THE MODEL OF A COMPLEX SYSTEM OF „HELICOPTER - AUTOMATIC CONTROL SYSTEM” MOTION

Prof. Eng. **Vasily N. KAZAK**, **N.A. TYMOSHENKO**, post-graduate student,
Senior lecturer Eng. **Dmitry O. SHEVCHUK**, Ph.D, Senior lecturer Eng. **Helen TACHININA,** PhD,

National Aviation University, Ukraine

REZUMAT. Este examinat un model al dinamicii mişcării sistemului complex «elicopter - sistem automat de control». A fost elaborat un model de soluţionare a problemei globale de stabilizare rigidă a situării elicopterului deasupra punctului stabilit pe suprafaţă limitată.

Cuvinte cheie: helicopter, control, stabilizare, observare, sistem, control automat.

ABSTRACT. Examined mathematical model of the dynamics of the motion of a complex systems „helicopter – automatic control system”. The model solution problems of global task of rigid stability of the helicopter hovering above a given point of the plane bounded had been developed.

Keywords: helicopter, control, stabilization, observation, system, automatic control.

It is necessary to carry out operations analysis of all factors that influence over this process, for discovering causes of deviation of the desired attitude of a given point a helicopter hovering.

We should create controlling forces and moments to ensure controllability and stability of single-rotor helicopter [1, p. 72]. Controlling forces and movements are deflect or reduce the effect on the helicopter during flight with respect to all three of its axes, that are designed to prevent the further development of emergency situations.

Parameters of motion of the helicopter during flight can be changed because of the influence of different factors. They are: relative air flow, intensive air turbulence, assembly of foreign matter (biological, mechanical, electrical), failures of various equipment or engine etc. That’s why necessary to add acceptable component to controlling forces and moments that can help to prevent (or stabilize or neutralize) negative effects of flight situation. We consider the dynamic characteristics key parameters of helicopter as a controlled element are: flight time, climb angle, velocity and acceleration change speed of angles, altitude, velocities and accelerations. Except above mentioned parameters we should also consider outside environment, psychophysical property of the crew and automatic control system capability [2, p. 162, 3, p. 12].

For definition of time necessary for prevention of destabilization factor negative effects we should take into account all dangerous factors that are influence over flight situation in time. For that definition we can use concept „helicopter- crew- automatic control system(ACS) - weather”. For research of behaviour of that complicated system, each component of „helicopter- crew- automatic control system – weather(ambient)” should be examined separately.

In that work was examined one of the basic elements of mentioned system – system „helicopter – automatic control system”, which is able to function in two modes: automatic control of trajectory helicopter movement mode (ACS-mode) and balance (axis of mass) movement control mode (autopilot mode). This refers to an expanded variaţion of a complex multiagent system (CMAS) with variables in time and space of a working environment of parameter its state.

Currently we shall define the working environment as difficult weather conditions, in which the „helicopter- automatic control system” system functions. The boundaries of the working environment are defined by technical flight characteristics of the helicopter (the controllable object) and by functional qualities and abilities of automatic control system, the most important quality here being the precision its parameters.

Each system (Fig. 1) has its task in the main system. In reality any global task is a variable in time and space of the working environment, the fuzzy multitude of mutual casual local tasks, which need to be given the decision in order of actuality and priority, to achieve the task. For our research the global task is a rigid stabilization of helicopter’s hovering about a predetermined point of the limited area (pipes of nuclear power stations, towers and other) in difficult weather conditions.

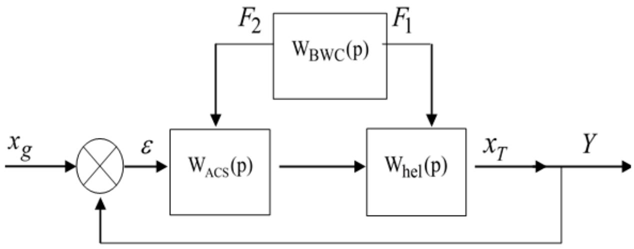

Fig. 1. The generalized structure of the „helicopter-automatic control system" system is: $W_{hel}(p)$, $W_{ACS}(p)$, $W_{BWC}(p)$, – transmission functions of the helicopter, automatic control system and bad weather conditions; x_g, x_T - the set entry parameter of stabilization and the current parameter accordingly; Y – measured current parameter; F_1, F_2 – parameters of the environmental influence.

