Cross connections in helicopter active flight control system

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Abstract. The issues of building automated control of a helicopter based on the principles of active control systems are considered. The use of such systems makes it possible to rationally change the design of the designed helicopter using traditional and non-traditional control methods. Active control systems can solve a number of specific tasks: comprehensive correction of stability and controllability characteristics, implementation of flight restrictions, countering wind disturbances, etc. The work considers the operation of an active control system in the mode of parry the cross influence of individual control channels. Such approaches to the construction of circuits of automatic control of aircraft, in particular using the ideas of direct control of aerodynamic forces are now intensively implemented in the practice of creating samples of aerobatic navigation equipment of promising aircraft. But for helicopters such a task was not expressed. It is proposed to use matrix methods of accounting for multidimensional feedback in the synthesis of cross-connection contours or to implement the structural synthesis of cross-connection contours. The proposed system of joint control with compensation for unwanted aerodynamic forces and moments and coordinated interaction of the pilot's control actions provides relative simplicity and comfort of the pilot in the control loop, which is reduced to the control of isolated aperiodic links. In the presence of schemes of compensation, the helicopter is able to perform most complicated maneuvers.

1. Introduction

The main lifting rotor determines the presence in the helicopter a strong cross-link between lateral and longitudinal motion, as well as between angular movements and the movement of the center of mass, and since the center of mass of the helicopter is located below the main rotor bushing, the movements of the helicopter are to some extent similar to pendulum motion. That is why, unlike an airplane, a helicopter as a control object is characterized by oscillatory instability, which is primarily due to the strong cross effect of changing the flight speed on the angular movements of the helicopter. The oscillation period of unstable motion (see Figure 1) is 15 ... 35 s, so manual control of the helicopter is quite possible, but causes certain difficulties for the pilot. That is why an obligatory element of helicopter automatic control systems (ACS) is a subsystem for increasing stability and controllability, which it is advisable not to turn off during the entire flight.

The analysis of the existing principles of constructing the contours of the joint control of the helicopter shows that the elimination of the oscillatory instability of the longitudinal and lateral movement is either assigned to the pilot, or is solved by the circuit of the automatic stabilization of

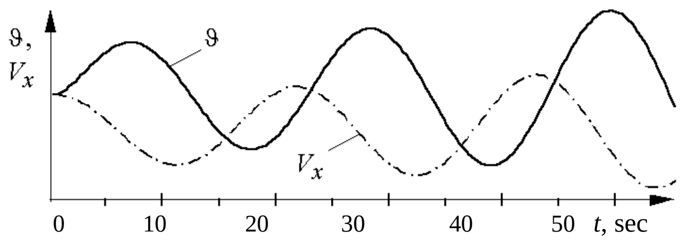


Figure 1. Oscillatory pattern of the change in the pitch angle ϑ and longitudinal speed V_x of the helicopter

angular positions. In the latter case, during control, joint control by deviation, which is not usual for the pilot, is realized, therefore, during prolonged work in such a control loop, the skills of manual piloting are forgotten, which, in the event of a failure of the semi-automatic system, makes control difficult. Control by deviation can be applied at the stages of minor flight trajectory correction, and at the stages of energetic maneuvering it is advisable to use the traditional control by the angular velocity by creating control torques.

The main disadvantage of such control is the complex dynamic nature of the angular displacements of the helicopter during trajectory control, which requires high professional training from the pilot in precise control tasks. The difficulty lies in the fact that when control by the angular velocity excites almost all phase coordinates of the helicopter, while unwanted changes in phase coordinates must be countered by the pilot by additional deviations of the control levers.

2. Problem statement

It is proposed to build a system of automatic control of the helicopter on the principles of active control systems, i.e. systems that improve the aerobatic characteristics of the control object. Such approaches to the construction of circuits of automatic control of aircraft, in particular using the ideas of direct control of aerodynamic forces are now intensively implemented in the practice of creating samples of aerobatic navigation equipment of promising aircraft. But for helicopters such a task was not expressed.

