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Real-time aerodynamic parameter identification for the purpose of aircraft intelligent technical state monitoring

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Abstract

The report deals with the problem of design the new generation of aircraft technical state monitoring systems using methods of artificial intellect. The key point in the intellectual support is the theory of system identification, applied to the problem of aerodynamic parameter estimation from the flight data. The report considers the specific aspects of the parameter identification problem as a part of real-time intelligent monitoring system. The aircraft model with the object noise and the identification algorithm with estimation of identification accuracy are formulated. The presented algorithms are tested through processing the data generated using a modern aircraft simulation facility.

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Keywords: technical state; system identification; aerodynamic parameter estimation.

Identification of aerodynamic coefficients can be an effective method of estimating the technical state of the aircraft. In this paper the aircraft movement model is formulated which includes also the atmospheric turbulence, flight parameter sensors and the aircraft control system. The identification of the aircraft aerodynamic parameters using the continuous-discrete extended Kalman filter is also discussed. For the simulation of atmospheric turbulence, it is recommended to use, for example, the Dryden model, according to which the spectral density of the turbulent wind in the vertical, longitudinal and lateral directions is given by:

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$$S_W(\omega) = \sigma_W^2 \frac{L_W}{\pi V} \frac{1+3\left(\frac{L_W}{V}\omega\right)^2}{\left(1+\left(\frac{L_W}{V}\omega\right)^2\right)^2},$$

$$S_U(\omega) = \sigma_U^2 \frac{L_U}{\pi V} \frac{1}{1+\left(\frac{L_\upsilon}{V}\omega\right)^2}, \qquad (1)$$

$$S_V(\omega) = \sigma_V^2 \frac{L_V}{\pi V} \frac{1+3\left(\frac{L_V}{V}\omega\right)^2}{\left(1+\left(\frac{L_V}{V}\omega\right)^2\right)^2},$$

where V - aircraft velocity, m/s;
ω - angular frequency, 1/s;
$\sigma_W, \sigma_U, \sigma_V$ - std. deviations of wind gust velocities, m/s;
L_W, L_U, L_V - turbulence scales, m;

The turbulence scales at the flight altitude $H > 525m$ $L_W = L_U = L_V = 525m$. At altitude $H < 525m$ $L_W = H, L_U = L_V = 43,5H^{1/3}$ In addition, we have the relation:

$$\frac{\sigma_W^2}{L_W} = \frac{\sigma_U^2}{L_U} = \frac{\sigma_V^2}{L_V} \qquad (2)$$

To estimate the influence of turbulence on the closed-loop contour the models of aircraft movement and aircraft control system must be coupled with the Dryden turbulence model. In this case, the linearized model is acceptable, for example, in the vicinity of a straight and horizontal flight.

Let us consider the longitudinal motion of the aircraft equipped with the fly-by-wire system in turbulence. The simplified model of the fly-by-wire system can be approximated by elements providing feedback signals of overload and angular velocity. The appropriate transfer functions are as follows

$$W_n(p) = \frac{K_n}{T_n p + 1}, \quad W_\omega(p) = K_\omega \frac{T_2 p + 1}{T_1 p + 1}.$$

In this case, the deviation of stabilizer is given by:

$$\varphi_B(t) = \varphi_P(t) - \varphi_n(t) - \varphi_\omega(t) \qquad (3)$$