Aircraft Automatic Control Systems and their Control Systems

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Summary

The high reliability of automatic control systems of aircraft is reflected in the practical implementation in order to reduce an already small number of elements, for example, connecting functional element checking and control circuits. Each of the elements of control, which represents a control circuit, also performs the function of the sensor control. It is similar to the element-node connections and can be a wave form that is used for controlling. This is the way how to use converters that perform functions such as comparators from which the output control signal passes to the input power member. The converters, power members, signalling devices and indicators, as well as programming elements are usually placed in the critical nodes and they are elements of not only embedded system checkings, but also backup elements of the aircraft automatic control system.

KEY WORDS
aircrafts
control system
automatic control
algorithm

INTRODUCTION

A system of automatic control of the aircraft is intended for automatic control and prescriptive control of aircraft. Functions of the automatic control system of the aircraft increase flight safety, improve stability and controllability characteristics of the aircraft during manual and command flying. The system consists of rudder actuators, gyro sensors, and accelerometers, sensors of negative pressure, transducers, correction circuits, computers, commutation systems, and programming equipment.

The set of elements intended to control various parts of automatic control of the aircraft, which represents the object of control, we refer to as an embedded control system.

The outputs of these built-in checking's are used to:

- notify the pilot about the failure of automatic control,
- disconnect a fault system,
- install a system backup function.

The important position between the elements of the system has built-in controls and power converters, data members, implementing control algorithms. The content of the algorithm is the criterion of the fault-free or failed objects of control. The complexity of these elements determines the choice of optimality criteria and checking quality processes.

The values of the control signal are compared with the "etalons" whose value is to inspect conditions of object criteria importance. In terms of flight safety two signals are important: a fault and fault-free, a line called switch on threshold which separates the fault from fault-free signal. The u_{prah}^{max}, u_{prah}^{min} values of upper and lower switch on threshold are identical and are functions of time expressed with the equation:

$$u_{threshold}^{min} \leq u(t) \leq u_{threshold}^{max} \quad (1)$$

The equation (1) describes the checked object as a trouble-free one. In case the following is applied:

$$u_{threshold}^{min} \succ u(t) \text{ or } u_{threshold}^{max} \prec u(t) \quad (2)$$

the checked object is faulty.

The purpose of an algorithm for optimal checking is to induce and measure the length of the period and amplitude of vibrations as a result of aircraft responses to the resulting failure of the automatic aircraft control. Vibrations of aircraft and size of amplitude oscillations provide quality information which evaluates the system of built-in controls and monitors the flight safety. The moment of reaching a threshold switching by a control signal is the time expressing the failure result of the checked object, and also duration i.e. the period of faults (Figure 2).

The moment of reaching switch on threshold check by a signal and a switching time element of built in check which puts into function a backup power control element, is measured and the output measured value determines the duration of fault expression.