In order to improve the working conditions of the pilot in the contours of joint control of the helicopter, it is advisable to divide the control into separate groups of phase coordinates. In part, this can be done with traditional control by creating control torques, but in full enough such control can be implemented only as a result of the procedure, which is called decoupling of control effects according to the laws of coordinated interaction of controls and parrying of undesirable cross of aerodynamic forces and moments when the excitation of one of the forms of movement of the helicopter.

3. Problem solution

Cross-links between lateral and longitudinal motion, as well as between angular motion and center of mass motion are reflected in its mathematical models, such as the linearized equations system [1], which describe the spatial motion of a helicopter.

$$\Delta\dot{\omega}_y + a_{my}^{\omega y}\Delta\omega_y + a_{my}^{Vz}\Delta V_z = a_{my}^{\delta_{\text{thr}}}\Delta\delta_{\text{thr}} + a_{my}^{\delta_{\text{ant.r}}}\Delta\delta_{\text{ant.r}} + f(M_{\text{r}});$$

$$\Delta\dot{\omega}_z + a_{mz}^{\omega x}\Delta\omega_x + a_{mz}^{\omega z}\Delta\omega_z + a_{mz}^{Vx}\Delta V_x + a_{mz}^{Vy}\Delta V_y + a_{mz}^{Vz}\Delta V_z + a_{mz}^{\Omega}\Delta\Omega =$$

$$= a_{mz}^{\delta_{\text{lon.pl}}}\Delta\delta_{\text{lon.pl}} + a_{mz}^{\delta_{\text{lat.pl}}}\Delta\delta_{\text{lat.pl}} + a_{mz}^{\delta_{\text{lif.r}}}\Delta\delta_{\text{lif.r}};$$

$$\Delta\dot{V}_x + a_x^{Vx}\Delta V_x + a_x^{Vz}\Delta V_z + a_x^{Vy}\Delta V_y + a_x^{\omega x}\Delta\omega_x + a_x^{\omega z}\Delta\omega_z + a_x^{\vartheta}\Delta\vartheta =$$

$$= a_x^{\delta_{\text{lon.pl}}}\Delta\delta_{\text{lon.pl}} + a_x^{\delta_{\text{lat.pl}}}\Delta\delta_{\text{lat.pl}} + a_x^{\delta_{\text{lif.r}}}\Delta\delta_{\text{lif.r}};$$

$$\Delta\dot{V}_y + a_y^{\omega z}\Delta\omega_z + a_y^{Vy}\Delta V_y + a_y^{Vx}\Delta V_x + a_y^{\Omega}\Delta\Omega =$$

$$= a_y^{\delta_{\text{lon.pl}}}\Delta\delta_{\text{lon.pl}} + a_y^{\delta_{\text{lat.pl}}}\Delta\delta_{\text{lat.pl}} + a_y^{\delta_{\text{lif.r}}}\Delta\delta_{\text{lif.r}};$$

$$\Delta\dot{\Omega} + a_m^{\Omega}\Delta\Omega + a_m^{Vy}\Delta V_y = a_m^{\delta_{\text{thr}}}\Delta\delta_{\text{thr}} + a_m^{\delta_{\text{lif.r}}}\Delta\delta_{\text{lif.r}};$$

$$\Delta\dot{\gamma} - \Delta\omega_x = 0;\ \Delta\dot{\psi} - \Delta\omega_y = 0;\ \Delta\dot{\vartheta} - \Delta\omega_z = 0;$$

$$\Delta\dot{x} - \Delta V_x + a_{\dot{x}}^{\vartheta}\Delta\vartheta = 0;\ \ \Delta\dot{y} - \Delta V_y + a_{\dot{y}}^{\vartheta}\Delta\vartheta;$$

$$\Delta\dot{z} - \Delta V_z = 0,$$

where δ_{thr} is the deviation of throttle handle; $\delta_{\text{ant.r}}$ is the deviation of anti-torque rotor; M_{r} is the reactive moment of main lift rotor; $\delta_{\text{lif.r}}$ is the deviation of main lifting rotor; $\delta_{\text{lat.pl}}$ is the lateral deviation of wobble plate (collective and cyclic pitch control mechanism); $\delta_{\text{lon.pl}}$ is the longitudinal deviation of wobble plate; ω_x, ω_y, ω_z are angular velocities about body axes of the helicopter; Ω is rotary speed of main lift rotor; V_x, V_y, V_z are speed components along body axes of the helicopter; ϑ, γ, ψ are angles of pitch, roll and course; x, y, z are center of mass displacement; $a_{my}^{\omega y} \ldots a_{\dot{y}}^{\vartheta}$ coefficients of mathematical models.

