THE USE OF PILOT TRANSMISSION FUNCTION FOR AIRPLANE CONTROL DURING THE PROCESS OF AIMING

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***Abstract**: This paper articulates the utilization of pilot transmission function for airplane control during the process of aiming. It identifies the amplification coefficients of transmission function using criteria of minimum time for discordance signals elimination.*

***Keywords**: aiming, airplane control, transmission function, discordance.*

1. INTRODUCTION

The aiming head-up display receives a signal, which forms the required angular coordinates of target β_1 and ε_1. The required coordinates of the target are compared with the observed coordinates of the target $\beta_{1т}$ and $\varepsilon_{1т}$.

The pilot registers the difference $\beta_1 - \beta_{1т}$, $\varepsilon_1 - \varepsilon_{1т}$ and tries to eliminate it, using the control surfaces of the aircraft. The aircraft, responding to the deflection of the control surfaces changes the parameters of its attitude in relation to the target. When the discordance absolute value becomes lower than the accepted permissive deviation, the pilot maintains the deviation differences within the admissible limits.

In order to get a model of the above - described process, the response of the pilot to the discordance has to be modelled, i.e. to get the calculated values of the aircraft control surfaces deflection depending on the angles of discordance.

$$\begin{aligned} \delta_{ви} &= \delta_{ви}(\varepsilon_1 - \varepsilon_{1т}) \\ \delta_{еи} &= \delta_{еи}(\beta_1 - \beta_{1т}) \end{aligned} \tag{1}$$

Where $\delta_{ви}$, $\delta_{еи}$ are the calculated values of the rudder and aileron deflection ($\delta_н = 0$).

The task of the pilot as a managing component of the closed pilot-aircraft system consists of the following stages:

- to receive and interpret the information, provided by the instruments and the environment;
- to process the information and decide on the corresponding managing action to control the aircraft;
- to apply the managing action to the control surfaces of the aircraft.

The mechanism of the aircraft control with the participation of the pilot functions on the principles of “tracking with pursuit “or “tracking with compensation” [1].

In the pilot-aircraft system based on the principle of “tracking with pursuit”, the pilot observes the value of the input and output signals of the system and his task are to minimize the discordance between the target position and the blip following it. In order to get an adequate description of the pilot’s work, his transmitting function or other mathematical description should reflect the main characteristics as a component of the control system. The most important of these are:

- temporary delay of the pilot’s response to the input signal;
- ability to adjust to the dynamic characteristics of the controlled object and the nature of the input influence;
- ability to respond to the parameter deflection of the assigned value, its derivative and the parameter deflection integral;

- ability to increase the value of the control impact;
- non-linear characteristics of the pilot;
- acting as a multi-channel device in the control system (the information which he receives can be processed separately or integrally);
- dependence of the quality of the pilot's control on his psychodynamic characteristics and potential.

2. LINEAR AND NON-LINEAR PILOT OPERATOR MODELS

There are different models (linear and non-linear) which are used to describe the pilot's performance and they include the abovementioned characteristics. Linear models, considered to be the most convenient from engineering point of view, have been extensively developed and are widely used. However, they have some disadvantages:

- they don't take into account the ability of the pilot to anticipate the process;
- they cannot interpret experimental data, so the pilot operator tends to behave discretely.

Some non-linear pilot-operator models are known to be based on the psycho-physiological analysis of the pilot's reactions. In a linear pilot-operator model based on "tracking with pursuit", pilot is represented as a section of the tracking system and it is possible to be described with transmitting function. It is suggested that the transmitting function of all pilots has the same structure and their individual features are read from the transmitting function coefficients values. The pilot model describes the real pilot's characteristics with approximation.

