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THEORY OF ANOMALIES AND ITS APPLICATION TO AIRCRAFT CONTROL

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Abstract

The anomalies are deviations in the system parameters or service characteristics initiating the changes in the technical and operational characteristics and finally generate decreasing of the prescribed or designed working quality of system.

The general lecture deals with the basic elements of the theory of system anomalies, describes the mean problems of theory and shows the recommended models for valuation of anomalies effects on system characteristics. The system anomalies play an important role in accuracy and dynamics of control systems. In many cases they can be modelled as the additive errors in the output characteristics (motion variables) measured and used as feedback signals. Some specific problems of application of system anomalies theory to the aircraft control systems are discussed in the second part of the paper.

Keywords: aircraft control systems, system anomalies.

1. Introduction

The parameters of the large systems like aircraft are scattering near their prescribed nominal levels. During operation of the systems these deviations in the characteristics are changing stochastically, mostly in cumulative way. According to our experiences gained in practice, the system parameter deviations [1, 2] can achieve 4 - 10% relatively to their nominal levels.

The system parameter deviations involve the changes in aerodynamic characteristics, performance data and characteristics of stability and controllability. The deviations in the system parameters are greater then which could be obtained by normal control methods which do not generate the failures or standstills of given systems can be called system anomalies. The investigation of these parameter deviations and their effects on system characteristics is an actual new theoretical and practical problem.

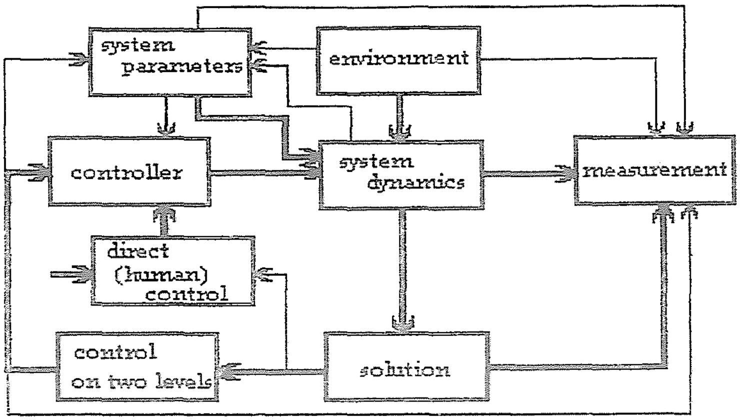

Fig. 1. Representation of system control

2. System Anomalies

The system can be given by its system parameters. The parameters describing the structure and geometrical characteristics can be called as constructional parameters. The parameters representing the operational process of the given system are the operational parameters.

The parameters of large systems, i.e. real constructional-technical characteristics of aircraft and its systems are scattered to a great extent in the neighbourhood of the rated values prescribed in technical documentation. During the operation the deviations mentioned above continue to increase stochastically mostly in a cumulative way as a function of [1, 2]:

- the physical-technical peculiarities of the structural material applied,
- the peculiarities of their design and manufacture,
- the technical and economical condition of operation, and
- the intensity of operation.

These deviations in parameters can be divided into three parts [3]:

- the parameter uncertainties, which can be obtained by some specific methods of control, i.e. robust control,
- the anomalies, which are greater deviations than uncertainties but they do not generate the failures or standstill of systems,
- errors, namely deviations in characteristics coming out of their prescribed tolerance zones and generating the failures and standstills of systems.

