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DESIGN OF ROBUST CONTROLLER FOR UAV INFORMATION-MEASURING DEVICES STABILIZATION SYSTEM

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Abstract. *The design problems of the information-measuring devices operated on the unmanned aerial vehicles in difficult conditions of the considerable parametric and vigorous external disturbances are considered. The mathematical model of the system is developed. The problem statement and basic stages of the robust controllers design are analyzed. The results of the synthesized system simulation in the modes of the preliminary and precision stabilization are given.*

Keywords: information-measuring devices; robust systems; structural synthesis; gyro devices; method of mixed sensitivity.

Introduction

Stabilization of the information-measuring devices operated on the vehicle of the wide class including the unmanned aerial vehicles (UAVs) is the actual problem of the modern control systems development. The typical information-measuring devices operated on modern UAVs may include the TV camera, digital photographic apparatus and laser scanner. The listed types of apparatus allow to solve the cartography and photography problems by means of the digital photogrammetry. To solve the aerial photography problem it is possible using the TV camera of the high resolution. The laser scanner may be used for the cartographic shooting. This technology allows to create the relief model by means of the laser pulsing and analysis of the reflected signals [1]. The high image quality may be achieved by means of the gyrostabilization, which may provide the information-measuring devices given position during shooting [2].

In accordance with the classification accepted by the UVS International the UAVs may be divided into micro and mini, light, middle and heavy by a mass and dimensions. The modern trend of the Ukrainian UAVs development is creation of the light ones. The gyrostabilized platforms are used by the light UAVs developed in Russia such as ZALA 421-16 [3]. As a rule, vehicles of such type use the changeable pay load, for example, the video camera, thermal imager or camera of the high resolution. The pay load weight may achieve 3 kg.

Operation of the information-measuring devices on the UAV board is implemented in conditions of the disturbances caused above all by the wind action. Usage of the gyrostabilized platforms provides stabilization of the pay load in the conditions of the aerial vehicle angular motion caused by the various vigorous disturbances. The modern trend of the stabilization systems design lies in application of the robust control, which may provide implementation of the requirements given to a system in the difficult operation conditions. Such conditions are accompanied by influence of both internal parametrical and external coordinate disturbances.

Analysis of the last researches and publications

Now the sufficient quantity of papers and textbooks, for example, [4], [5] deals with the problems of the robust system design. It should be noted, that in the modern scientific and technical literature the significant place is taken to design of the robust control systems for the aerial vehicles including unmanned ones.

At the same time the proper attention yet was not given to the design problems of the robust systems for stabilization of the information-measuring devices operated on the vehicles of the wide class in general and UAVs in particular.

The problem statement

In the paper the basic principles of robust structural synthesis of systems for stabilization of the information-measuring devices operated on UAV in the difficult conditions of the considerable parametric and vigorous external disturbances are represented.

Mathematical Description of the Stabilization System

To provide the high accuracy of the observation processes, the appropriate equipment stabilization must be implemented by three axes connected with the aerial vehicle. For this the stabilized platform with the information-measuring devices is mounted in the triaxial gimbals. Such construction must provide the possibility of the platform to turn in the sufficiently wide range such as 360° by an angle of the yaw and ± 90° by the angles of the pitch and roll. The stabilization system of the studied type may support the modes of the preliminary and precision stabilization. Implementation of these modes requires appli-

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cation of the accelerometers and gyro measuring instruments, for example, the angular rate gyro sensors. For the studied system such sensors as the pendulum accelerometers and fiber-optic gyros may be used.

The mathematical description of the stabilized platform must include the dynamics and kinematics description.