This model makes it possible to solve the problem of decoupling of control effects for longitudinal and lateral motion, in particular, to separate the control of the yaw motion and control of the generic pitch of main lifting rotor, but for the problems of synthesis of cross-connection contours for an isolated longitudinal or lateral motion it is very difficult.

Therefore, for a helicopter, the study of some flight modes, including the synthesis of cross-connection contours, is usually performed on the basis of isolated models of lateral and longitudinal motion, from which it is possible to separate the vertical velocity channel, longitudinal and lateral channels, and yaw channel.

For example, the cross-effect of vertical velocity channels and the longitudinal translational and angular motion of a helicopter can be investigated using the linearized equations [1].

$$\Delta\dot{V}_y + a_y^{V_y}\Delta V_y + a_y^{\Omega}\Delta\Omega + a_y^{V_x}\Delta V_x + a_y^{\omega_z}\Delta\omega_z = a_y^{\delta_{\text{lon.pl}}}\Delta\delta_{\text{lon.pl}} + a_y^{\delta_{\text{lif.r}}}\Delta\delta_{\text{lif.r}};$$

$$\Delta\dot{\Omega} + a_{\Omega}^{V_y}\Delta V_y + a_{\Omega}^{\Omega}\Delta\Omega = a_m^{\delta_{\text{thr}}}\Delta\delta_{\text{thr}} + a_m^{\delta_{\text{lif.r}}}\Delta\delta_{\text{lif.r}};$$

$$\Delta\dot{V}_x + a_x^{V_y}\Delta V_y + a_x^{V_x}\Delta V_x + a_x^{\omega_z}\Delta\omega_z + a_x^{\vartheta}\Delta\vartheta = a_x^{\delta_{\text{lon.pl}}}\Delta\delta_{\text{lon.pl}} + a_x^{\delta_{\text{lif.r}}}\Delta\delta_{\text{lif.r}};$$

$$\Delta\dot{\omega}_z + a_{m_z}^{V_y}\Delta V_y + a_{m_z}^{V_x}\Delta V_x + a_{m_z}^{\omega_z}\Delta\omega_z = a_{m_z}^{\delta_{\text{lon.pl}}}\Delta\delta_{\text{lon.pl}} + a_{m_z}^{\delta_{\text{lif.r}}}\Delta\delta_{\text{lif.r}};$$

$$\Delta\dot{\vartheta} - \Delta\omega_z = 0;\ \Delta\dot{x} - \Delta V_x + a_{\dot{x}}^{\vartheta}\Delta\vartheta = 0;\ \ \Delta\dot{y} - \Delta V_y + a_{\dot{y}}^{\vartheta}\Delta\vartheta,$$

If the helicopter has a system for stabilizing the speed of rotation of the main lifting rotor Ω, then the second equation of the system can be neglected in this system of equations, and the component $a_y^{\Omega}\Delta\Omega$ can be excluded from the first equation.

The procedure for the synthesis of circuits for compensation of cross-connection involves a preliminary analysis of the usefulness and harmfulness of these links.

In particular, the influence of changes in airspeed V_x and vertical speed V_y on the pitch stabilization loop is undesirable; on the other hand, a change in airspeed V_x must affect vertical speed and therefore cannot be compensated for. For example, an increase in airspeed naturally causes an increase in vertical speed, sometimes it is used in piloting techniques.