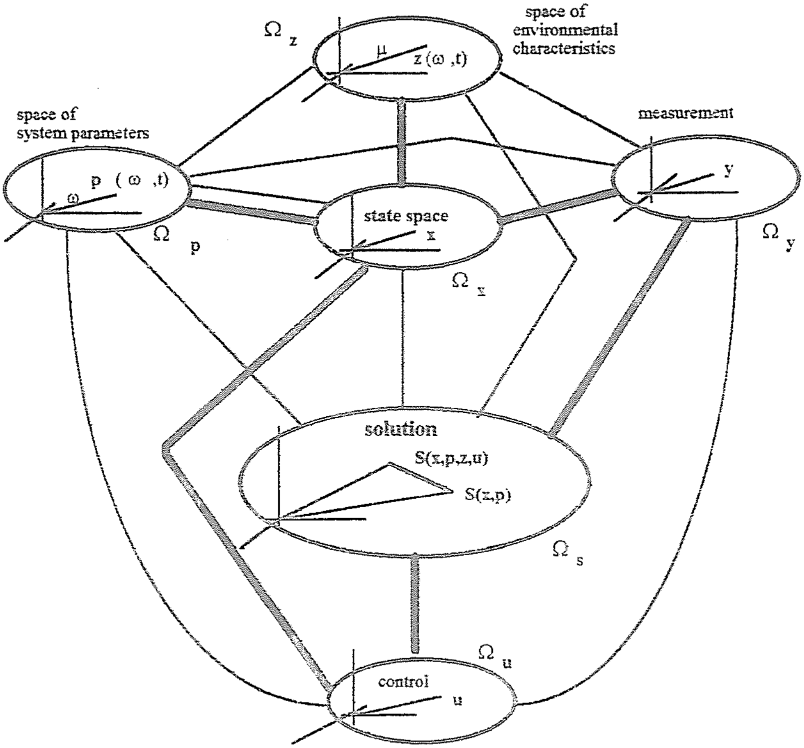

Fig. 2. Aircraft control in general case

Generally, the errors are investigated by reliability theory and risk analysis very well [4, 5]. The small disturbance in parameters, e.g. parameter uncertainties, are investigated very well, too [6]. The robust control gives possibilities to manage with uncertainties. But the influences of system parameter anomalies on the system characteristics have not been studied yet on the level needed. The investigation of the aircraft system parameter anomalies on real flight situations, on risk of flight operation and on the control quality is one of the most actual problem of aeronautical sciences.

The changes in the system parameters naturally involve also the changes in system characteristics, in our case the deviations in aerodynamic, flight engineering and flight safety characteristics. Therefore these anomalies and their effects on the system characteristics should be investigated in details. For this aim we recommend to develop the system anomalies theory.

The theory of anomalies deals with system anomalies and their effects on the system dynamics. It should determine the methods of description

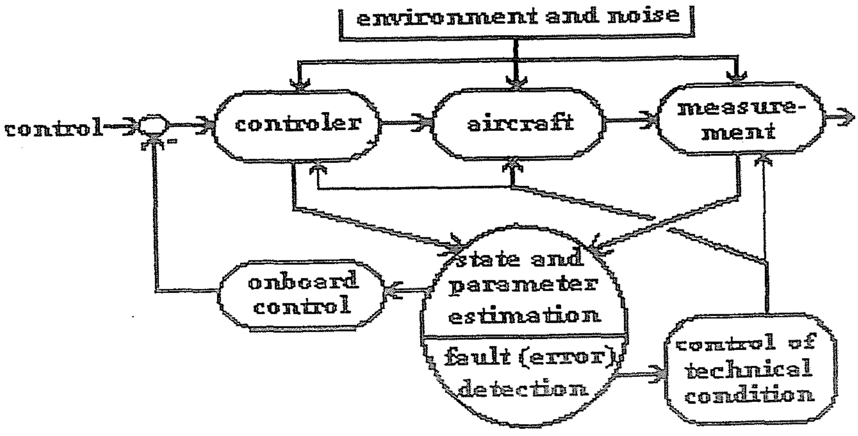

Fig. 3. System anomalies control

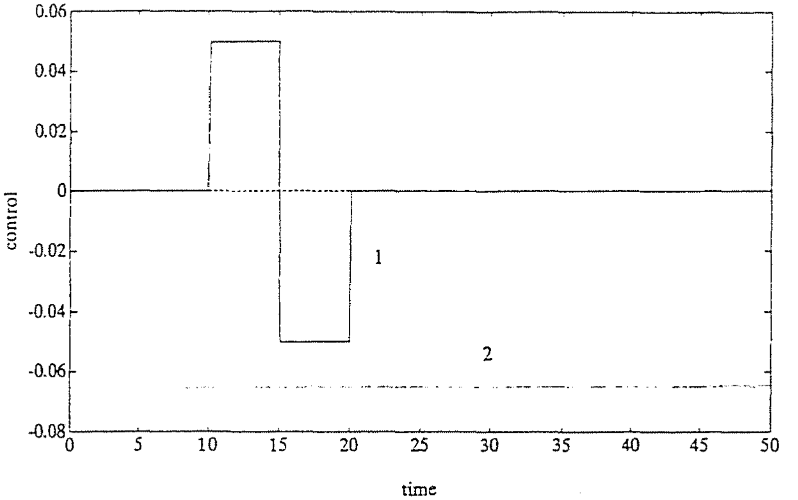

Fig. 4. Aileron deflection input (1) and the modelled anomaly in the rolling moment (2)

of anomalies, the mean tasks of theory and the methods of solving the problems.

Generally, the deviations in the structural, operational and service characteristics can reach and even exceed the tolerance limits essentially in three different ways [3]. In first case the system anomalies take place

