fit [leastsquare [[x, y], y=a*x^2+b*x+c]] ([[81.4,86.5,91.6], [705,746,791]])); evalf (%);

$$r1 := 0.00393x^2 + 10.3x - 175.$$

> r2: = rhs (fit [leastsquare [[x, y], y=a*x^2+b*x+c]] ([[81.4, 86.5,91. 6], [740,782,950]])); evalf (%);

$$r2 := 0.479x^2 - 27.2x - 425.$$

> plot ([r1, r2], x=81.. 92, y=700.. 1100,
> style = [line, line, point], color=black);

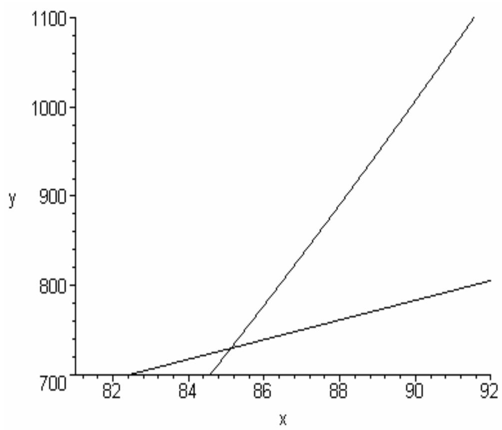

Fig. 2..2. **Dependence of the temperature of gases behind the turbine of the engine of the aircraft (y) on frequency of the second cascade when there was a malfunction (x)**

For an economy estimation of engines it is necessary to watch the change of the specific charge of fuel of engines automatically. Haring the first operating function of regress in the specific charge of fuel we can determine the coordinates of frequency of rotation of rotors of engines at a minimum of specific charge of fuel [12, 13, 14].

Analyzing functional characteristics of aviation engines at occurrence malfunctions it is possible to watch process of malfunction at the further operation of the concrete engine. It is possible in the future at reception of more information under the analysis of characteristics.

3. The use of the complex non-destructive testing over interrelation while diagnosing the engine

The use of methods of non-destructive testing over diagnostics the HELL under functional characteristics is the basic auxiliary means for decision-making on a condition of engines in elements of a flowing part of the engine. The basic kinds of not destroying control are: ultrasonic, electromagnetic, optical, magnetic and capillary.

The ultrasonic method allows to reveal fatigue cracks, blades and disks of engines where there is an approach for the control. The important advantage of a method is the opportunity of revealing destruction at the unilateral approach to a controllable detail of an element of the engine, located in the big depth or leaving left on an inaccessible surface. However, the method demands development of special control samples and it is not sufficiently sensitive for defects. Therefore, the ultrasonic method is expedient for using with the electromagnetic method of non-destructive testing.

Modern devices: electromagnetic, optical and ultrasonic non-destructive testing allow to carry out the control as blades and other power (force) elements of aviation engines.

The complex non-destructive testing of details, connections, units and mechanisms of flying devices apply in the following basic cases:

1. If necessary revealing in controllable products various in character, the form, the sizes, an arrangement and quantity(amount) of internal and external defects.
2. At introduction of new materials, kinds of one-piece connections and products.
3. At introduction of new, more effective methods of not destroying control.
4. If there is a doubt in reliability of a used method os non-destructive testing.

At a choice of a method of non-destructive testing it is necessary to take into account the following:

- place of possible(probable) defects;
- physical properties of materials;
- condition, the form and the sizes of a controllable detail;
- conditions of the control and the approach to a controllable surface;
- specifications on a controllable place.

It is necessary to take into account, that the electromagnetic method is suitable only up to depth of 1 mm.

The modern optical non-destructive testing allows to examine surfaces of places of the engine in accessible places and to carry out(spend) computer visualization.

For a capillary color method the surface should be a rack for solvents and should be probably remove solvents after the control. For the capillary control there are difficulties with (a handicap) of a covering. Ultrasonic method it is impossible to supervise fine and rough surfaces. At the control of not difficultly accessible places it is necessary to use special gauges, rotary mirrors, gaffers, manipulators, devices of fastening. It the control makes more also creates additional complexities of a choice of a quality monitoring.

At use of each method of non-destructive testing, those defects which influence safety of flights should be only controllable.

Actions on high quality maintenance of aircraft by means of a recreation center maker great technical and economic benefit. According to foreign data, each dollar spent for these purposes gives economy of 7 dollars.

For maintenance of high operational reliability of aircraft oh great value is also the periodic control of its technical condition during dismantling or with a limited disassembly, spent at service, in operation and repair. The role of a recreation center in operation when urgent there is a necessity of prolongation of term of use of aircraft, that recommended the preserves on reliability, instead of purchasing new ones that are not enough checked up, but the cost especially rises. Thus big charges on the control, including its scientific support and the attendants, nevertheless much less, than losses after heavy flight incidents. And special value is given to defectoscopic the control over operation aircraft on a technical condition [15].

At operation and repair the HELL of some detail and units where dangerous defects such as infringement are formed first of all fatigue cracks possible are and destruction can lead to refusals of aircraft, due to flight to incidents, pass НК.

Periodicity of the control of details and units at maintenance service establish in view of growth rate of cracks till the critical size, and at increase in time of operating time aircraft the terms between checks are reduced.

The list of details and the units checked by the restoration centre is given. Operation and repair, and also periodicity of checks at the maintenance service is on the basis of operating experience of aircraft of the given type (by results of processing statistics of refusals and malfunctions the HELL and to other data), in connection with the development of fatigue and thermal cracks, corrosion defects and the stratifications related to increase of the term of operation, volume of the control increases.

Some objects are a remove from the control. It is supposed to exclude only details and units on which actually working pressure (voltage) appeared essentially get or which are subject to scheduled replacement. Not detection of defects at the initial stage of operation of aircraft cannot form the sufficient basis for exception of details and units from the specified list [15] .

Analyzing the results of the research work it is possible to allocate the basic problems which will be necessary for solving in the future:

- in the aviation enterprises sites for use of development of computer mathematics are not prepared;
- the majority of the experts carrying out (spending) diagnosing of aviation engines do not own new systems of computer mathematics.

Conclusion

The method of use of computer systems for the analysis of functional characteristics of aviation engines is investigated. With use of the system Maple9 the analysis and visualization of functional characteristics and complex methods of non-destructive testing diagnostics aviation engines are proposed.

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V. Valavičius

Aviacijos variklių diagnozavimas pagal funkcines charakteristikas taikant kompiuterines sistemas

Reziumė

Parengtas aviacijos variklių diagnozavimo pagal funkcines charakteristikas taikant kompiuterines sistemas metodas. Aviacijos variklių funkcinėms charakteristikoms analizuoti ir vizualizuoti naudojama sistema *Maple9*. Ištirti neardomųjų bandymų kompleksiniai metodai, taikytini diagnozuojant aviacijos variklius.

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