Selected Method of Diagnosing Aviation Ergatic Systems

Odabrana metoda dijagnosticiranja ergativnih sustava u zrakoplovstvu

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Summary

Insufficiency in showing errors in aviation ergatic system is understood to be a situation when there is no available information about the system or some of the board information is unreliable. With the use of the method of automatic diagnosis it is possible to analyse the symptoms of analytical redundancy. Residual differences, i.e. residuents, which are the final value expression of the consequences (effects) of function observation, which are measured on obtained mathematical model, are the keystones of this method. The content of the mathematical model application contains generator of residuents, i.e. signals, which carry the information about the incorrectness (errors) and aviation ergatic system (AES) failures.

KEY WORDS

automatic diagnosis
residuents
reliability
quality
functional diagnostics

Sažetak

Nedostatnost pokazivanja grešaka u ergativnom sustavu u zrakoplovstvu jest situacija kada nema podataka o sustavu ili su neki podatci iz zrakoplova nepouzdani. Upotrebom metode automatskog dijagnosticiranja moguće je analizirati simptome analitičke redundancije. Preostale razlike, t.j. reziduenti, kojima se manifestira konačni rezultat posljedica (učinaka) promatranja funkcije, koji se mjere dobivenim matematičkim modelom, ključni su segment ove metode. Sadržaj primjene matematičkog modela sadrži generator reziduenata, t.j. signale koji prenose informaciju o neispravnostima (greškama) i greškama u ergativnim sustavima u zrakoplovstvu (AES).

KLJUČNE RIJEČI

automatska dijagnoza
reziduenti
pouzdanost
kvaliteta
funkcionalna dijagnostika

INTRODUCTION

High price of aeronautical technics, its movement in air space and tasks which are solved require to keep quality and reliability. One of the ways to increase the quality of aviation technology, namely its reliability, is based in the use of new methods of checking and diagnostics in all periods of its operation. Functional diagnostics, which is aimed at the check and diagnostics of actual functional state of the systems being used in safeguarding and maintaining aircraft flight features has an important role among many other renowned methods. The base of finding out of such errors is the system of evaluation and their correction in the process of diagnostics. Its task is to perform the evaluation, which undergoes the decision-making process.[1],[2].

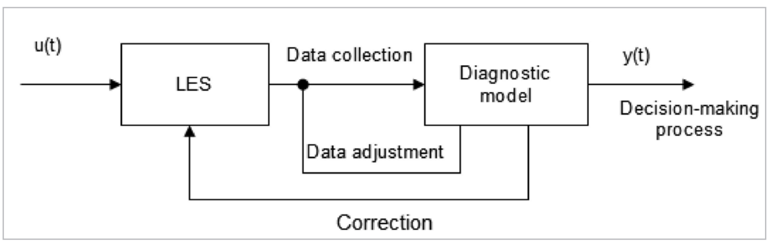

Figure 1 AES stabilisation process with the use of diagnostic analogy [14].

In diagnosing incorrect AES functions it is necessary to bear in mind the task of the aircraft, which is subordinate to two dominant systems during the flight:

- control and manoeuvring aircraft,
- control and manoeuvring engine.

One of the common aims with maintaining flight safety is the compensation of the occurrence and influence of the failure[10].

ERROR GNOSEOLOGY IN DIAGNOSTIC PROCESS

During measurements residuents from the generator on mathematical model there can be seen values obtained in the period of pre-processing; relatively high in the cases when the errors showed, and small (close to zero) if the error has not occurred ([9] p. 178). The fact that the generator residuents output value is not zero is the consequence of the influence of the error, noise model. However, it is possible to define the threshold of residuent output value, crossing of which is significant in error demonstration. Residuents generating base is the method of parity (equal) space, principle of estimation (assessment) and system state filtration [3],[11].