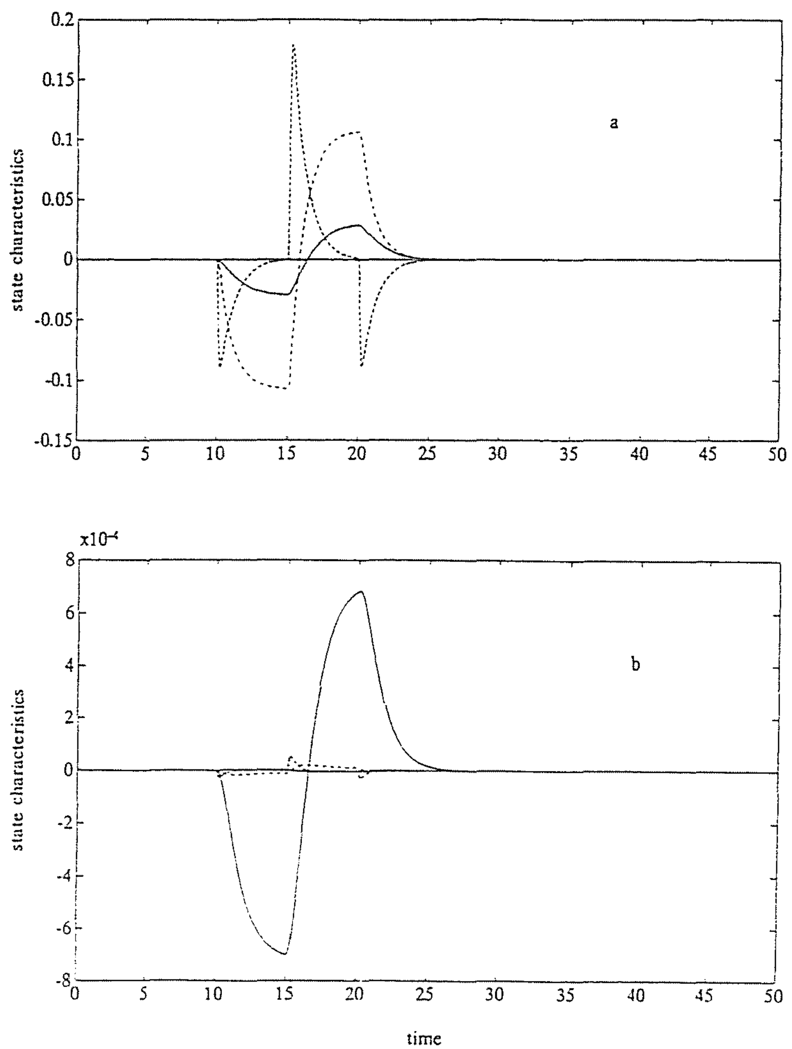

Fig. 5. The response of the system with a simple feedback (a) and the system with the robust feedback controller (b) on the aileron deflection input. (— slideslip angle, – – – roll rate, · · · yaw rate, – · –· roll angle)

under influence of sudden loads greater than which was taken into account during design. In second case characteristics are changing gradually and reaching the tolerance range in a predictable way. In the third case the tolerance range becomes restricted for some other reason, e.g. by effect of other anomalies or errors, and the excess of the tolerance range can occur

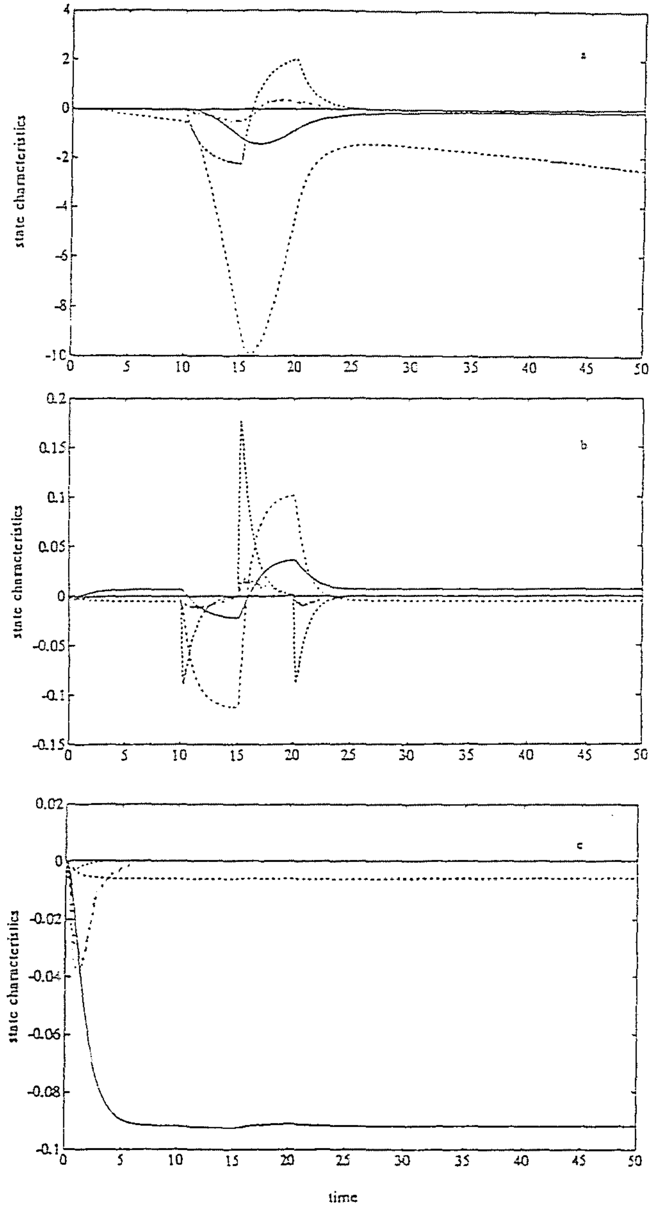

Fig. 6. Effect of anomaly in the rolling moment in case of initial system (a), system with simple feedback (b) and system with robust feedback controller (c). (— slideslip angle, – – – roll rate, ··· yaw rate, – · –· roll angle)