The system dynamics may be described by the Euler equations [6]

$$\begin{aligned}
&\dot{\omega}_x J_x + \omega_y \omega_z (J_z - J_y) - (\omega_y^2 - \omega_z^2) J_{yz} \\
&-(\omega_x \omega_y + \dot{\omega}_z) J_{xz} + (\omega_x \omega_z - \dot{\omega}_y) J_{xy} = M_x; \\
&\dot{\omega}_y J_y + \omega_x \omega_z (J_x - J_z) - (\omega_z^2 - \omega_x^2) J_{xz} \\
&-(\omega_z \omega_y + \dot{\omega}_x) J_{xy} + (\omega_x \omega_y - \dot{\omega}_z) J_{yz} = M_y; \\
&\dot{\omega}_z J_z + \omega_x \omega_y (J_y - J_x) - (\omega_x^2 - \omega_y^2) J_{xy} \\
&-(\omega_x \omega_z + \dot{\omega}_y) J_{yz} + (\omega_x \omega_z - \dot{\omega}_x) J_{xz} = M_z,
\end{aligned} \tag{1}$$

where $\omega_x, \omega_y, \omega_z$ are projections of the platform angular rates onto its proper axes; J_x, J_y, J_z are the inertia moments relative to the gimbals axes; J_{yz}, J_{xz}, J_{xy} are the centrifugal inertia moments relative to the gimbals axes; $\dot{\omega}_x, \dot{\omega}_y, \dot{\omega}_z$ are the platform angular acceleration projections onto its proper axes; M_x, M_y, M_z are the moments acting by the gimbals axes. It should be noted, that J_x, J_y, J_z represent the equivalent inertia moments which take into consideration the inertia moment of the platform with pay load installed on it J_{pi} and the inertia moments of the servo motors J_m. These moments may be determined by the expressions $J_i = J_{pi} + n_r^2 J_m$, $i = x, y, z$, where J_{pi}, J_m are the inertia moments of the platform and the motor, n_r is the reducer gear-ratio. In the similar way, the expressions for the centrifugal moments may be obtained [7].

The moments acting by the gimbals axes include such components as the dry friction moments in ball bearings of the gimbals, the moments developed by the stabilization motors and the disturbance moments.

The mutual position of the axes of the coordinate systems necessary for description of the system kinematics is represented in Fig. 1. Here the following systems are used such as the body-axis coordinate system $Ox_0 y_0 z_0$, the coordinate systems connected with the external and internal frames of gimbals $Ox_1 y_1 z_1$ and $Ox_2 y_2 z_2$, the coordinate system connected with the platform $Oxyz$.

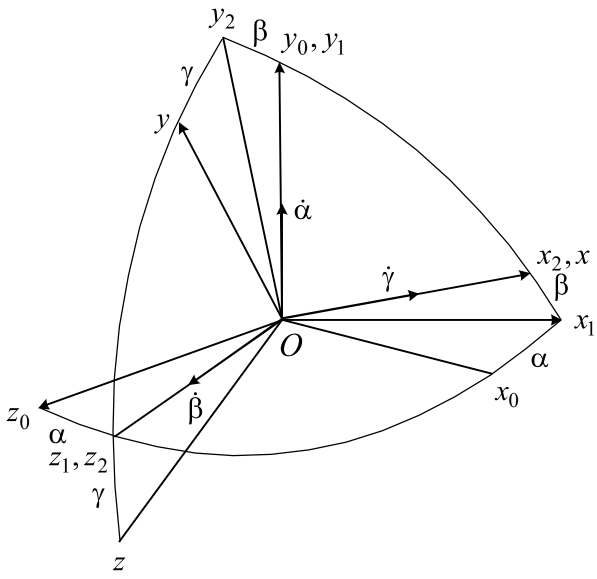


Fig. 1. The mutual position of the coordinate systems connected with the UAV and platform

In accordance with Fig. 1 the expressions for determination of the platform angular rates may be represented in the following form

$$\begin{aligned}
\omega_x &= \dot{\beta}\cos\gamma + \dot{\alpha}\cos\beta\sin\gamma; \\
\omega_y &= \dot{\alpha}\cos\beta\cos\gamma - \dot{\beta}\sin\gamma; \\
\omega_z &= \dot{\gamma} - \dot{\alpha}\sin\beta.
\end{aligned} \tag{2}$$