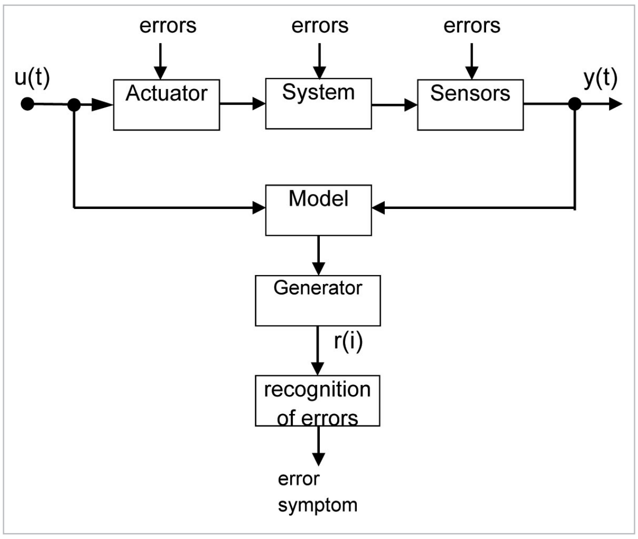

Figure 2 Error recognition system structure

The content of the above mentioned terminology, their mutuality, usability, value demonstrations, etc. have been well worked out in [5],[8], which proves the effectiveness of analytical procedures in automatic diagnostics. Knowledge and skills of experiment operators, namely in solving discreet and linear state equations, are essential in experimental work and modelling. The creations of models of relevant actuators (action element) are shown in a similar way. The authors draw their attention to the influence of sensor noise as well as the described system. The knowledge of the residuent generator function on the base of models, described in the paper, is important for the need of experimental work on complex circuits used on aircraft boards. However, it is important to remark that the presentation of presented theory application has pragmatic character, aimed at understanding the need to connect the effectiveness of experimental research with diagnostic (automatic) equipment, which belongs to the equipment of every aircraft system, and influences flight safety.[4],[5].

ALGEBRAIC PARITY SPACE

Let the system, equipped with diagnostic device determined for error detection, be the subject of experimentation. The experiment plan programme contains screening of parity measurements of momentary values of the system and values obtained with the help system mathematical description. Examination with the help of the second state equation of the system description is suitably stated then, for the system without direct ties between input and output (*d* = 0), with considering noise existence, there will be [5],[6]:

$$\vec{y}(i) = C\vec{q}(i) + \vec{f}_s(i) + \vec{n}(i) \tag{1}$$

where:

$\vec{y}(i)$ – is output parameter vector,
$\vec{q}(i)$ – state parameters vector,
$\vec{f}_s(i)$ – sensor errors vector,
$\vec{n}(i)$ – noise measurement vector,
C – output matrix.

Error detection supposes that the system will contain*p*output sensors which create signal redundancy, i.e. each output parameter can be monitored by several sensors. It is possible to create a set of equations (pre-stated system of algebraic equations) from this vector to detect errors, the matrix form of which is [7]:

$$\bar{\vec{y}}(i) = \bar{C}\vec{q}(i) + \vec{f}_s(i) + \vec{n}(i) \tag{2}$$

where the line above the variable presents a difference:

$\bar{\vec{y}} = \vec{y} - \Delta\vec{y}$; $\bar{C} = C - \Delta C$; etc.

$$\vec{r}(i) = V_M \bar{\vec{y}}(i) = V_M \bar{C}\vec{q}(i) + V_M\left(\vec{f}_s(i) + \vec{n}(i)\right) \tag{3}$$

where:

$\vec{r}(i)$ – is residuant vector2),
V_M – parity matrix (redundant equality), where matrix lines are parity vectors[12].

When:

$$V_M \bar{C} = 0 \tag{4}$$

then it is true:

$$\vec{r}(i) = V_M\left(\vec{f}_s(i) + \vec{n}(i)\right) \tag{5}$$

From the equations (4), (5) it follows that residuents vector $\vec{r}(i)$ depends on the error of output sensors and is independent on system states $\vec{q}(i)$.

Fault detection decision function (DDF) is possible to be defined in the shape of residuent vector standard quadrate:

$$f_{DFD} = \vec{r}^{\,T}(i) \cdot \vec{r}(i) \tag{6}$$

where:

T – present transportation operation.

The equation (6) will gain value higher than defined threshold when sensor error occurs in the system. Knowledge of parity matrix and parity function is important due to this fact. The synthesis of parity matrix and parity function is well described in quoted literature ([5] pp. 26 – 31). Considering the purposive focus of this paper and the need to experiment it is sufficient that the authors´ [5] equations be adjusted to the forms which are possible to be solved in the environment of MATLAB with the application of concrete needs of aviation turbo jet engine (TJE) diagnostics. For this reason, in the following used the symbolism of MATLAB. Final solution finds support in the following form [5,[11]:

$$\vec{r}(i) = V_M\left(\vec{y}_Y(i) - \vec{q}_u\vec{u}_u(i)\right) = V_M\vec{q}_u\vec{f}_a\ (i) + V_M\vec{f}_s\ (i) \qquad (7)$$

EXAMPLE OF AUTOMATIC DIAGNOSTICS ANALYTICAL MODEL SUGGESTION METHOD

Hypothetical structure of automatic diagnostics is presented in Fig. 3. The scheme presents aviation turbo jet engine continuous control in time [12], The task is to determine analytical redundancy $\vec{r}(i)$ which is the output of residuent generator (3), (5), (7) on the base of the knowledge of object structure (state equations). The successiveness of task solution accepts the methodology presented in [5].