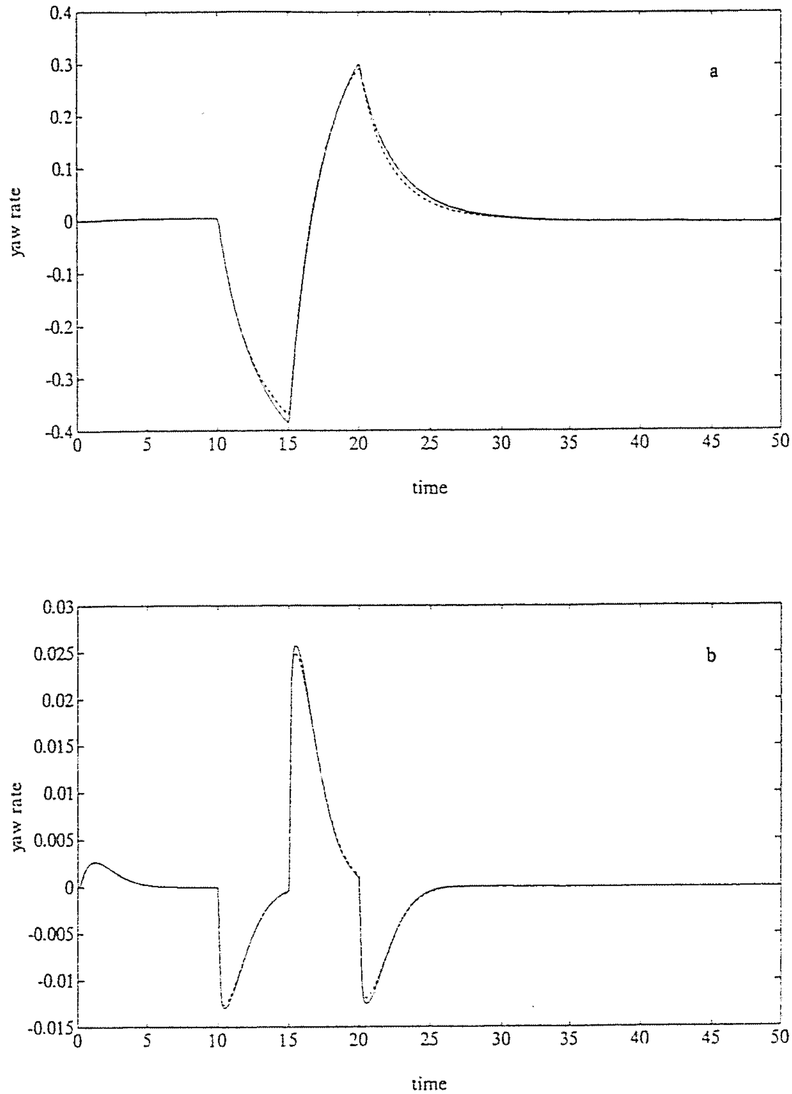

Fig. 7. The effect of decreasing in state matrix element $\mathbf{A}(2,2)$ of initial system with simple feedback (a), and system with robust feedback controller (b) on the response in case of aileron deflection only

even under the influence of otherwise normal design loads.

The system anomalies formed in the described way can be called as sudden, gradual (or parametric) and relaxation anomalies. Consequently, the probability of the dwelling of the characteristics within the tolerance

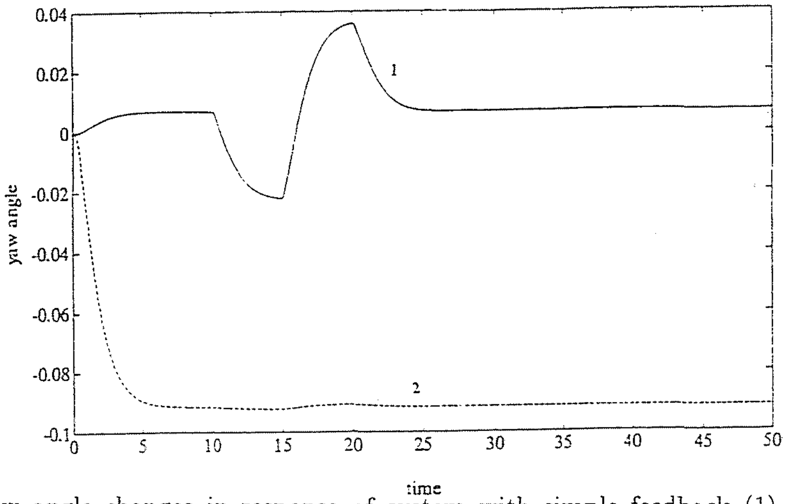

Fig. 8. Yaw angle changes in response of system with simple feedback (1) and system with robust feedback controller (2) in case of system anomaly in rolling moment

range can be given according reliability theory with the help of exponential, normal and two-parameter exponential laws.