The interference of the stabilization contours of the vertical velocity and pitch angle is determined by a system of equations in which the influence of the component ΔV_x, as well as the deviation of wobble plate $\Delta\delta_{\text{lon.pl}}$ in the vertical velocity channel and the deviation of the generic pitch of main lifting rotor $\Delta\delta_{\text{lif.r}}$ in the channel of pitch angle will be considered as disturbance.

$$\begin{aligned}
&\Delta\dot{V}_y + a_y^{V_y}\Delta V_y + a_y^{\omega_z}\Delta\omega_z = a_y^{\delta_{\text{lif.r}}}\Delta\delta_{\text{lif.r}} + (a_y^{\delta_{\text{lon.pl}}}\Delta\delta_{\text{lon.pl}} - a_y^{V_x}\Delta V_x);\\
&\Delta\dot{\omega}_z + a_{m_z}^{V_y}\Delta V_y + a_{m_z}^{\omega_z}\Delta\omega_z = a_{m_z}^{\delta_{\text{lon.pl}}}\Delta\delta_{\text{lon.pl}} + (a_{m_z}^{\delta_{\text{lif.r}}}\Delta\delta_{\text{lif.r}} - a_{m_z}^{V_x}\Delta V_x).
\end{aligned} \tag{1}$$

The system of equations (1) is written in matrix form,

$$\dot{\mathbf{x}} = \mathbf{Ax} + \mathbf{Mc} + \mathbf{f}\ , \tag{2}$$

where $\mathbf{x} = (\Delta V_y \quad \Delta\omega_z)^{\text{T}}$; $\mathbf{c} = (\Delta\delta_{\text{lif.r}} \quad \Delta\delta_{\text{lon.pl}})^{\text{T}}$; $\mathbf{f} = \begin{bmatrix} a_y^{\delta_{\text{lon.pl}}}\Delta\delta_{\text{lon.pl}} & a_{m_z}^{\delta_{\text{lif.r}}}\Delta\delta_{\text{lif.r}} \\ -a_y^{V_x}\Delta V_x & -a_{m_z}^{V_x}\Delta V_x \end{bmatrix}^{\text{T}}$;

$$\mathbf{M} = \begin{bmatrix} a_y^{\delta_{\text{lif.r}}} & 0 \\ 0 & a_{m_z}^{\delta_{\text{lon.pl}}} \end{bmatrix}^{\text{T}}; \qquad \mathbf{A} = \begin{bmatrix} -a_y^{V_y} & -a_y^{\omega_z} \\ -a_{m_z}^{V_y} & -a_{m_z}^{\omega_z} \end{bmatrix}.$$

It is necessary to synthesize such control **c**, in which a closed system is described by a matrix equation

$$\dot{\mathbf{x}} = \mathbf{Bx} + \mathbf{Nu} + \mathbf{f}, \tag{3}$$

where $\mathbf{B} = \begin{bmatrix} -b_{11} & 0 \\ 0 & -b_{22} \end{bmatrix}$; $\mathbf{N} = \begin{bmatrix} b_{11} & 0 \\ 0 & b_{22} \end{bmatrix}^{\text{T}}$; $\mathbf{u} = \begin{bmatrix} \Delta V_y & \Delta\omega_z \end{bmatrix}^{\text{T}}$.

In matrices **B** and **N**, the elements b_{11}, b_{22} are the quantities which inversely proportional to the time constant of autonomous aperiodic processes in the control contours of the vertical velocity and the rate of change of the pitch angle, respectively.

These coefficients can be selected from the conditions $t_{pVy} = 3/b_{11}$; $t_{p\omega_z} = 3/b_{22}$, where $t_{pVy} \approx 5...10$ c is control time in the vertical speed control loop; $t_{p\omega_z} \approx 3...6$ c – control time in the control loop of the angular velocity of the pitch.

Equating the right-hand sides of equations (2), (3), we obtain the relation

$$\mathbf{Ax} + \mathbf{Mc} = \mathbf{Bx} + \mathbf{Nu}\ . \tag{4}$$

Matrix equation (4) has a solution

$$\mathbf{c} = \mathbf{M}^{+}\left[\left(\mathbf{B} - \mathbf{A}\right)\mathbf{x} + \mathbf{Nu}\right]\ . \tag{5}$$

Here $\mathbf{M}^{+} = \left(\mathbf{M}^{\mathbf{T}}\mathbf{M}\right)^{-\mathbf{1}}\mathbf{M}^{\mathbf{T}}$ – pseudoinverse matrix.