Based on the expressions (2), the differential equations, which characterize a change of the platform angular position, become

$$\begin{aligned}
\dot{\alpha} &= (\omega_x \sin\gamma + \omega_y \cos\gamma) / \cos\beta; \\
\dot{\beta} &= \omega_x \cos\gamma - \omega_y \sin\gamma; \\
\dot{\gamma} &= \omega_z + \mathrm{tg}\beta(\omega_x \sin\gamma + \omega_y \cos\gamma).
\end{aligned} \tag{3}$$

During creation of the model of a platform in the gimbals it is necessary to take into account that stabilization motors are mounted at the gimbals axes. At the same time the platform model (1) is defined by its projections onto the proper axes. The expressions for the moments of control by the platform in projections onto its proper axes may be determined in the following way [8]

$$\begin{aligned}
M_x &= M_{x2} + \sin\beta M_{y0}; \\
M_y &= \sin\gamma M_{z1} + \cos\beta\cos\gamma M_{y0}; \\
M_z &= \cos\gamma M_{z1} - \cos\beta\sin\gamma M_{y0}.
\end{aligned} \tag{4}$$

Creating the stabilized platform model it is necessary to take into account that every system channel includes the plant, motor, pulse-width-modulator and the gyro measuring instrument for angular rate determination.

The components of the moments acting by the gimbals axes may be represented in the following form [9]

$$M_{1i} = M_{fr}\,\mathrm{sign}\,\omega_i;$$
$$M_{2i} = c_m U_{a_i} / R_a; \qquad (5)$$
$$M_{3i} = M_{dist_i};\ i = x_2, y_0, z_1,$$

where M_{fr} is the nominal value of the moment of friction at the ball bearings mounted at the gimbals axes; c_m is the coefficient of loading at the motor shaft; U_{a_i} are the voltages of the motor armature control winding; R_a is the resistance of the motor armature circuit; M_{dist_i} are the disturbance moments.

Forming of the voltage in the motor armature control winding may be described by the expressions [7], [9]

$$T_a \dot{U}_{a_i} + U_{a_i} = k_{PWD} U_{PWD_i} - n_r c_e \omega_i,\ i = x_2, y_0, z_1, \qquad (6)$$

where T_a is the armature circuit time constant; c_e is the coefficient of proportionality between the motor angular rate and the electromotive force; k_{PWD} is the coefficient of the linearized pulse-width-modulator; $U_{PWD\,i}$ are the voltages at the pulse-width-modulator input. Control voltages at the outputs of the angular rate gyro sensors U_{ω_i} may be described in the following way [9]

$$T_g^2 \ddot{U}_{\omega_i} + 2\xi T_g \dot{U}_{\omega_i} + U_{\omega_i} = k_g \omega_i,\ \ i = x, y, z, \qquad (7)$$

where T_g is the time constant of the angular rate gyro sensor; ξ is the attenuation coefficient; k_g is the transfer constant of the angular rate gyro sensor.

The relationships (1) – (7) represent the mathematical description of the system for stabilization of the information-measuring devices operated on UAVs. In the modern practice of the robust systems design it is accepted to implement this process in two stages. At the first stage the robust synthesis based on the liner model represented as the state space one is carried out. At the second stage the check of the synthesized system by means of simulation is implemented. The first stage may be carried out repeatedly after analysis of the simulation results.

To carry out the robust structural synthesis it is necessary to use the linear model of the system to be synthesized. Such model may be obtained based on the relationships (1) – (7) using the following basic suppositions:

1) neglect of the centrifugal platform moments and differences of the axial moments for simplification of the expression (1);

2) taking into account the small platform turns only that allows to simplify the trigonometric functions in the expression (2);

3) change of the non-linear dry friction moments by the linearized moments [7];

4) usage of the linear model of the pulse-width-modulator;

5) neglect of the disturbance moments applying to the platform in the expression (2).