On the other hand the system anomalies can be classified as multiplicative (β_1), delay-time (β_2) and additive (β_3) deviations in the parameters and they can be taken into account in the mathematical normalisation by following way:

$$\mathbf{p} = (1 + \beta_1)\mathbf{p}_n(t - \beta_2) + \beta_3 \,, \qquad (1)$$

where $\mathbf{p}_n$ is the initial (nominal) values vector of parameters and the random coefficients β depend on the realised control and real operational situations (flight situations).

3. General Model

When examining the dynamics or technical condition of complicated systems like aircraft, it seems to be describable easily for an engineer if the variation of its state vector $\mathbf{x}$ chosen appropriately is expressed as follows

$$\dot{\mathbf{x}} = \mathbf{F}(\mathbf{x}, \mathbf{u}, t) \,, \qquad (2)$$

where $\mathbf{u}$ is a control vector.

In reality the controlled dynamics of the systems can be investigated on the basis of much more complicated picture shown on *Fig. 1.*

In fact, the variation of state vector $\mathbf{x}$ is influenced by the variation in the instantaneous values of a number of factors (service conditions, methods of maintenance and repair applied, the realised management, the characteristics of the flight, the atmospheric conditions, etc.). These influences can be given in terms of stochastic processes, random variables or random space (turbulence of atmosphere). Moreover, state vector $\mathbf{x}$ cannot generally be measured directly. Instead, some output signal vector $\mathbf{y}$ can be measured. Consequently, the controlled motion of the aircraft or their technical conditions, their dynamics can be described only by a much more complicated model than in (2), namely by the following general set of stochastic differential equations [3]:

$$\begin{aligned} \mathrm{d}\mathbf{x} &= f_x[\mathbf{x}(t), \mathbf{x}(t-\tau_x), \mathbf{p}(\mathbf{x}, \mathbf{z}, \omega, \mu, t), \mathbf{z}(\mu, t), \mathbf{u}(t), \omega, \mu, t]\mathrm{d}t + \\ &\quad + \sigma_x(\mathbf{x}, \mathbf{p}, \mathbf{z}, \omega, \mu, t)\mathrm{d}W, \\ \mathbf{y} &= f_y[\mathbf{x}(t), \mathbf{x}(t-\tau_y), \mathbf{p}(\mathbf{x}, \mathbf{z}, \omega, \mu, t), \mathbf{z}(\mu, t), \mathbf{u}(t), \omega, \mu, t] + \\ &\quad + \sigma_y(\mathbf{x}, \mathbf{p}, \mathbf{z}, \omega, \mu, t)\xi\,, \qquad\qquad (3) \\ \mathbf{u}(t) &= f_u[\mathbf{x}(t), \mathbf{x}(t-\tau_u), \mathbf{p}(\mathbf{x}, \mathbf{y}, \omega, \mu, t), \mathbf{z}(\mu, t), \mathbf{u}(t), \omega, \mu, t]\,, \\ \mathbf{x}(t=t_0) &= \mathbf{x}_0(t=t_0, \omega_0, \mu_0)\,, \\ \mathbf{y}(t=t_0) &= \mathbf{y}_0(t=t_0, \omega_0, \mu_0)\,; \end{aligned}$$

where $\mathbf{x} \in R^n$ is the state vector, $\mathbf{p} \in R^k$ is the parameter vector characterising the state of the aircraft, $\mathbf{z} \in R^1$ is the vector of environmental characteristics (vector of service conditions), $\mathbf{u} \in R^m$ is the input (control) vector, $\mathbf{y} \in R^r$ is the output (measurable) signal vector $\mathbf{W} \in R^s$ and $\xi \in R^q$ are the noise vectors (in simplified case the Wiener and Gaussian noise vectors, respectively), σ_x, σ_y are the noise transfer matrices, ω and μ are the random variables assigning the position of vectors $\mathbf{p}$ and $\mathbf{z}$ within admissible space Ω_p Ω_z described by density functions $f_p(\cdot)$, $f_z(\cdot)$, t is the time, and τ_x, τ_y, τ_u are the time-delay vectors.

In general case, the aim of aircraft operation is to use the aircraft for their primary purposes (transport the passengers) to maximum time with minimum specific (related to the unit time of operation) life-cycle-cost at prescribed level of safety and reliability. It can be seen that the knowledge of the changes in the operational and structural characteristics is indispensably required for controlling the service and operational process of this kind.

The realising of this kind of aircraft control can be based on the principle shown on *Fig. 2.* The system parameters $\mathbf{p}$ are changing under the real environmental conditions $\mathbf{z}$ real flight situation and technical works, e.g. control $\mathbf{u}$ realised on aircraft and generate the given realisation of state vector $\mathbf{x}$. The state realisations, of course, depend on the system parameters and real environmental conditions, too. The measurable input vector $\mathbf{y}$ depends on these system parameter deviations, real environmental conditions and real state change realisations. As it can be understood, the real system parameter, environmental characteristic and state vectors are mapped by solution on the solution space into $\mathbf{S}(\mathbf{x}, \mathbf{p}, \mathbf{z}, \mathbf{u})$. From the other hand the system parameters and states can be estimated on basis of measured $\mathbf{y}$. (The difference in the solution guided by real processes and result of identification can generate the systematic anomalies in the constructed system.) The estimated solution $\acute{\mathbf{S}}(\mathbf{x}, \mathbf{p})$ should be applied [7] to synthesis of control $\mathbf{u}$ having the two levels. The first is the operative control or state control (real control on the board) and the second is control of system parameter deviations (technical maintenance and repair include the regulation of system parameters). Connection between these two levels should be realised through the fault and failure detection.

