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SIMULATION RESULTS OF COMPOSITED AND INTEGRATED AIRCRAFT FLIGHT ALTITUDE CONTROL SYSTEM

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Abstract. *The article deals with simulation results of the structure of flight altitude control system by means of elevator rudder controlling and integrated the structure of flight altitude control system by means of composited control over aerodynamic configuration of control surfaces.*

Keywords: aerodynamic configuration of control surfaces, flight altitude control system, turbulence.

1. Introduction

The modern automatic aircraft flight control systems are based on the concept of intelligent control. Their primary tasks are increase of aircraft flight safety level and improvement in quality of flight path control.

TCAS is one component of a multi-layered defense against mid-air collision. The structure of airspace and operational procedures provide the first, strategic layer of protection. Traffic flow are organized along airways at segregated altitudes to aid air traffic controllers in managing aircraft and predicting potential conflicts well before problems arise. Aircraft are normally kept three to five miles apart laterally or 100 ft vertically, to provide sufficient safety margins. Air traffic control ensures that separation minima are not violated by issuing tactical commands (including altitude restrictions and heading change vectors) to the pilots in response to nearby traffic. Should these nominal traffic separation processes fail, the TCAS system aid pilots in visually acquiring potential threats and, if necessary, provides last-minute collision avoidance guidance directly to the flight crew (ACAS…2000; Kuchar, Drumm 2007).

There are active turbulence acting compensation system and passive turbulence acting compensation system (Dobrolensky 1969). But Control Configured Vehicle Technology, which is used in military aircraft, is not applied in civil aircraft for the purpose of improvement in quality of piloting and passenger comfort. There is a patent on Method of Reducing Wind Gust Loads Acting On an Aircraft. A method of reducing the bending moment effect of wind gust loads acting on the wing of an aircraft involves adjusting the aerodynamic configuration of the wing so as to alter the distribution of lift generated by the wing during phases of flight in which critical wind gusts are expected to occur. It says that direct lift control is performed by all wing components (Regan, Jutte 2012). But the patent does not deal with the application of flexible load transfer between deflectable wing components for improving aerodynamic effect. The Airbus A330 aircraft and the Airbus A340 aircraft incorporated maneuver load alleviation system as well as a flying quality enhancement system known as Comfort in Turbulence by actively controlling the rudder. The Boeing 787 aircraft is report to use a maneuver load alleviation system as well as a flying quality enhancement system and uses ailerons and spoilers (Patent…2000; Russian…2009).

The object of the article is quality analysis of transient processes in structures of aircraft flight control by means of elevator rudder controlling and changing of composited control over aerodynamic configuration of control surfaces. The combinative control of automatic control theory and the invariance theory are used.

The model is created in MATLAB.

2. Composited Control Structure

The structure of composited flight altitude control system is shown in Fig. 1. Flight altitude control system structure includes a structure of the flight altitude control system by means of controlling elevator rudder, and an additional loop of direct lift control by means of composited control over aerodynamics of wing. In the structure the measured value of turbulence acting on aircraft is transferred to on-board computer. The on-board computer determines any possible variants of lift generation, which is equivalent to value of turbulence acting. The computer determines the most appropriate combination of changing wing profile with use of weighting coefficients in function of decision support.

The composition of aerodynamic forces and moments allows for compensating turbulence acting and improves the quality of flight path control (Pavlov, Kopytova 2011).

The structure of flight altitude composited control in perturbed atmosphere, where h_1 and h_2 means input value and output value of flight altitude, is shown in Fig. 1.

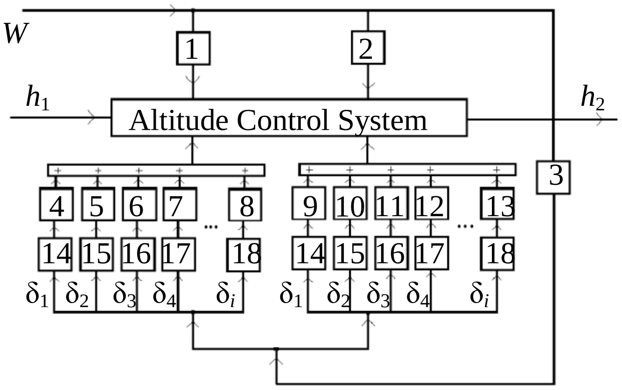

Fig. 1. The structure of composited flight altitude control system:
1 – m_z^{α}; *2* – C_y^{α}; *3* – K; *4* – $m_z^{\delta_1}$; *5* – $m_z^{\delta_2}$; *6* – $m_z^{\delta_3}$; *7* – $m_z^{\delta_4}$; *8* – $m_z^{\delta_i}$; *9* – $C_y^{\delta_1}$; *10* – $C_y^{\delta_2}$; *11* – $C_y^{\delta_3}$; *12* – $C_y^{\delta_4}$; *13* – $C_y^{\delta_i}$; *14* – γ_1; *15* – γ_2; *16* – γ_3; *17* – γ_4; *18* – γ_i