Based on the relationships (1) – (7) and above listed suppositions the considered system linear model may be represented as the state space model for the vector of state variables **x** by the four matrices **A**, **B**, **C**, **D**

$$x^T = [\alpha\ \ \beta\ \ \gamma\ \ U_{\omega_x}\ \ U_{\omega_y}\ \ U_{\omega_z}\ \ U_{a_{x2}}\ \ U_{a_{y0}}\ \ U_{a_{z1}}\ \ \omega_x\ \ \omega_y\ \ \omega_z\ \ U_{\omega d_x}\ \ U_{\omega d_y}\ \ U_{\omega d_z}],$$

where $U_{\omega d_x}, U_{\omega d_y}, U_{\omega d_z}$ are derivatives by the voltages $U_{\omega_x}, U_{\omega_y}, U_{\omega_z}$;

$$\mathbf{A} = \begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & -1/T_a & 0 & 0 & -n_r c_e/T_a & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & -1/T_a & 0 & 0 & -n_r c_e/T_a & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1/T_a & 0 & 0 & -n_r c_e/T_a & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & c_m/(R_a J_x) & 0 & 0 & -f_x/J_x & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & c_m/(R_a J_y) & 0 & 0 & -f_y/J_y & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & c_m/(R_a J_z) & 0 & 0 & -f_z/J_z & 0 & 0 & 0 \\
0 & 0 & 0 & -1/T_0^2 & 0 & 0 & 0 & 0 & 0 & k_g/T_g^2 & 0 & 0 & -2\xi/T_g & 0 & 0 \\
0 & 0 & 0 & 0 & -1/T_0^2 & 0 & 0 & 0 & 0 & 0 & k_g/T_g^2 & 0 & 0 & -2\xi/T_g & 0 \\
0 & 0 & 0 & 0 & 0 & -1/T_0^2 & 0 & 0 & 0 & 0 & 0 & k_g/T_g^2 & 0 & 0 & -2\xi/T_g
\end{bmatrix}$$

where f_x, f_y, f_z are the coefficients of the linearized friction moments [7];

$$\mathbf{B}^T=\begin{bmatrix}0&0&0&0&0&0&k_{PWD}&0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&k_{PWD}&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0&k_{PWD}&0&0&0&0&0&0\end{bmatrix},$$

$$\mathbf{C}=\begin{bmatrix}0&0&0&1&0&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&1&0&0&0&0&0&0&0&0&0&0\\0&0&0&0&0&1&0&0&0&0&0&0&0&0&0\end{bmatrix},\ \mathbf{D}=\begin{bmatrix}0&0&0\\0&0&0\\0&0&0\end{bmatrix}. \qquad (8)$$

The Algorithm of the Robust Regulator Structural Synthesis

One of the modern approaches to the structural synthesis of the robust regulator for the stabilization system is the H_∞-synthesis. Its basic principles are represented in many textbooks [4], [5]. In this case the designed system is represented as it is shown in Fig. 2.

Such system consists of a plant $\mathbf{G}$ and a controller $\mathbf{K}$ and may be represented by the output signals to be optimized $\mathbf{z}$, input signals $\mathbf{w}$, control signals $\mathbf{u}$ and output signals $\mathbf{y}$, which enter to the controller [4], [5]. The statement of the H_∞-synthesis problem is based on introducing of the so-called generalized or interconnected system $\mathbf{P}$ [4], [5].

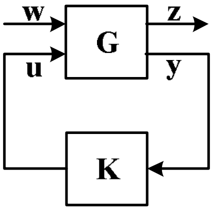


Fig. 2. The standard H_∞-configuration

Consider a system represented in Fig. 3 [4].

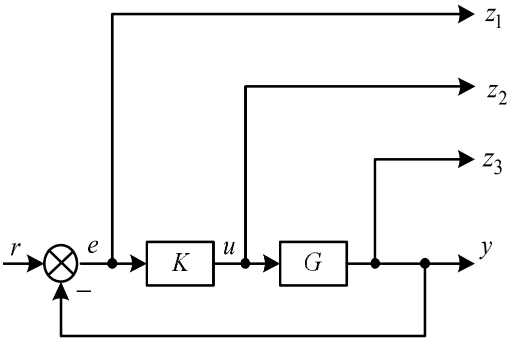


Fig. 3. The structural scheme of the designed system

For such system the interconnection between signals using the generalized system concept looks like [4]