Set of *Eq.* (3) can be given also in a very simplified time-invariant linearized uncertain system form

$$\begin{aligned} \dot{\mathbf{x}}(t) &= \mathbf{A}(\omega, t)\mathbf{x}(t) + \mathbf{B}(\omega, t)\mathbf{u}(t) + \mathbf{H}(\mu, t)\mathbf{z}(t) + \\ &\quad + \mathbf{A}_{nx}(\mathbf{x}, \mathbf{u}, \omega, t) + \mathbf{G}_x(\nu, t)\eta(t) , \qquad (4) \\ \mathbf{y}(t) &= \mathbf{C}(\omega, t)\mathbf{x}(t) + \mathbf{D}(\omega, t)\mathbf{u}(t) + \mathbf{G}_y(\nu, t)\xi(t) + \mathbf{A}_{ny}(\mathbf{x}, \mathbf{u}, \omega, t) , \end{aligned}$$

where $\mathbf{A}$, $\mathbf{B}$, $\mathbf{H}$, $\mathbf{C}$ and $\mathbf{D}$ are the state, control, environmental, output and input influence matrices of $n \times n$, $n \times m$, $n \times l$, $r \times m$ and $r \times m$ dimensions, respectively, $\mathbf{G}_x$, $\mathbf{G}_y$ are the noise transfer matrices, η and ξ are the noise vectors, ω and ν are the random values determining the deviations in the matrix elements. The stochastic time-varying vectors $\mathbf{A}_{nx}$, $\mathbf{A}_{ny}$ include the effects of system anomalies depending on the real flight situations initiated by realised control.

In a simple case, for the first approximation the linearized model with system anomalies can be given in following form:

$$\begin{aligned} \dot{\mathbf{x}}(t) &= \mathbf{A}(\omega, t)\mathbf{x}(t) + \mathbf{B}(\omega, t)\mathbf{u}(t) + \mathbf{A}_{nx}(\omega, t) , \\ \mathbf{y}(t) &= \mathbf{C}(\omega, t)\mathbf{x}(t) . \qquad (5) \end{aligned}$$

4. Description of the System Anomalies Effects

In consideration of types of anomalies described in part titled system anomalies, the general model in simplified case can be rewritten in form of multivariable perturbed linear system with time-delay and additive system anomalies:

$$\begin{aligned} \dot{\mathbf{x}}(t) &= (\mathbf{A} + \Delta A)\mathbf{x}(t) + (\mathbf{A}_d + \Delta\mathbf{A}_d)\mathbf{x}(t - \tau_d) + \mathbf{A}_n + (\mathbf{B} + \Delta\mathbf{B})\mathbf{u}(t) , \qquad (6) \\ \mathbf{y}(t) &= (\mathbf{C} + \Delta\mathbf{C})\mathbf{x}(t) + (\mathbf{D} + \Delta\mathbf{D})\mathbf{u}(t) + \mathbf{H}_m , \end{aligned}$$

where the $\Delta\mathbf{A}$, $\Delta\mathbf{A}_d$, $\mathbf{A}_n$, $\Delta\mathbf{B}$, $\Delta\mathbf{C}$, $\Delta\mathbf{D}$ and $\mathbf{H}_m$ represent the uncertainties and anomalies.

In set of *Eqs* (6) the $\Delta\mathbf{A}$, $\Delta\mathbf{A}_d$, $\Delta\mathbf{B}$, $\Delta\mathbf{C}$ and $\Delta\mathbf{D}$ contain the changes in the partial derivatives of vector functions f_x and f_y of model (3) respectively to state and control vector elements. So, they take into account the changes in gradient of these functions only. They are the multiplicative anomalies.

The $\mathbf{A}_n$ and $\mathbf{H}_m$ are the additive anomalies in the state and measurement characteristics.

The effects of the system anomalies can be given by the following type of probabilities [1]:

$$P_1\{\mathbf{y}(t) \in \Omega_y | t_0 \le t \le t_0 + \tau\,,\ \mathbf{x} \in \Omega_x,\ \mathbf{u} \in \Omega_u,\ \mathbf{z} \in \Omega_z,\ \mathbf{p} \in \Omega_p\}\,,$$
$$P_2\{\mathbf{u}(t) \in \Omega_u | t_0 \le t \le t_0 + \tau\,, \mathbf{x} \in \Omega_x,\ \mathbf{z} \in \Omega_z,\ \mathbf{p} \in \Omega_p,\ \mathbf{y} \in \Omega_y\}\,; \tag{7}$$

where the admissible vectorial fields of characteristics are given by Ω.