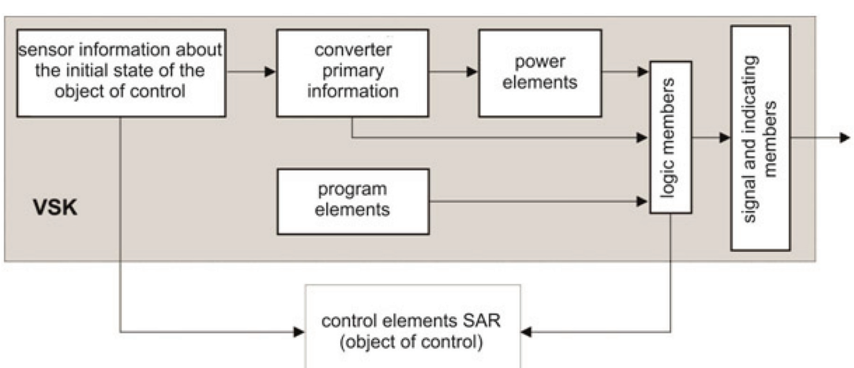

Figure 1. Parts of an embedded control system of an aircraft

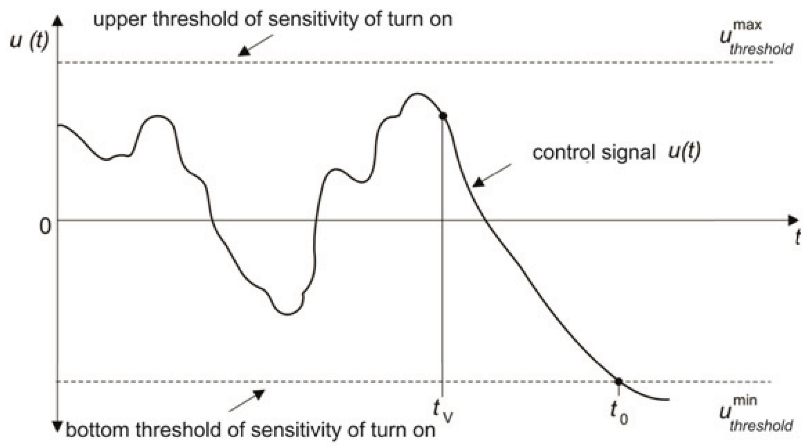

Figure 2. Parameters of the control algorithm

PROBABILISTIC OF THE EMBEDDED CONTROL SYSTEM CHARACTERISTICS

The control signal has a random character, i.e. except unstable automatic control system parameters and elements and also characteristics of random external events enter into its frequency spectrum acting on the "aircraft - a system of automatic control." In reality a control signal is a random time function. The number of passes of given level control signals is a discrete random variable that will have distinctive features:

- switching on the threshold crossing moments are spread everywhere with the same mean density. This density is marked as a mathematical chance of crossing per unit time symbol $\lambda_{\phi i}$,
- the probability of one or another number of false switching on during the specified time does not depend on how many they occurred in the following section,
- probability of two or more false switching on the embedded control system in a small time interval Δt is unlikely. Likelihood of in correct switch symbol m denote the element P(m) embedded control system that has emerged over time t. In this case, the following is applied:

$$P(m)=\frac{(\lambda_\phi t)}{m!}e^{-\lambda_\phi t} \quad (3)$$

From the relation (3) the probability of false switching on in the time t is calculated:

$$P(0)=e^{-\lambda_\phi t}$$

and the probability, that in the time t there is only a false switching on, occurs:

$$q_{n,z}=1-P(0)=1-e^{-\lambda_\phi t} \quad (4)$$

The algorithm of the control signal and the threshold switching on is chosen by compromise so as to ensure the possibility of detecting a fault in the checked object accepting the probability of spurious switching on of an embedded checking system.

METHODS OF INSPECTING THE AIRCRAFT AUTOMATIC CONTROL SYSTEMS

The method of checking the aircraft automatic control system and its parameters are possible by:

- forming a control signal with the parameters of aircraft automatic control, an internal checking done when in turning the aircraft rudder the control signals formed in special districts are generated,
- forming control signals with aircraft motion parameters, external checking is implemented in which the control signals are generated by fluctuations, tilt, angle deviations from the trajectory.

Less vivid response requires internal checking the aircraft, where the checking signal represents the time function, which expresses the difference in actual valueand Y_{SK} *(t)* the standard value Y_E *(t)*, which the required value of a checked object refers to in values.

The written form of an output variable in the operator's registration form is:

$$u(s)=[Y_{SK}(s)-Y_E(s)]\,W_P(s) \quad (5)$$

where:

W_P (s) - information transfer function of the converter.

FORMING A CONTROL SIGNAL BY A THRESHOLD VALUE OF THE ACTUAL SIGNAL

In this case, the initial calculated signal Y_P has a zero value and estimation about the state of an object checking is carried out according to the size of the actual signal i.e.:

$$u(s)=Y_{SK}(s)W_P(s) \quad (6)$$

In the method of external checking the signals of the initial information are used (such as shutting down the system) under the automatic control signal exceeding the permitted multiples, deflection from the equilibrium glide zone of an equivalent signal marker beacon. In the internal checking, the computer signals of drives etc. are used (e.g.to disconnect the sub-circuit computer of a landing system by a large value of the output signal).

At the additional check the formed signals are typically used, they are sensed in failure of automatic control of the aircraft and produce the emergence of the aircraft. This method, however, may cause undesirable movement of an aircraft and the consequent increase in the frequency of false switching on.