Calculating this matrix, where

$$\mathbf{M}^{\text{T}}\mathbf{M} = \begin{bmatrix} a_y^{\delta_{\text{lif.r}}} & 0 \\ 0 & a_{m_z}^{\delta_{\text{lon.pl}}} \end{bmatrix} \begin{bmatrix} a_y^{\delta_{\text{lif.r}}} & 0 \\ 0 & a_{m_z}^{\delta_{\text{lon.pl}}} \end{bmatrix} = \begin{bmatrix} (a_y^{\delta_{\text{lif.r}}})^2 & 0 \\ 0 & (a_{m_z}^{\delta_{\text{lon.pl}}})^2 \end{bmatrix};$$

$$\mathbf{M}^{+}=\left(\mathbf{M}^{\mathrm{T}}\mathbf{M}\right)^{-1}\mathbf{M}^{\mathrm{T}}=\begin{bmatrix}\dfrac{1}{(a_y^{\delta_{\text{lif.r}}})^2} & 0\\ 0 & \dfrac{1}{(a_{m_z}^{\delta_{\text{lon.pl}}})^2}\end{bmatrix}\begin{bmatrix}a_y^{\delta_{\text{lif.r}}} & 0\\ 0 & a_{m_z}^{\delta_{\text{lon.pl}}}\end{bmatrix}=\begin{bmatrix}\dfrac{1}{a_y^{\delta_{\text{lif.r}}}} & 0\\ 0 & \dfrac{1}{a_{m_z}^{\delta_{\text{lon.pl}}}}\end{bmatrix}, \quad (6)$$

and substituting the corresponding values from relations (2), (3), (6) into solution (5) after certain operations on matrices, we obtain the control laws:

$$\begin{aligned}\delta_{\text{lon.pl}} &= (a_{m_z}^{\delta_{\text{lon.pl}}})^{-1}\left[a_{m_z}^{V_y}\Delta V_y+(a_{m_z}^{\omega_z}-b_{22})\Delta\omega_z+b_{22}\Delta\omega_{z_3}\right];\\ \delta_{\text{lif.r}} &= (a_y^{\delta_{\text{lif.r}}})^{-1}\left[(a_y^{V_y}-b_{11})\Delta V_y+a_y^{\omega_z}\Delta\omega_z+b_{11}\Delta V_{y_3}\right].\end{aligned} \quad (7)$$

It is possible to compensate the influence of V_x on the pitch angle stabilization loop and on the vertical speed loop by additional components of the control laws:

$$\delta_{\text{lon.pl}}=-a_{m_z}^{V_x}(a_{m_z}^{\delta_{\text{lon.pl}}})^{-1}\Delta V_x;\quad \delta_{\text{lif.r}}=-a_y^{V_x}(a_y^{\delta_{\text{lif.r}}})^{-1}\Delta V_x. \quad (8)$$

Cross-effect of control actions (the influence of a change of the generic pitch of main lifting rotor on the channel of wobble plate and the influence of the deviation of wobble plate on the channel of the generic pitch of main lifting rotor), which were considered as disturbances in the synthesis of control loops, are compensated by the components of the control laws:

$$\delta_{\text{lon.pl}}=-a_{m_z}^{\delta_{\text{lif.r}}}(a_{m_z}^{\delta_{\text{lon.pl}}})^{-1}\Delta\delta_{\text{lif.r}};\qquad \delta_{\text{lif.r}}=-a_y^{\delta_{\text{lon.pl}}}(a_y^{\delta_{\text{lif.r}}})^{-1}\Delta\delta_{\text{lon.pl}}. \quad (9)$$

The greatest difficulties in the implementation of such relationships lie in the inaccurate knowledge of the coefficients of the mathematical model of the helicopter, as well as the dependence of these coefficients on the flight mode. A radical solution to this problem is the application of procedures for the identification of a mathematical model of a helicopter in flight with the subsequent use of the coefficients obtained in the identification process in the control laws. Another approach involves the use of passive self-tuning of coefficients in the contours of cross-links, for example, depending on altitude and flight speed. But all this complicates the hardware implementation of the automatic helicopter control system. Therefore, it is proposed to exercise the decoupling of control actions only in a dynamic mode, by including in the circuits of cross-links isodromic elements.