If joint density function

$$f_\Sigma = f[\mathbf{x}(t), \mathbf{u}(t), \mathbf{z}(t), \mathbf{p}(t), \mathbf{y}(t)] \tag{8}$$

is known, then the recommended characteristics (7) can be calculated as follows:

$$P_1\{\mathbf{y}(t) \in \Omega_y | \ldots\} = \frac{\int_{\Omega_i} f_\Sigma \,\mathrm{d}\mathbf{x}\,\mathrm{d}\mathbf{u}\,\mathrm{d}\mathbf{z}\,\mathrm{d}\mathbf{p}\,\mathrm{d}\mathbf{y}}{\int_{-\infty}^{+\infty} \mathrm{d}\mathbf{y} \int_{\Omega_j} f_\Sigma \,\mathrm{d}\mathbf{x}\,\mathrm{d}\mathbf{u}\,\mathrm{d}\mathbf{z}\,\mathrm{d}\mathbf{p}} \qquad \begin{matrix}(i \in \mathbf{x}, \mathbf{u}, \mathbf{z}, \mathbf{p}, \mathbf{y})\\ (j \in \mathbf{x}, \mathbf{u}, \mathbf{z}, \mathbf{p})\end{matrix}$$

$$P_2\{\mathbf{u}(t) \in \Omega_u | \ldots\} = \frac{\int_{\Omega_i} f_\Sigma \,\mathrm{d}\mathbf{x}\,\mathrm{d}\mathbf{u}\,\mathrm{d}\mathbf{z}\,\mathrm{d}\mathbf{p}\,\mathrm{d}\mathbf{y}}{\int_{-\infty}^{+\infty} \mathrm{d}\mathbf{u} \int_{\Omega_j} f_\Sigma \,\mathrm{d}\mathbf{x}\,\mathrm{d}\mathbf{z}\,\mathrm{d}\mathbf{p}\,\mathrm{d}\mathbf{y}} \qquad \begin{matrix}(i \in \mathbf{x}, \mathbf{u}, \mathbf{z}, \mathbf{p}, \mathbf{y})\\ (j \in \mathbf{x}, \mathbf{z}, \mathbf{p}, \mathbf{y})\end{matrix} \tag{9}$$

5. Problems and Control of System Anomalies

The problems of theory of system anomalies can be classified as the mean tasks of given theory:

- initial task – investigation of the structural and operational characteristics, signalization of the anomalies and the statistical description of the anomalies,
- direct task – study the effects of system parameter anomalies on the aerodynamics, flight mechanics, controllability and stability,

- inverse task (synthesis) – determining of the bounds for the system parameters from the given bounds (admissible field) of operational characteristics, e.g. flight safety, quality of manoeuvres, controllability,
- basic task – create the control for the system with anomalies,
- complementary task – determining the basic and additional information for solving the different problems connected with system anomalies, e.g. model- formation, optimal control, identification, etc.

The initial task can be solved by application of theory of measurement, statistics and stochastic approximation. The direct and the inverse tasks are based on the theory of flight and on using the sensitivity theory.

The basic task is the completely new task. The mean idea is the change of the goal of operation. The new goal is using the aircraft to maximum time with specific life cost expenditure under predefined service condition with keeping the system parameters in the prescribed tolerance zones. Therefore we should define the control of anomalies. The technical condition of aircraft can be controlled on two different levels [7]. At first, we can use the pilot or automatic control of aircraft in case if the motion characteristics are different from given values. In this case the control should be realised on the board of aircraft. Secondary, on the basis of state or parameter estimation results we can use some technical methods of operation (e.g. methods of maintenance or repair) for replacing the nominal system parameters. The connection between these two different levels of control is the fault or error detection (*Fig. 3*).

The complementary task should be solved through the application of the different theories like state and parameter estimation, theory of diagnosis, etc.

6. Control System Anomalies

We have a long period experience on the investigation of deviations in the structural (e.g. geometrical) characteristics of supersonic fighter and middle-size passenger aircraft [1, 2]. For example, we found the permanent deformation, e.g. permanent deviations in the geometrical characteristics of wings of fighters MiG-21 generated by micro motion of wing elements under big loads. The extent and form of these anomalies depend on the duty of the airplanes to be carried out, on the flying hours, on the circumstances of operation, on the technique of piloting the airplane (especially on the landing mode of operation), and on man's physiological characteristics. According to our experience the geometrical characteristic deviations of wings generate the changes in the zero-lift angles, relative cambers and asymmetry in the rolling direction.

These types of characteristic deviations generate the deviations in the aerodynamic characteristics and performance data and cause the problem in the flight stabilising, especially during flight test. The asymmetry in the deformations of right and left hand wings can be modelled as the additive errors in the measuring of the roll angle, $\Delta\phi_m$. This error in measurement is the element of the measurement anomalies vector $\mathbf{H}_m$.