To receive the estimated values of the airplane control surfaces in dependence with the discordance angles:

$$\delta_{ви} = \delta_{ви}(\varepsilon_1 - \varepsilon_{1т}),\ \ \delta_{еи} = \delta_{еи}(\beta_1 - \beta_{1т})$$

The following pilot's transmitting function is used [2]:

$$W_л(p) = \frac{K_0 e^{-\tau p}(T_1 p + 1)K_1}{(T_2 p + 1)(T_3 p + 1)} \qquad (2)$$

where

- τ is the time characterizing the delay of the input signal;
- K_0 – coefficient of pilot increase;
- T_1 – constant coefficient characterizing the ability of the pilot to differentiate and react to the speed of input signal change;
- T_2 – constant coefficient of inertia section of the pilot;
- T_3 – constant coefficient identifying the nerve-shoulder response;
- K_1 – coefficient of increasing the nerve-shoulder unit.

The structural scheme of the pilot transmitting function is on Fig. 1:

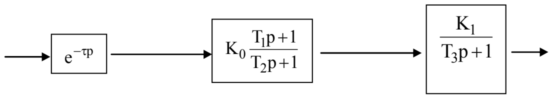

Fig. 1 Structural scheme of the pilot transmitting function

The first section of the chart is the amplifying section with delay. Here the calculated information from the indicators is received. And the signals in proportions based on dynamic characteristics are added. The second section is a calculating element processing amplification and differentiation of the received signals. That element has the feature to amplify the signal. The third section is inertial and it uses its dynamic features. It reflects the neuro-muscular effect on the managed object.

The experiments [3] show that the operator changes his transmission characteristics in dependence with the managed object features and the disturbance function. The experience, training and fatigue are factors with an influence on the type of the transmitting characteristics, therefore the operator does not possess one defined transmitting function and he is able to tune his work up in relation with what the function is.

The experiment results show the pilot changes his transmitting characteristics in dependence with managed object features and the type of disturbance. That means that the pilot is able to tune himself up according to the concrete task.

For identified task circle and concrete airplane the increasing coefficients values K_0

and K_1 and constant coefficients T_1, T_2, T_3 and τ change in particular narrow limits.

The pilot transmission function is used to receive the estimating angles of ventral surfaces deflection, when the discordance signals proceed to the input (Fig.2).

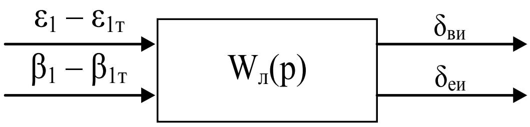

Fig. 2 The pilot transmission function

If use the Taylor decomposition limited with first two terms

$$e^{-\tau p} = 1 - \tau p \tag{3}$$

and introducing the symbols:

$$\begin{aligned} \varepsilon_1 - \varepsilon_{1т} &= \varepsilon_{11} \\ \beta_1 - \beta_{1т} &= \beta_{11} \end{aligned} \tag{4}$$

We receive:

$$\frac{\delta_{ви}}{\varepsilon_{11}} = -\frac{K_{с.в}(T_1 p + 1)(1 - \tau p)}{(T_2 p + 1)(T_3 p + 1)} \tag{5}$$

$$\frac{\delta_{ве}}{\beta_{11}} = \frac{K_{с.е}(T_1 p + 1)(1 - \tau p)}{(T_2 p + 1)(T_3 p + 1)} \tag{6}$$

where $K_c = K_0 K_1$ is general coefficient of amplification.

As the value of T_1 is greater the process of airplane control from pilot's point of view becomes more difficult. Additionally, the requested amplification of T_1 requires greater accuracy in terms of identification of rate of change of input signal.