$$\mathbf{w}=\mathbf{r};\quad \mathbf{z}=\begin{bmatrix}e\\u\\y\end{bmatrix};\quad \mathbf{P}=\begin{bmatrix}\mathbf{P}_{11}&\mathbf{P}_{12}\\\mathbf{P}_{21}&\mathbf{P}_{22}\end{bmatrix}=\begin{bmatrix}\mathbf{I}&-\mathbf{G}\\0&\mathbf{I}\\0&\mathbf{G}\\\mathbf{I}&-\mathbf{G}\end{bmatrix}, \qquad (9)$$

and the transfer function from input $\mathbf{w}$ to output $\mathbf{z}$ becomes

$$\mathbf{T}_w^z=\mathbf{P}_{11}+\mathbf{P}_{12}\mathbf{K}(\mathbf{I}-\mathbf{P}_{22}\mathbf{K})^{-1}\mathbf{P}_{21}.$$

The statement of the optimization problem may be represented in the following form [4]

$$\mathbf{K}_{\text{opt}}=\arg\inf_{K_{\text{opt}}\in K_{\text{per}}} J(\mathbf{G},\mathbf{K}), \qquad (10)$$

where

$$J(\mathbf{G},\mathbf{K})=\left\|\begin{bmatrix}(\mathbf{I}+\mathbf{GK})^{-1}\\\mathbf{K}(\mathbf{I}+\mathbf{GK})^{-1}\\\mathbf{GK}(\mathbf{I}+\mathbf{G}K)^{-1}\end{bmatrix}\right\|_\infty. \qquad (11)$$

The H_∞-synthesis problem (10) may be solved by the method of the mixed sensitivity [4], [5].

The modern approach to solution of the robust structural optimization problem is based on forming of the system desired frequency characteristics (loop shaping). It is implemented by means of the augmented object forming due to introducing of the weighting transfer functions, as it is shown in Fig. 4.

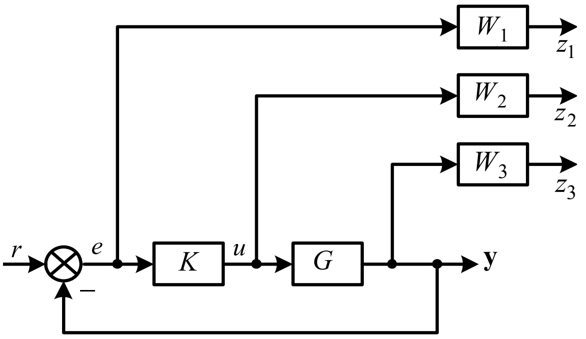


Fig. 4. The structural scheme of the augmented system

H_∞-norm of the augmented system mixed sensitivity function is used as the optimization criterion instead of the expression (11) [4, 5]

$$J(\mathbf{G},\mathbf{K})=\left\|\begin{bmatrix}\mathbf{W}_1(\mathbf{I}+\mathbf{GK})^{-1}\\\mathbf{W}_2\mathbf{K}(\mathbf{I}+\mathbf{GK})^{-1}\\\mathbf{W}_3\mathbf{GK}(\mathbf{I}+\mathbf{GK})^{-1}\end{bmatrix}\right\|_\infty=\left\|\begin{bmatrix}\mathbf{W}_1\mathbf{S}\\\mathbf{W}_2\mathbf{R}\\\mathbf{W}_3\mathbf{T}\end{bmatrix}\right\|_\infty, \qquad (12)$$

where $\mathbf{W}_1, \mathbf{W}_2, \mathbf{W}_3$ are the weighting transfer functions; $\mathbf{S}, \mathbf{R}, \mathbf{T}$ are the sensitivity functions by the given signal, control and the complementary sensitivity function.

Implementation of the H_∞-synthesis by the method of the mixed sensitivity is based on solution of two Riccati equations, check of some conditions and minimization of the system mixed sensitivity function H_∞-norm (12) [4, 5]. It should be noted, that there are automated means of this problem solution, which require mathematical description of the interconnected system (9).