The analytical form of the model object diagnosis is expressed by transfer functions:
s = tf('s');
He=0.110*exp(-0.019)/(1.97*s+1); transfer function TJE (Fig. 3);
Hc=-42.673*(0.82018*s+1)/s;transfer function of rpm regulator (Fig. 3);
Hf=0.9876*exp(-0.089*s)/(0.1058*s+1);transfer function of fuel distribution (Fig. 3);
Transfer functions: He, Hc, Hf are described in [12];
The analytical form of the model object diagnosis obtained using the command:
sv=feedback(ss(He),-Hf*Hc),feedbackcircuit of RPM control;
transition function is:
step(sv,'r'),transition function;
bode(),
bode(sv),
sysc=tf([1.1892 -1.4162],[1.0000 2.9737 2.8217 0.9142 0.0908]),
The calculated terms in the form of time-response and frequency characteristics show that the object is diagnosable.
Discrete form of transition function is:
sysd=c2d(sysc,0.2),0.2- clock frequency;
step(sysc,'--',sysd,'r-'),
bode(sysc,'--',sysd,'r-'),
Note: By implementing command to display of amplitude, phase-frequency characteristics of object diagnosis.

Analytical model of automatic diagnosis:
Position throttle control of TJE(delta TJE = 0).
Constants of state value (see comandsv),are:
a=[-0.5076 -2.552 -3.112;7.013 -9.452 0;0 1 0];stock variables of object,
b=[0.25 0 0]';matrix ofstate control;
c=[0.2191 0 0];coefficientsmatrixoutputs,
Procedure according step of text: (7);
qp=obsv(a,c),observability
qp =[0.2191 0 0;-0.1112 -0.5591 -0.6818;-3.8648 4.8870 0.3461];
qu=[0 0 0;c*b 0 0;c*a*b c*a^0*b, 0],see (7);
[U S,V]=svd(qp),decomposition-determinethe parity matrixVM (5);
VM=U';parity matrix (synonymic);
Parity matrix include rowvectors of which selected rowscreateprojection matrix: v(i,j). Whenwe exclude theeffect of errors (Fig. 3), then is possible to estimatethe errors(residue) of

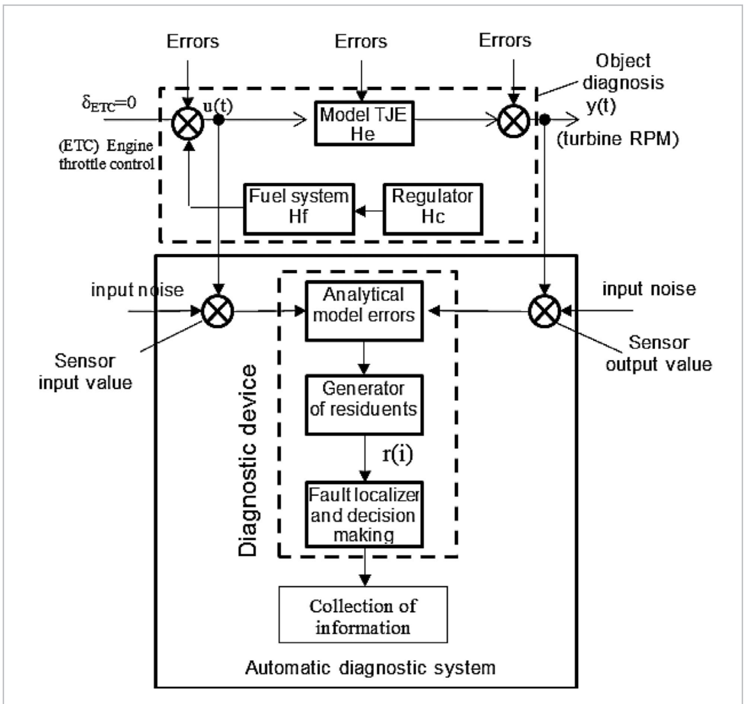

Figure 3 Hypothetical automatic diagnostics system

control circuitforone input

v12=VM([1:2],:),selectionofrowsmatrix VM for detection errors;

By substituting VM in (7),will be:

r12=v12*(c'-qu*b),

Residual error expressed as a percentage is pointed by sensors for RPM 0.3 of errors signals "allowable norm", it does not apply in case if output of generator of residuents will be out of tolerance

CONCLUSION

Sufficient controllability of observed object in the used state space is the assumption of scheme of diagnostics according to Fig. 3 by the described method. Current validity of this requirement, the fulfilment of which has enabled to determine the symptom of error in turns, with fixed position of engine control, has been proved. Determined error, expressed in percent, belongs to the range of allowed errors, diagnostic system does not evoke error occurrence system. In spite of its complexity, the used method shows satisfactory results, usable in a laboratory and is possible to be used as an algorithm in practice.

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