If the pilot possesses sufficient professional skills the transition process ends faster if the following values of τ, T_1, T_2, T_3 [4] have been accepted:

$$\tau = 0{,}1s;\ T_1 = 0{,}1s;\ T_2 = 0{,}1s;\ T_3 = 0{,}1s \tag{7}$$

The formulas (5), (6) and (7) lead to the following differential equations determining the longitudinal and lateral control channels:

$$\ddot{\delta}_{ви} + 20\dot{\delta}_{ви} + 100\delta_{ви} = -\ddot{\varepsilon}_{11}K_{св} + 100\varepsilon_{11}K_{св} \tag{8}$$

$$\ddot{\delta}_{еи} + 20\dot{\delta}_{еи} + 100\delta_{еи} = \ddot{\beta}_{11}K_{се} - 100\beta_{11}K_{се} \tag{9}$$

After introducing the symbol:

$$z_1 = \dot{\delta}_{ви} + 20\delta_{ви} + K_{св}\dot{\varepsilon}_{11} \tag{10}$$

After differentiation the result is:

$$\dot{z}_1 = \ddot{\delta}_{ви} + 20\dot{\delta}_{ви} + K_{св}\ddot{\varepsilon}_{11} \tag{11}$$

Then from equation (8):

$$\dot{z}_1 = 100K_{св}\varepsilon_{11} - 100\delta_{ви} \tag{12}$$

And introducing the symbol:

$$\dot{z}_2 = \dot{\delta}_{ви} + K_{св}\dot{\varepsilon}_{11} \tag{13}$$

From equation (10) the result is:

$$\dot{z}_2 = z_1 - 20\delta_{ви} \tag{14}$$

From formula (13) we receive:

$$\dot{\delta}_{ви} = \dot{z}_2 - K_{св}\dot{\varepsilon}_{11} \tag{15}$$

After integration using nil initial conditions:

$$\delta_{ви} = z_2 - K_{св}\varepsilon_{11} \tag{16}$$

At the end from equation (8) the system is received:

$$\begin{aligned} \delta_{ви} &= z_2 - K_{св}\varepsilon_{11} \\ \dot{z}_2 &= z_1 - 20\delta_{ви} \\ \dot{z}_1 &= 100K_{св}\varepsilon_{11} - 100\delta_{ви} \end{aligned} \tag{17}$$

From (9) by analogy:

$$\begin{aligned} \delta_{еи} &= z_4 + K_{се}\beta_{11} \\ \dot{z}_4 &= z_3 - 20\delta_{еи} \\ \dot{z}_3 &= -100K_{се}\beta_{11} - 100\delta_{еи} \end{aligned} \tag{18}$$

Using equations (17) and (18) the angles of altitude controlling surface and ailerons deflection can be determined in dependence with discordance angles β_{11}, ε_{11} in the lateral and longitudinal channels. To comply with that target it is necessary to determine general coefficients of amplification in the abovementioned equations systems for both channels using criteria of minimum time for discordance signals elimination.

In result from the integration of those equations angles needed for airplane control are determined:

$$\delta_в = \delta_{ви} + \delta_{в.бал};\ \delta_е = \delta_{еи} \tag{19}$$

where $\delta_{ви}$, $\delta_{еи}$ are values of altitude control surface angle estimated using the pilot transmission function, $\delta_{в.бал}$ – balanced value of altitude control surface angle.

For the purpose of discordance signals that tend to zero $\varepsilon_1 - \varepsilon_{1T}$, $\beta - \beta_{1T}$, there is a need to determine amplification coefficients Kсв, Kсе. The studies are accomplished separately for longitudinal and literal channels and for both channels simultaneously.

The process modeling is accomplished with initial air speeds $V_{1,0} = 160, 240, 320$m/s; initial altitudes $H_0 = 600, 1100, 1600, 2100$m and initial angles of descent:

$\lambda_0 = -10^0, -30^0, -50^0$.

3. CONCLUSIONS

From research done in mathematical modelling of airplane track and vertical profile in the stage of descent when the transmitting function is used the following conclusions can be made:

1. The amplification coefficient $K_{св}$ of the pilot model for longitudinal channel depends on the airplane speed;
2. The airplane trajectory is influenced by aiming error that depends on amplification coefficient $K_{св}$;
3. The amplification coefficients $K_{св}$, $K_{се}$ and time constants T_1, T_2, T_3 and τ are determined experimentally when the pilot model is used with the model of concrete airplane. The determined transmission function characterizes pilot actions only for concrete airplane and when the required conditions are met [2].

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