The basic approaches to the robust structural synthesis of the information-measuring devices of the wide class are represented in the paper [10]. Features of the H_∞-synthesis procedure for the information-measuring devices operated on the ground vehicles are represented in the paper [11]. The developed models (1) – (7) and (8) allow to carry out the H_∞-synthesis of the system for stabilization of the observation devices operated on the UAV. The considered stabilization system is configured as a rate servo one, since many types of the modern gyros sense angular rates [2].

The H_∞-synthesis includes such stages as creation of the system mathematical description both linear and non-linear, choice of the weighting transfer functions, augmentation of the plant and synthesis of the robust controller. All these stages may be implemented by means of the computing system MatLab.

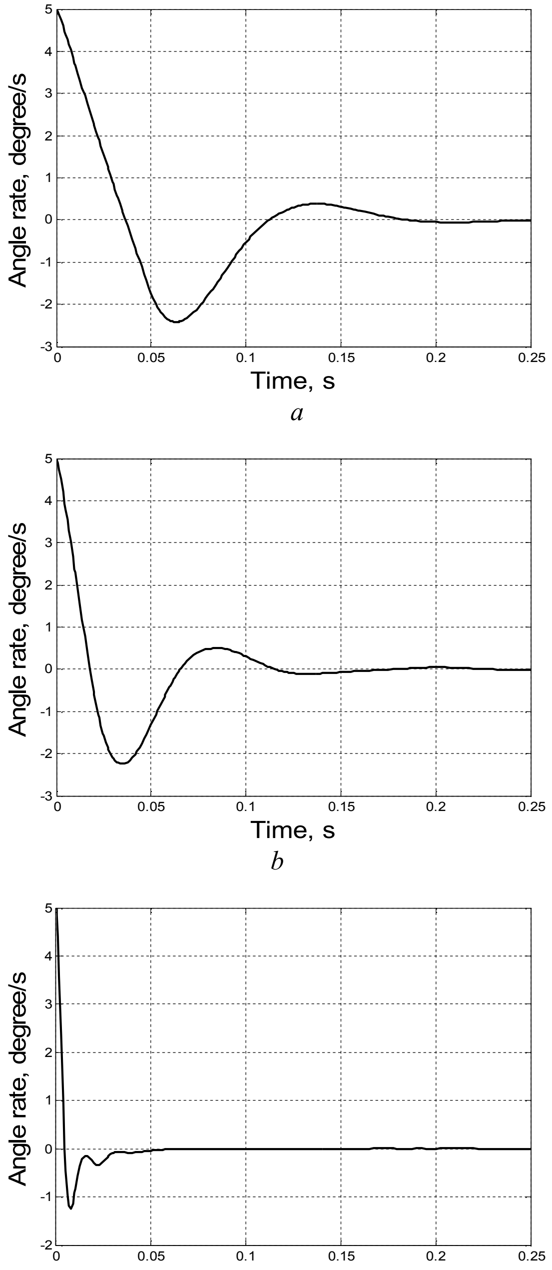
The results of the synthesized system simulation in the mode of precision stabilization are represented in Fig. 5.

One of the most important stages of the robust structural optimization is the choice of the weighting transfer functions, which is implemented based on the heuristic approaches. For the studied system the expressions for the matrix weighting transfer functions may be represented in the following form

$$\mathbf{W}_1 = \begin{bmatrix} \frac{1}{s}\frac{0{,}1s+20}{s+0{,}005} & 0 & 0 \\ 0 & \frac{1}{s}\frac{0{,}02s+10}{s+0{,}002} & 0 \\ 0 & 0 & \frac{0{,}01s+10}{s+0{,}001} \end{bmatrix};$$

$$\mathbf{W}_2 = \begin{bmatrix} 0{,}04 & 0 & 0 \\ 0 & 0{,}04 & 0 \\ 0 & 0 & 0{,}04 \end{bmatrix};$$

$$\mathbf{W}_3 = \begin{bmatrix} \frac{s}{0{,}005s+50} & 0 & 0 \\ 0 & \frac{s}{0{,}002s+20} & 0 \\ 0 & 0 & \frac{s}{0{,}001s+10} \end{bmatrix}.$$



a

b

c

Fig. 5. The results of the stabilized platform simulation by the yaw channel (*a*); the pitch channel (*b*); the roll channel (*c*)

The results of the synthesized system simulation in the mode of the preliminary stabilization are shown in Fig. 6.