Turbulence acting on the aircraft *W*. The value of this acting as lift coefficient increment C_y^{α} and pitch moment m_z^{α} is transferred to flight altitude control system structure. In other words, wind velocity vector summarizes to aircraft flight velocity vector. Resulting vector causes deflection of flight velocity vector to angle of attack. Changing the angle of attack leads to changing lift force and centre travel of gravity of aircraft. It produces an additional pitch moment.

The measured value of turbulence acting is transferred to the structure of composited control over wing mechanization with proportionality coefficient *K*. The value of turbulence acting and the value of the compensation of such acting are transferred to flight altitude control system structure via wing lift coefficients C_y^{δ} and pitch moment m_z^{δ}. The values of elements deflection of wing mechanization – $\delta_1, \delta_2, \delta_3, \delta_4, \ldots, \delta_i$, means lift coefficient increment with the help of the deflection of different elements of wing mechanization $C_y^{\delta_i}$, means pitch moment increment with the help of the deflection of different elements of wing mechanization $m_z^{\delta_i}$, means weighting coefficients of decision support γ_i, $\sum_{i=1}^{n} \gamma_i = 1$, are shown in Fig. 1.

The period of time of tracking the specified signal for changing the flight altitude by means of elevator rudder controlling reduces in 2 times compared with the period of time of tracking this signal by changing of wing section configuration.

3. Integrated control structure

The structure of integrated flight altitude control system is shown in Fig. 2.

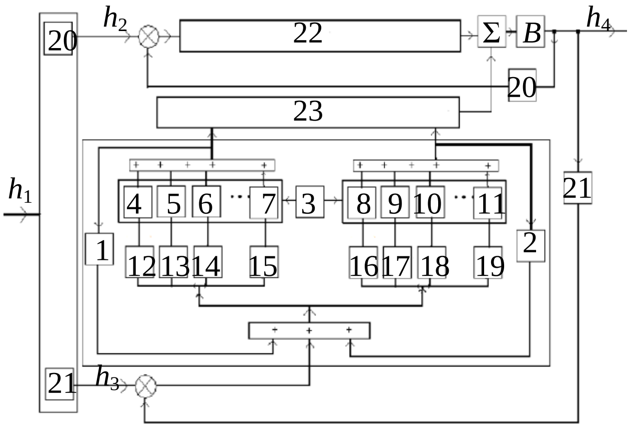

Fig. 2. The structure of integrated flight altitude control system:
1, 2 – units for the check of tracking the input signal of control on deflection of wing section elements;
3 – unit of computation of control signal for each of wing mechanization elements; *4* – γ_1; *5* – γ_2; *6* – γ_3; *7* – γ_i; *8* – λ_1; *9* – λ_2; *10* – λ_3; *11* – λ_i; *12* – $m_z^{\delta_1}$; *13* – $m_z^{\delta_2}$, *14* – $m_z^{\delta_3}$; *15* – $m_z^{\delta_i}$; *16* – $C_y^{\delta_1}$; *17* – $C_y^{\delta_2}$; *18* – $C_y^{\delta_3}$; *19* – $C_y^{\delta_i}$; *20* – *K*; *21* – 1-*K*; *22* – flight altitude control system; *23* – additional flight altitude control system.

The integrated control structure contains: flight altitude control system structure and additional flight altitude control system structure with the control unit of aerodynamic wing configuration. The additional structure includes: units for the check of tracking the input signal of control on deflection of wing section elements – *1* and *2*, unit of computation of control signal for each of wing mechanization elements – *3*; value of deflection of wing mechanization elements – $\delta_1, \delta_2, \delta_3, \delta_4, \ldots, \delta_i$, increment of lift force coefficients by means of deflection of wing mechanization elements – $C_y^{\delta_i}$, increment of pitch moment by means of deflection of wing mechanization elements – $m_z^{\delta_i}$, weighting coefficient in function of decision support – γ_i and λ_i, input signal of flight altitude control – h_1, input signal of flight altitude control for flight altitude control system configuration – h_2, input signal of flight altitude control for additional altitude control system configuration – h_3, actual flight altitude – h_4, altimeter – *B*, specified proportionality coefficients – *К* and 1-*К*.

