ANALYSIS OF UNMANNED AERIAL VEHICLE CONTROL SYSTEM

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Abstract. The principles of construction and comparative evaluation of control systems unmanned aerial vehicle is considered.

Keywords: control system; command forming device; operator; line transmission command; stiffness, damping.

Introduction

Interest that is shown to the unmanned aerial vehicles (UAV), is completely obvious. Different industries of application pay attention them. Thus the basic task of developers of UAV is providing of quality of controlling an object.

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Control systems, based on their level of automation can be manual or semi-automatic. In the manual system the operator is located in the contour of UAV controlling. He assesses the UAV position at the route and through the CFD forms controlling commands. The last is passed for LTC on the unmanned aerial vehicle, providing its flight on the set trajectory.

In semi-automatic systems (fig. 1, b) an operator is excluded from the control circuit. Its main task is forming of the route line (RL). And UAV controlling takes place automatically. Thus CFD controls position of UAV enroute and forms controlling commands.

That or other type of control system is used depending on tasks, fixed on UAV. Researching of basic indexes of control systems quality allows to hold their comparative estimation and produce recommendations, directed on UAV effective application.

Solution of problem

Structure schemes of semi-automatic control systems are presented in fig. 2. Unmanned aerial vehicles as control object is described by the transfer function $W_0(s) = \frac{k_0}{sT_0s + 1}$. An input signal is the angle $\psi_g$ of the reference track (course angle), which sets by the operator, output – the angle $\psi_o$ of UAV course. In general, at the control object is influenced by the disturbance moment $M_{\Sigma}s$.

![Fig. 2. Block diagrams of semi-automatic control system: a – single-circuit; b – double-circuit](image)
The analysis of variant implementation of the control systems shows that they are the position systems of automatic control on the UAV inconsistency angle in relation to the direction set by operator. Thus the moment $M_s$, of UAV stabilizing can be formed both on one and on two channels.

At single-circuit system implementation (fig. 2, a) a stabilizing moment is formed on the sensor channel of angular rejection of management object.

$$M_s = M_g + M_d = k_G G_m,$$

where $G_m$ – structural inflexibility of control systems, which depends on the constant transmission coefficients of elements input into it: $0 \leq k_G \leq 1$ – coefficient of inflexibility regulation.

At the double-circuit variant of stabilizing moment forming, it provides sensor channels of an angular rejection and speed sensor of an angular rejection of management object

$$M_s = M_g + M_d = k_G G_m + k_D D_m,$$

where $D_m$ – structural control system damping; $0 \leq k_D \leq 1$ – damping regulation coefficient.

The system’s block diagram with separated channels of moment forming is resulted on fig. 2, b. The area of control system stability [1; 2] in parameters $k_D D_m - k_G G_m$ has the form, shown on fig. 3. It limits the possible values of the stiffness and damping of the system.

![Fig. 3. Area of control system stability](image)

As in the single-circuit systems $k_D D_m = 0$, they are stable only at the small values of stiffness $0 - k_{1g} G_m$, which correspond to a damping the UAV by friction $f_0$. Thus the single-circuit systems can provide necessary quality of management completely. The dynamics change of single-circuit system surge characteristic at the inflexibility values increasing $k_G G_m = 0,01 G_m; 0,05 G_m; 0,068 G_m$ is presented on fig. 4.

![Fig. 4. Surge characteristics of single-circuit control system: $a - k_G G_m = 0,01 G_m; b - k_G G_m = 0,05 G_m; c - k_G G_m = 0,068 G_m$](image)

Presence of the speed sensor of the angular management object rejection at the dual-channel system extends the area of it’s stability, allowing to adjust the system on greater stiffness and as a result – to provide the higher exactness of UAV stabilizing. From the fig. 4 we can see that at the damping that is equal to $k_{1d} D_m$, maximum stiffness of the double-circuit system as compared to the single-circuit can be increased from $k_{1g} G_m$ to $k_{2g} G_m$.

Fig. 5 illustrates the change of surge process at introduction in the complement of the control system of the speed sensor circuit – the system which is on the firmness border at $k_G D_m = 0$ and $k_G G_m = 0,068 G_m$, becomes serviceable if damping $k_D D_m = 0,06 D_m$ is provided and former stiffness – $k_G G_m = 0,068 G_m$.

![Fig. 5. Surge characteristic of single-circuit (a) and double-circuit (b) systems: $a - 0 D_m \leftrightarrow 0,06 G_m; b - 0,06 D_m \leftrightarrow 0,068 G_m$](image)

The block diagram of hand control system is presented on the fig. 6. An operator in the UAV control circuit is presented in accordance with [3] by a transfer function

$$W_{op}(s) = \frac{e^{-\tau s}}{(T_s s + 1)^2}.$$

Sensorimotor of an operator determines it’s time constant $T_{op}$ and delay $\tau$ of the executive reaction.

Including of the operator in the UAV control circuit definitely influences on the system dynamics.
Transitional descriptions of the single-circuit semi-automatic and hand controlled systems at the equality of their stiffness’s $0.03G_{m}$ and mean values of operator parameters presented on the fig. 7 a, b. Comparison of descriptions is not obviously folded in behalf of the hand controlled system. It costs to search a principal reason in the selected parameters of an operator.

On the fig. 7, c is showed the surge characteristic of the single-circuit hand control system at the operator parameters that are higher than average. It is not difficult to notice that the system dynamics became better notedly. At the high preparation level of an operators, quality of hand UAV control systems can be maximally close to the semi-automatic systems quality.

**Conclusions**

Thus, going out from the tasks, fixed on UAV:

– semi-automatic and hand control system can be realized in practice;

– introduction in the complement of the controlling system of the adjusting channel for speeds of control object rejection is extended by the area of its stability, allowing by the same to provide higher exactness of controlling;

– at the estimation of UAV control system quality, their accordance’s to the requirements it is necessary to take into account not only the perfection of the systems construction, but ability and skills of an operator, level of his preparation and qualification.

**References**


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O. K. Ablesimov, K. V. Sarapina. Analysis of system control of unmanned aerial vehicles

A method is presented for the construction and comparative evaluation of the unmanned aerial vehicle control system.

Keywords: control system, operator, device for forming commands, command line, rigidity, damping.

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