According to this, the differential equation, which describes the non-linear and non-stationary dynamics of the „helicopter- automatic control system" system with variables, may be depicted as following:

$$\dot{X}(t) = \varphi[X(t), U(t), G(t), N(t), t], \tag{1}$$

where: $X(t)$ is the vector of the dimension state variables; $U(t)$ and $G(t)$ – the m-sized vectors of managing and external (revolting influences of bad weather conditions) accordingly; N – is a diagonal matrix of variaţions of parameters of the unstable state of dimension $s \times s$.

To simplify the task of research, at this work assumption is made, that a research object is a system „helicopter- automatic control system", which is described by nonlinear stationary differential equations that present a partial case of equation (1), but not linearity in question, which is typical for automatic control system: continuous or partially-continuous. We shall assume also, that external influences on this stage of research are nil, meaning $f(t) = f_1(t) + f_2(t) = 0$. Initial conditions is $X(t) = X_0(t_0)$.

So, in a mathematical model (1) it is expedient in an obvious kind to define dependence of state variables on parameters and their variaţions. For this purpose the state of system (Fig. 1) is presented as such, that depends on additive parametrical linear $NV(t)$ and nonlinear influences $\Delta\varphi(V)$. In this case a mathematical model (1) will open out in such composition:

$$\begin{aligned}
&\dot{X}(t) = AX(t) + BU(t) + G_{f_1}F_1(t) + G_{f_2}F_2(t) + D\varphi(x);\\
&Y(t) = CX(t) + B_1U(t) + G_{f_1}F_1(t) + G_{f_2}F_2(t);\\
&V(t) = A_1X(t) + B_2U(t) + G_{f_1}F_1(t) + G_{f_2}F_2(t) + D_1\varphi(x);\\
&F(t) = F_1(t) + F_2(t) = NV(t) + \Delta\varphi(v),
\end{aligned} \tag{2}$$

where: $Y(t)$ is the r-sized vector of outcoming variables which are being measured; $V(t)$ – sized vector of additive parametrical influences; $N(t)$ and $\varphi(t)$ are diagonal matrixes of variaţions of parameters of linear unstable influences and increases, that arose as the consequence of nonlinearity variaţions of parameters, initial variable nonlinear elements of system of dimension $s \times s$; A, B, G, D, C are matrixes of corresponding vectors. The system of equalizations (2) will use automatic control system as parametrical model. The $U(t)$ components of management vector are assumed to be determined as well as socasual functions of time; $N, \varphi(v)$ is of the same character.

In case of initial forming of measurable $Y(t)$ and entrance variables of unstable influences of $V(t)$ only due to state of $X(t)$ variables expediently to simplify the system (2) to the next level:

$$\begin{aligned}
&\dot{X}(t) = AX(t) + BU(t) + G_{f_1}F_1(t) + G_{f_2}F_2(t) + D\varphi(x);\\
&Y(t) = CX(t) + \vartheta;\\
&V(t) = A_1X(t);\\
&F(t) = NV(t) + \Delta\varphi(v).
\end{aligned} \tag{3}$$

For the linearized systems, correlation (3) can be once again simplified:

$$\begin{aligned}
&\dot{X}(t) = AX(t) + BU(t) + G_{f_1}F_1(t) + G_{f_2}F_2(t);\\
&Y(t) = CX(t) + \vartheta;\\
&V(t) = A_1X(t);\\
&F(t) = NV(t).
\end{aligned} \tag{4}$$

Variant of structures of „helicopter- automatic control system" difficult multiagent system, which correspond to a model (4) can be depicted as following (Fig. 2) [2, p. 150].

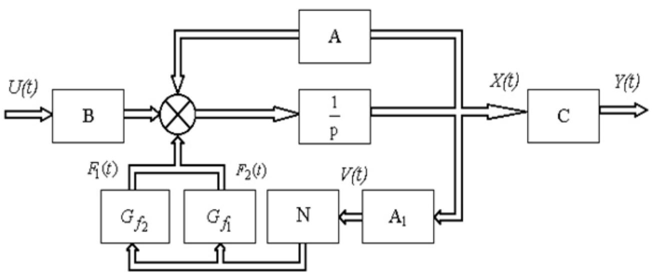

Fig. 2. The generalized system flow diagram according to parametrical disturbances).