In this case, the generalized control laws of joint control of the helicopter will have the form:

$$\delta_{\text{lon.pl}}=\delta_{\text{lon.pl}}^{\text{pil}}+\delta_{\text{lon.pl}}^{\text{aut}};\qquad \delta_{\text{lif.r}}=\delta_{\text{lif.r}}^{\text{pil}}+\delta_{\text{lif.r}}^{\text{aut}};$$

$$\begin{aligned}\delta_{\text{lon.pl}}^{\text{aut}} &= \frac{T_{\text{lon.pl}}p}{a_{m_z}^{\delta_{\text{lon.pl}}}(T_{\text{lon.pl}}p+1)}\left[a_{m_z}^{V_y}\Delta V_y+a_{m_z}^{\delta_{\text{lif.r}}}\Delta\delta_{\text{lif.r}}+a_{m_z}^{V_x}\Delta V_x+\left(a_{m_z}^{\omega_z}-b_{22}\right)\Delta\omega_z\right];\\ \delta_{\text{lif.r}}^{\text{aut}} &= \frac{T_{\text{lif.r}}p}{a_y^{\delta_{\text{lif.r}}}(T_{\text{lif.r}}p+1)}\left[\left(a_y^{V_y}-b_{11}\right)\Delta V_y+a_y^{\delta_{\text{lon.pl}}}\Delta\delta_{\text{lon.pl}}+a_y^{V_x}\Delta V_x+a_y^{\omega_z}\Delta\omega_z\right],\end{aligned} \quad (10)$$

where $\delta_{\text{lif.r}}^{\text{pil}}$, $\delta_{\text{lon.pl}}^{\text{pil}}$ are deviations of the generic pitch of the main lifting rotor and the wobble plate by the pilot; $\delta_{\text{lif.r}}^{\text{aut}}$, $\delta_{\text{lon.pl}}^{\text{aut}}$ are deviations by automatic control of the generic pitch of the main lifting rotor and the wobble plate.

The block diagram of control loops of the generic pitch of the main lifting rotor and the wobble plate, which implements the control laws (8)… (10), is shown in Fig. 2.

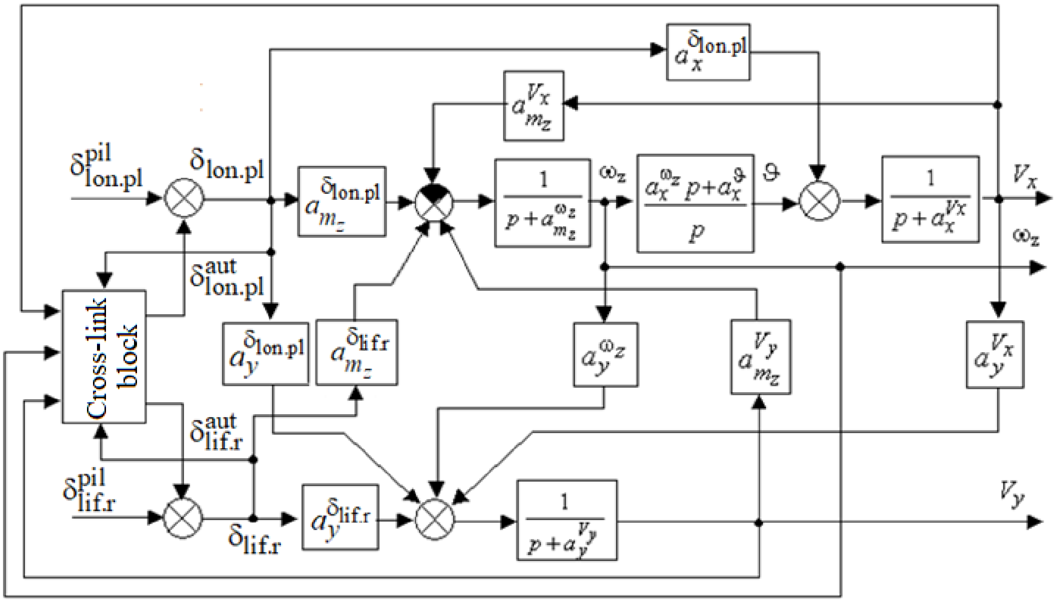


Figure 2. The block diagram of control loops of the generic pitch of the main lifting rotor and the wobble plate with cross-link compensator.