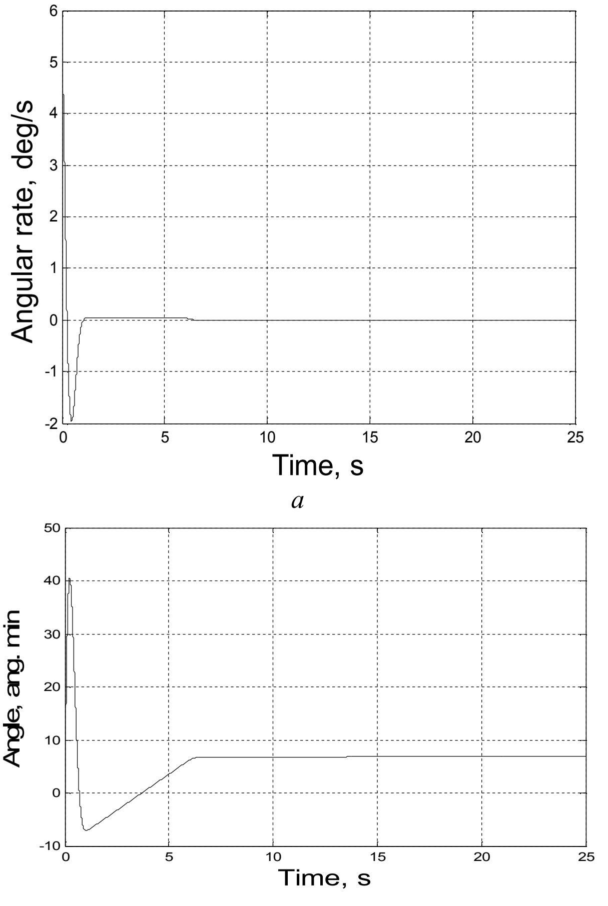
The synthesised controller structure may be described by four state space matrices

$$\mathbf{A}_c = \begin{bmatrix} 186{,}3 & 352{,}6 & 45{,}83 & 11{,}33 & 43{,}7 \\ 711{,}8 & -966{,}3 & -179{,}7 & -12{,}17 & -11{,}6 \\ -117{,}75 & 126{,}7 & -18{,}41 & -15{,}84 & -15{,}62 \\ -343{,}7 & 517{,}3 & 136{,}8 & 19{,}39 & -23{,}43 \\ -218{,}3 & 268{,}8 & 20{,}53 & 18{,}75 & -25{,}89 \end{bmatrix};$$

$$\mathbf{B}_c^T = \begin{bmatrix} 20{,}98 & -37{,}1 & -8{,}3 & -5{,}36 & -7{,}25 \\ 17{,}6 & -32{,}1 & -7{,}3 & -4{,}2 & 6{,}23 \\ 15{,}6 & -30{,}5 & 5{,}4 & -3{,}1 & -5{,}21 \end{bmatrix};$$

$$\mathbf{C}_c = \begin{bmatrix} 8{,}31 & -9{,}8 & -4{,}78 & -1{,}43 & 2{,}35 \\ 9{,}6 & -6{,}4 & 12{,}2 & -1{,}2 & 16{,}3 \\ 11{,}2 & -7{,}5 & 9{,}2 & -11{,}1 & -15{,}21 \end{bmatrix};$$

$$\mathbf{D}_c = \begin{bmatrix} -0{,}9 & -0{,}543 & -0{,}217 \\ -0{,}6 & -0{,}312 & -0{,}123 \\ -0{,}4 & -0{,}213 & -0{,}223 \end{bmatrix}.$$



a

b

Fig. 6. The results of the gyrostabilized platform motion in the mode of the preliminary stabilization: *a* is transient by the given angular rate; *b* is the error of the angular position stabilization

These matrices were obtained taking into consideration reduction of the synthesized controller order.