THE CHOICE OF THRESHOLD SWITCHING ON

The threshold value of switching on should be chosen from the conditions determining the permissible incorrect probability of switching on the control elements, whose moderate intensity is

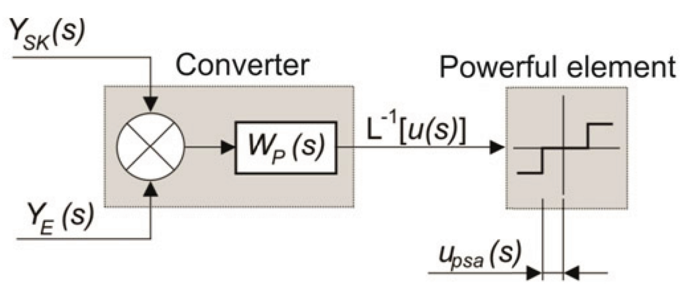

Figure 3. Illustration of a forming control signal

determined from the inequality:

$$\lambda_{\phi} \le \lambda_{\phi_{POV}} \quad (7)$$

Accurate, but laborious and complex mathematical possibility of determining the value λ_{ϕ} is a statistical method or the method of Monte-Carlo, which is also suitable for nonlinear time-varying tasks. The experience has shown that if the analytical calculation is possible, assuming that the signal u (t) is stationary and derived in parts, which complies with the flight mode.

In terms of simplification of the calculation, we assume that the upper and lower switching threshold is numerically identical, i.e. so that the following is applicable:

$$\left|u_{threshold}^{max}\right| = \left|u_{threshold}^{min}\right| = \left|u_{threshold}\right| \quad (8)$$

Then the check, in already mentioned conditions, will be as follows:

$$\lambda_{\phi} = \frac{\sigma_i}{\Pi \sigma_u} e^{-\frac{(u_{threshold} - m_u)^2}{2\sigma_u^2}} \quad (9)$$

where:

σ_u, σ_i - mean-square deviation check signal and its derivative,

m_u- mathematical expectations, the check signal.

The statistical characteristics, σ_u, σ_i and m_u apply to:

- determining the value $\tilde{\sigma}_u$, $\tilde{\sigma}_i$, $\tilde{m}_u$ when the automatic control system parameters are fixed
- probability of averaged statistical characteristics $\tilde{\sigma}_u$, $\tilde{\sigma}_i$ a $\tilde{m}_u$ and including all the parameters of automatic control

In the first stage of calculating the values $\tilde{\sigma}_u$, $\tilde{\sigma}_i$, $\tilde{m}_u$ will be determined by known methods of probabilistic analysis, which are the most common analytic methods and a method of Monte-Carlo. In the first stage of calculations under the analytical method of the analogue way of forming a checking signal, we apply the operation of mathematical hope.

We will get:

$$\tilde{m}_u = (k_{\Omega} - k_A) k_{kor} \cdot \sum_{i=1}^{n} k_{\delta i} m_f \quad (10)$$

where:

m_{ij} – mathematical hope of i - external failure,

k – amplification coefficient of the transfer function (3.8).

The calculation of the values σ_u, σ_i is based on the relation:

$$\sigma_y^2 = \frac{1}{\Pi} \int_0^{\infty} \left|W_{y/x}(j\omega)\right|^2 S_X(j\omega) d\omega \quad (11)$$

where:

S_X- spectral density of the input signal x of frequency ω;

$W_{y/x}$ $(j\omega)$ - a transfer function(x by y);

σ_y^2 - dispersion of the output signal y;

We´ll calculate the dispersion $\tilde{\sigma}_{\mu_i}^2$ and $\tilde{\sigma}_{\mu_i}^2$, falling to the i-th interference.

$$\tilde{\sigma}_{u_i}^2 = \frac{1}{\pi} \int_0^{\infty} \left| \left[W_{OK}(j\omega) - W_A(j\omega) \right] W_{kor}(j\omega) W_{fi}(j\omega) \right|^2 \cdot S_{fi}(\omega) d\omega \quad (12)$$

where:

S_{fi} (ω)- a spectral value of the i-th interference.