In simple case, if the model can be written as follows

$$\begin{aligned} \dot{\mathbf{x}}(t) &= \mathbf{A}\mathbf{x}(t) + \mathbf{B}\mathbf{u}(t) , \\ \mathbf{y}(t) &= \mathbf{C}\mathbf{x}(t) + \mathbf{H}_m , \end{aligned} \tag{10}$$

and the control given as feedback control

$$\mathbf{u}(t) = -\mathbf{K}\mathbf{y}(t) = -\mathbf{K}(\mathbf{C}\mathbf{x}(t) + \mathbf{H}_m) , \tag{11}$$

then the close loop dynamics can be described by following equation:

$$\begin{aligned} \dot{\mathbf{x}}(t) &= \mathbf{A}\mathbf{x}(t) - \mathbf{B}[\mathbf{K}(\mathbf{C}\mathbf{x}(t) + \mathbf{H}m)] = \mathbf{A}\mathbf{x}(t) - \mathbf{BKC}\mathbf{x}(t) - \mathbf{BKH}_m = \\ &= (\mathbf{A} - \mathbf{BKC})\mathbf{x}(t) - \mathbf{BKH}_m . \end{aligned} \tag{12}$$

Here the $\mathbf{BKH}_m$ represents the additive anomaly in state characteristics. So, the deviation in the structural characteristics can be modelled as the additive anomaly in the state characteristics or as the measurement error in the system input.

During our investigation of system anomalies, there were investigated different types of anomalies on the lateral feedback stabilising system. The nonlinearities and the time-delays are investigated very well in the theory of aerodynamics and flight mechanics. The nonlinearities should be taken into account only on the flight near the operational limits, for example at high angle of attack [8]. The third type of anomalies, the additive anomalies like rolling moment at zero roll angle caused by asymmetry in wing geometry could be more interesting for study.

There was investigated a lateral disturbed motion of the middle-size supersonic fighter at high subsonic speed equal to Mach number 0.9 flying on the altitude more than 10 km. The system of equation and the values of matrix elements were the following [9, 10]:

$$\begin{aligned} \dot{\mathbf{x}}(t) &= \mathbf{A}\mathbf{x}(t) + \mathbf{B}\mathbf{u}(t) + \mathbf{A}_n , \\ \mathbf{y}(t) &= \mathbf{C}\mathbf{x}(t) + \mathbf{D}\mathbf{u}(t) , \end{aligned}$$

$$\mathbf{x} = \begin{bmatrix} \beta & = & \text{slideslip angle} \\ p & = & \text{roll rate} \\ r & = & \text{yaw rate} \\ \phi & = & \text{roll angle} \\ \psi & = & \text{yaw angle} \end{bmatrix} , \quad \mathbf{u} = -\begin{bmatrix} \delta_a & = & \text{aileron deflection} \\ \delta_r & = & \text{rudder deflection} \end{bmatrix} ,$$

$$\mathbf{A} = \begin{bmatrix} -98 & 0 & -0.995 & 0.35 & 0 \\ -18.9 & -1.23 & 1.6 & 0 & 0 \\ 2.79 & -0.3 & -0.263 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix}, \quad \mathbf{B} = \begin{bmatrix} 0 & 0.185 \\ -34.7 & 5.07 \\ -3.85 & -1.44 \\ 0 & 0 \\ 0 & 0 \end{bmatrix}.$$

Here $\mathbf{C}$ is a unit $\mathbf{D}$ is a zero matrices.

The control was realised as shown in *Fig. 4.* On this figure anomaly generated in the rolling moment is shown, too.

The control was realised by feedback control (11). The simple feedback was determined by applicating the optimal linear quadratic problem to the initial system [10]. The other feedback system was designed as the robust feedback controller based on the LQR/LTR algorithm. The feedback matrix was determined application of the software MATLAB.

There are some interesting results of investigation demonstrated on the Figures. The input, e.g. aileron deflection and the modelled anomaly in the rolling moment are shown in the *Fig. 4.* The difference in the systems and their response on the aileron deflection input in case of simple feedback and robust feedback controller can be checked from *Fig. 5.* The effects of additive system anomalies like rolling moment at zero roll angle are shown in *Fig. 6.* The influences of deviation in the state matrix element $\mathbf{A}(2,2)$ are represented by *Fig. 7.*

At last on the *Fig. 8* the interesting effect of additive system anomalies is demonstrated, when the robust feedback controller application has a greater final error than the simple feedback system. In addition to them the final errors in controlled systems have the different signs.

7. Summa

The aim of this paper was to draw the attention to a new theoretical and practical problem caused by operational life-dependent, stochastic changes in the structural and operational characteristics of aircraft systems. These deviations in the characteristics can be called as system anomalies, if they are greater then could be covered in an easy way by modern methods of control and they do not involve the failures or standstills of given systems.

The process of deviations in system characteristics should be controlled in two levels by optimal design of aircraft operational processes including the maintenance and repair and by operative, on-board control systems, including adaptivity and robustness.

For general investigation of given problems we offer to develop the theory of system anomalies. In this paper the elements of the mentioned theory were described and concrete recommendations were offered for possibly available models for description of system anomalies and their effects on the system characteristics.

The developed system anomalies theory was applied to aircraft control systems. In case of automatic control the system anomalies can be taken into account as the deviations in output (motion variables) of systems measured for feedback input. Finally some effects of anomalies on the aircraft control system were demonstrated by the results of investigation of stabilising the aircraft lateral disturbed motion.

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