The research of the active control system of the helicopter was carried out in the Simulink graphical environment on a complete mathematical model of the longitudinal motion of the helicopter with variations of the models of synthesized control loops. The oscillogram in Fig. 3 shows changes in the pitch angle and flight speed of the helicopter in response to a stepped deflection of the wobble plate control lever. In the presence of cross-link compensation loops, an almost linear dependence of the angular velocity   of the pitch on the control action is observed, and vice versa, in the absence of cross-link this dependence exists only at the beginning of the control action followed by a transition to oscillatory instability.

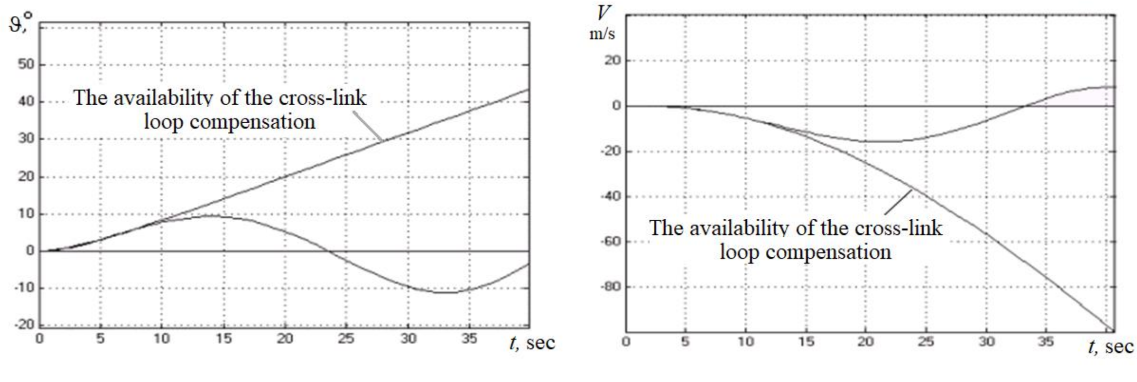
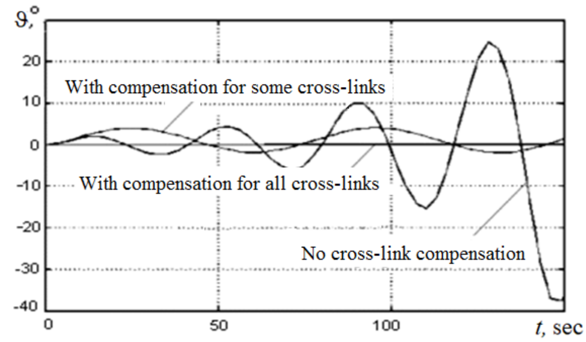


Figure 3. Reaction of the helicopter in the pitch angle and airspeed to the deflection of wobble plate

The effect of individual cross-links from the vertical velocity channel to the pitch angle channel was also investigated. The research results are presented in the oscillogram in Figure 4.



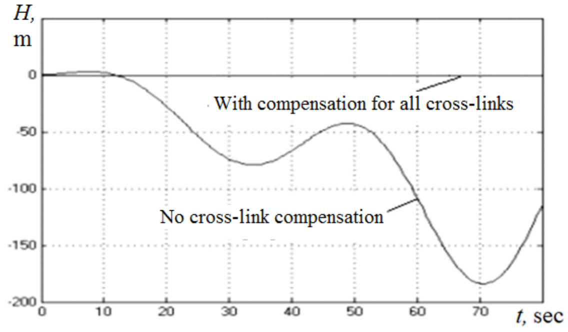


Figure 4. Reaction of the helicopter in the pitch to the deflection of of the generic pitch of the main lifting rotor

Figure 5. Reaction in the altitude to the deflection of of the generic pitch of the main lifting rotor

Here we analyzed the response of the pitch angle of the helicopter in response to a step change of generic pitch of the main lifting rotor. Studies show that if the control law to take stock of complete list of cross-links, when the generic pitch of the main lifting rotor changes autonomous vertical speed control is provided, ie without changing the pitch angle. The oscillogram in Fig. 5 shows how the step change of the swashplate, which changes the pitch angle and flight speed, affects the change in flight altitude.