The probability of determining the mean random process value of random parameters of automatic control system resulting from the calculation of mathematical hope of functions:

$$z = \varphi\left[u(t)\right] \quad (13)$$

and for calculating the dispersion of a random process:

$$z = \left[u(t) - \tilde{u}_u\right]^2 \quad (14)$$

If the control signal u(t) depends on the random parameters x_1, x_2,...,x_s, whose distribution law corresponds to the distribution density $f_1(x_1) \cdot f_2(x_2) \ldots f_s(x_s)$, then, at the parameter independence of automatic aircraft control, we can write:

$$\mu_Z = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \ldots \int_{\infty}^{-\infty} f_1(x_1) \cdot f_2(x_2) \cdot \ldots f_S(x_S) \cdot \mu_Z(x_1, x_2, \ldots, x_S) dx_1, dx_2, \ldots, dx_S \quad (15)$$

or

$$\mu_Z = M\left[\mu_Z(x_1, x_2, \ldots, x_S)\right] \quad (16)$$

which represents a random function that at specific values of random variables x_1, x_2,...,x_s, is equal $\mu_z(x_1, x_2, \ldots, x_S)$

With known values $\sigma_u, \sigma_{\dot{u}}$ and μ_z

$\sigma_u, \sigma_{\dot{u}}$ a μ_Z it is possible to determine the dependence:

$$\lambda_{\Phi} = f\left(\left|u_{threshold}\right|\right) \quad (17)$$

and using the known values $\lambda_{\Phi pov}$ for obtaining the minimum value of threshold switching $\left|\lambda_{\Phi allowed\ min}\right|$ on at conditions of the permit the probability of incorrect switching on of a control element.

The maximum permissible value of switching on threshold is $\left|\lambda_{\Phi allowed\ max}\right|$ determined from the condition of the desired level of flight safety using imitations of all available faults of objects of checking as the maximum switching on threshold value in which failures still not exist.

At:

$$\left|u_{pov.\min}\right| \le \left|u_{prah}\right| \le \left|u_{pov.\max}\right| \quad (18)$$

the necessary condition is implemented $\lambda_{\Phi} \le \lambda_{\Phi\, max}$ not a fault is dangerous. If the inequality is valid, $\left|\lambda_{\Phi allowed\ mim}\right| \succ \left|\lambda_{\Phi allowed\ max}\right|$ then it is suggested that any increased value of the probability of incorrect switching on is reduced or indirectly $\left|\lambda_{\Phi allowed\ mim}\right|$ control algorithm.

The described method of a switch on threshold is laborious, especially on the stage of probable averaging. In the practical approach a used method of estimating the smallest threshold, $\left|\lambda_{\Phi allowed\ mim}\right|$ whose value corresponds to

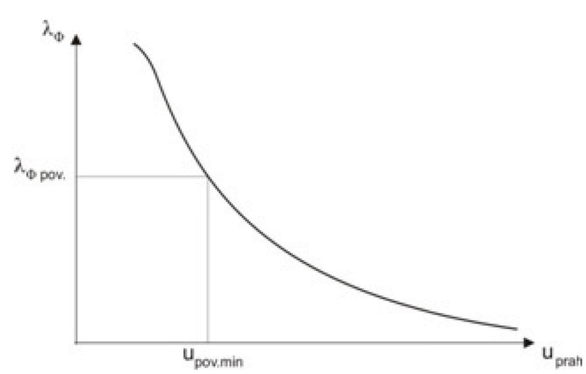

Figure 4. Example of failure λΦ dependence on the value of the threshold switching on

the worst threshold of possible switching on. The essence of this calculation referred to the acceptable for flight mode to random external noise - failure is replaced by deterministic. Automatic control system parameters and failure plane are set to limit the allowed values so the maximum values of a checking signal could be measured. Under these conditions modelling of the "aircraft - a system of automatic control" shall be performed without failure imitations of s and measuring will determine the wanted maximum checking signal.

CONCLUSION

The proposal of the automatic control system of aircraft, with the specified level of safety, is complex and requires a lot of mathematical operations. The process simplifies the distribution of the theoretical stage, which includes the desired structure of the automatic aircraft control system on terms that they are structurally feasible and meet the operating conditions. These elements of the theoretical basis of the proposal mean an expected level of safe flight operations. In an experimental-analytical phase the indicators of a security model of the aircraft automatic control system are identical and the structure is close to real.

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