At the represented graphs the angular motion of the UAV was considered as the disturbance. The represented results prove the possibility to achieve the stabilization accuracy and speed of operation sufficient for the information-measuring devices operated on the UAV.

Conclusions

The basic approach to the robust structural synthesis of the stabilization system of the information-measuring devices operated on the UAVs is represented. The mathematical description of the system providing stabilization and control by orientation of the observation devices lines of sight is obtained. The matrix weighting transfer functions for the robust structural synthesis are chosen. The simulation results are represented.

References

[1]. www.balt-agp.ru/services/aerofoto.htm.

[2] Hilkert, M. "Inertially stabilized platform technology." *IEEE Control Systems Magazine*. New York. no. 1. vol. 28. 2008. pp. 26–46.

[3] www.bp-la.ru/bespilotnyj-apparat-zala-421-16.

[4] Gu, D. W.; Petkov, P. Hr.; Konstantinov, M. M. "Robust Control Design with MATLAB." London: *Springer-Verlag*. 2005. 389 p.

[5] Skogestad, S.; Postlethwaite, I. "Multivariable Feedback Control." New York. *Jonh Wiley*. 1997. 559 p.

[6] Lurye, A. I. "Analitical Mechanics." Moscow. *Gostechizdat*. 1961. 822 p. (in Russian).

[7] Kochergin, V. V. "Servo Systems with Direct Current Motor." Leningrad. *Energoatomizdat*. 1988. 168 p. (in Russian).

[8] Sushchenko, O. A. "Mathematical Model of Inertially Stabilized Platform for Aircraft Observation Equipment." 2010. *Proceedings of the fourth world congress "Aviation in the XXI-st century*. Safety in Aviation and Space Technology". Kyiv. vol. 1. pp. 21.43–21.46.

[9] Pelpor, D. S. "Gyro Systems." Part 1. Theory of Gyros and Gyrostabilizers. Moscow. *Vishaya shkola*. 1971. 566 p. (in Russian).

[10] Sushchenko, O. A. "Research of H_∞-synthesis methods for stabilization systems of information-measuring devices." *Proceedings of NAU*. no. 3. 2012. pp. 64–68. (in Ukrainian).

[11] Sushchenko, O. A.; Chaplay, I. V. "Synthesis of robust controller for stabilizing system of informational-measuring devices." *Proceedings of NAU*. no. 3. 2011. pp. 36–42.

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О. А. Сущенко. Проектування робастного контролера для системи стабілізації інформаційно-вимірювальних пристроїв БПЛА

Розглянуто проблеми проектування інформаційно-вимірювальних пристроїв, експлуатованих на БПЛА в складніх умовах значних параметричних та интенсивних зовнішніх збурень. Розроблено математичну модель системи. Проаналізовано постановку проблеми та основні етапи проектування робастних контролерів. Представлено результати імітаційного моделювання синтезованої системи у режимах попередньої і точної стабілізації.

Ключові слова: информаційно-вимірювальні пристрої, робастні системи, структурний синтез, гіроскопічні пристрої, метод змішаної чутливості.

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О. А. Сущенко. Проектирование робастного контроллера для системы стабилизации информационно-измерительных устройств БПЛА

Рассмотрены проблемы проектирования информационно-измерительных устройств, эксплуатируемых на БПЛА в сложных условиях значительных параметрических и интенсивных внешних возмущений. Разработана математическая модель системы. Проанализированы постановка проблемы и основные этапы проектирования робастных контроллеров. Представлены результати имитационного моделирования синтезированной системы в режимах предварительной и точной стабилизации .

Ключевые слова: информационно-измерительные устройства, робастные системы, структурный синтез, гироскопические устройства, метод смешанной чувствительности.

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