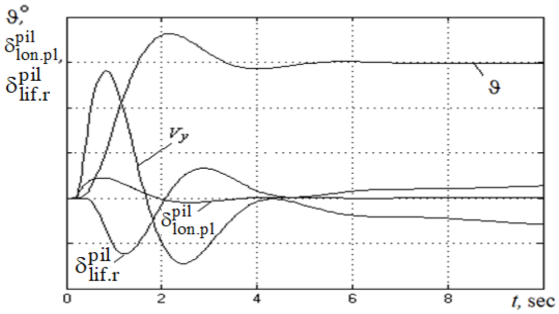
To analyze the operating conditions of the pilot in the automated control loop, a mathematical model was used, which reflects the properties of the pilot during compensating tracking in the frequency range of the input signal change (0,3 ... 0,4) Hz.

In the general case, this model is nonlinear, nonstationary, and even discrete. However, as a first approximation, we can amount ourselves to a continuous stationary linear model connecting the input signal (control error) ε and the pilot response in the form of a control lever deflection x_{pil}. Such model of a pilot can be represented as a transfer function:

$$W_{\text{pil}}(p) = \frac{x_{\text{pil}}(p)}{\varepsilon\,(p)} = \frac{K_{\text{pil}}\left(T_2 p + 1\right)\, e^{-\tau\, p}}{\left(T_3 p + 1\right)\left(T_1 p + 1\right)},$$

where K_{pil} is the conversion coefficient by the pilot of the input signal in the deflection of the control lever; τ is the delay time; T_1, T_2, T_3, are time constants of the pilot's mathematical model components.

The performance of the pilot in the automated control loop was investigated in the hover mode with a change in the desired pitch angle and with simultaneous stabilization of the flight altitude. During the research, deviations of the control levers of the generic pitch of the main lifting rotor $\delta_{\text{lif.r}}^{\text{pil}}$ and the swashplate $\delta_{\text{lon.pl}}^{\text{pil}}$ by the pilot were registered. The results of investigation are presented on the oscillograms of fig. 6, 7.



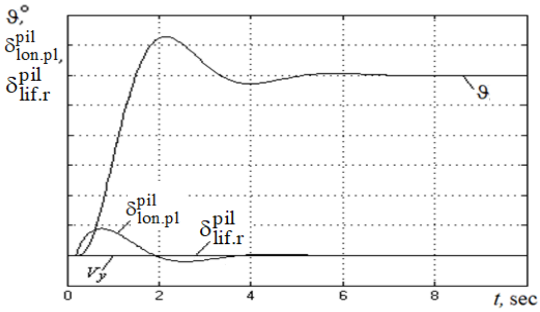


Figure 6. Changing by the pilot the desired pitch angle in manual control mode.

Figure 7. Changing by the pilot the desired pitch angle in the joint control mode.

Analysis graphs of the transient processes shows that with traditional manual control, the pilot when deflected the swashplate to change the pitch angle, at the same time, must parry the effect of cross-links by deflecting the generic pitch of the main lifting rotor. In the proposed loop of automated control, the pilot's work is reduced to the control of isolated aperiodic links, because the mutual influence of the contours of the stabilization of the vertical speed and pitch angle is compensated by automation.

Conclusions

The proposed system of active control of the helicopter with compensation of interrelations between lateral and longitudinal movement, and also between angular movements and movement of the center of mass cardinally changes conditions of work of the pilot in a control contour. The work of the pilot in the synthesized loop of automated control is greatly facilitated and is reduced to the control of isolated aperiodic links.

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