4. Weighting coefficients in function of decision support

Composited control over aerodynamics of wing activate all part of wing mechanization. The main goal of the control is achievement of flight path control quality. Intelligent control of flight altitude allows to effective distribute aerodynamic forces and moments of aircraft. Precision measuring aircraft position allows raising the response velocity of automatic control system on position deflection into space. Weighting coefficients in function of decision support activate aerodynamic wing.

System of equations for calculates of wing profile composited control is write.

The equations are the values of the turbulence acting on the aircraft flight, and the sum of the changes values in the aerodynamic characteristics of wing aircraft. Flight altitude is invariant under the atmosphere acting:

$$\begin{cases} C_y^{\alpha}\alpha_{в} = K\sum_{j=1}^{i} C_y^{\delta_i}\delta_i; \\ C_x^{\alpha}\alpha_{в} = K\sum_{j=1}^{i} C_x^{\delta_i}\delta_i; \\ m_z^{\alpha}\alpha_{в} = K\sum_{j=1}^{i} m_z^{\delta_i}\delta_i, \end{cases}$$

where

$$K = \frac{C_y^{\alpha}}{C_y^{\delta_i}} = \frac{C_x^{\alpha}}{C_x^{\delta_i}} = \frac{m_z^{\alpha}}{m_z^{\delta_i}}.$$

In the system of equations, we substitute NACA 23012 wing data (Petrov 1985).

$$\begin{cases} 0,5\delta_1 + 0,93\,\delta_2 + 0,9\,\delta_3 + 1,28\delta_4 + 1,88\delta_5 + 2,36\delta_6 + 1,19\delta_7 = 0,85; \\ 1,18\delta_1 + 0,21\delta_2 + 0,27\delta_3 + 0,25\delta_4 + 0,12\delta_5 + 0,19\delta_6 + 0,4\delta_7 = 0,2; \\ 0,12\delta_1 + 0,158\delta_2 + 0,158\delta_3 + 0,306\delta_4 + 1,11\delta_5 + 1,38\delta_6 + 0,4\delta_7 = 0,108. \end{cases}$$

Formula function of decision support calculates energy costs at a deviation component of the wing mechanization:

$$\Delta E = \sqrt{\left(\delta_i(n) - \delta_i(n-1)\right)^2 + \left(\delta_j(n) - \delta_j(n-1)\right)^2}.$$

5. Quality increase estimation

The formula of the mean-square deviation for different altitudes allow to compare the quality of altitude control by structure of flight system by means of elevator rudder controlling and integrated the structure of flight altitude control system by means of composited control over aerodynamic configuration of control surfaces. For the altitude H = 4 km mean-square deviation is 16.8 and 1.88, it is more accurate to 8.9 times, for H = 8 km – 15.5 times, for H = 12 km – 20.6 times. The altitude control quality is improved by 11.2%, 6.5% and 4.9%.

Turbulence is the main source of disturbances acting on the aircraft during the flight.

Dryden wind turbulence model and wind Shear model is consider. Dryden wind turbulence model generate atmospheric turbulence. White noise is passed through a filter to give the turbulence the Dryden velocity spectra. It simulate in the package MatLab.

Standard model of Shear turbulence simulate in the package MatLab.

6. Conclusions

The flight altitude control system by means of composited control over aerodynamic wing configuration increase of aircraft flight safety level and improvement in quality of flight path control.

The altitude control quality is increased by 2 times.

The control signal calculation unit allows including of the weighting coefficient in functions of support decision for each of the wing components.

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К.А. Копитова. Моделювання композиційного та розподіленого керування висотою польоту повітряного судна

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Розглянуто результати моделювання схеми системи керування висотою польоту відхиленням руля висоти та комплексної схеми системи керування висотою польоту з розподіленою аеродинамічною схемою поверхонь керування.

Ключові слова: аеродинамічна схема поверхонь керування, система керування висотою польоту, турбулентність.

Е.А. Копытова. Моделирование композиционного и распределённого управления высотой полёта воздушного судна

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Рассмотрены результаты моделирования схемы системы управления высотой полёта отклонением руля высоты и комплексной схемы системы управления высотой полёта с распределённой аэродинамической схемой поверхностей управления

Ключевые слова: аэродинамическая схема поверхностей управления, система управления высотой полёта, турбулентность.

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