A flow diagram (Pic.2) has converted into one equation in relation to the vector of state variables:

$$\begin{aligned}
&\dot{X}(t) = A_N X(t) + BU,\\
&A_N = A + (G_{f_1} + G_{f_2})NA_1.
\end{aligned} \tag{5}$$

For linear ACS of equations in time area (5) it is possible to pass to the system of equations of algebra for depicting variables, applying Laplace's transformation at zero initial conditions[2, p. 149]:

$$pX(p) = AX(p) + BU(p) + G_{f_1} F_1(p) + G_{f_2} F_2(p);$$
$$Y(p) = CX(p);$$
$$V(p) = A_1 X(p);$$
$$F_1(p) + F_2(p) = NV(p), \qquad (6)$$

where p is a variable of Laplace's transformation.

From the analysis of (6) we conclude that the observation equation can be depicted as following:

$$Y(p, \mathrm{N}) = = C\left[pE - \left(A + G_{f_1} NA_1 + G_{f_2} NA_2\right)\right]^{-1} BU(p), \qquad (7)$$

where E is a identity matrix.

So, expanding the state vector of X by measuring accelerations in the system (1) to its values in (5), we can consider the impact of the external disturbance vector and internal processes on the accuracy of helicopter's stabilization relatively about a predetermined point of the limited area. To maintain the ability to contour of „helicopter-automatic control system" to perform global target, we propose to reshape the measurement vector, so, that effect of a disturbance, caused by weather conditions will have kept to a minimum [2, p. 128]:

$$\min r_i(t_i) = y_i(t_i) - c_i \bar{x}_i(t_i),\ i = 1, 2, ..., \quad t = [t_0, t_k],\ t_i > t_0, \qquad (8)$$

where: $r(t)$ is a vector of desynchronization; $\bar{x}(t)$ – is a state estimate of $x(t)$ to measurements on the i-th step.

CONCLUSION

Composite model of the dynamics of the motion „helicopter- automatic control system" makes it possible to solve the global task of the rigid stabilization of helicopter's hovering above a predetermined point of the limited area in conditions of the destabilizing effect of external and internal influences.

BIBLIOGRAPHY

[1] Bramvell A.R.S. *The dynamics of helicopters.* Translation from English, Moskow.:Mashinostroenie, 1982. – 368pp. (in Russian).

[2] Kazak V.M. *System recovery methods survivability of aircraft in special situations in flight: monograph* / V.M. Kazak. – K.: NAU, 2010. 284 pp. (in Ukrainian).

[3] Harchenko V.P., Shmelova T.F., Sikirda Y.V. *Making decisions operator's air navigation system* / V. P. Xarchenko, T. F. Shmelova, Y. V. Sikirda. – Kirovograd: KLA NAU, 2012. – 292 pp. (in Ukrainian).

[4] Dalin V. N., Maheev S. V. *The construction of helicopters.* – Moskow: MAI, 2001. – 352 pp. (in Russian)

[5] Zhulev V. I., Ivanov V. S. *Safety of aircraft (Theory and Analysis)*, Moskow, Transport, 1986. – 224 pp. (in Russian).

[6] Kazak V.M. *Fundamentals of control and technical diagnostics.* K.: NAU, 2013. 300 pp. (in Ukrainian).

[7] Kazak V.N., Tunik A.A., Salimon V.I., *Fundamentals of automatic control of the aircraft,* K.: NAU, 2000. – 244 pp. (in Ukrainian).

[8] Kazak V.N., Tunik A.A., Salimon V.I., *System of automatic and semi-automatic flight control: monograph.* / V.M. Kazak. – K.: NAU, 2002. – 207 pp. (in Ukrainian).

About the authors

Prof. Eng. **Vasily N. KAZAK**, Dr. Sc.
National Aviation University, Ukraine

Doctor of Science, engineer, professor at the National Aviation University. Scientific interest: methods of recovering survivability of airplanes in special flight situations, optimal control complex systems.

N. A. TYMOSHENKO, post-graduate student
National Aviation University, Ukraine

Post-graduate student. Scientific interest: control system.

Senior lecturer Eng. **Dmitry O. SHEVCHUK**, Ph.D.,
National Aviation University, Ukraine

Senior lecturer of the Department of automation and energy control systems National Aviation University. Scientific interest: methods of recovering survivability of airplanes in special flight situations.

Senior lecturer **Helen TACHININA,** PhD, candidate of science
National Aviation University, Ukraine

Senior lecturer of the Department of automation and energy control systems National Aviation University. Scientific interest: control of complex dynamic systems.