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Stabilization system for UAV at low flight speeds

Angular stabilization system for UAV on base fans, which are build-in at wings or UAV planer. The results of modeling the work of such stabilization system in Mathlab is provided. To simulate the stabilization system, a UAV with parameters similar to those of the M-7 "Sky Patrol" UAV was chosen. Developed system may be used for decreasing runway of UAV.

One of the disadvantages of unmanned aerial vehicles (UAVs) with airplane type is that such UAVs, as a rule, have a fairly high stall speed [1]. The high speed of the UAVs stall limits the possibilities of their application and creates the preconditions for aviation accidents when entering flight modes at low speeds.

At providing of such type UAV stabilization at law speed expands range of their flight performance and there is a possibility of their landing on a runway of smaller size.

It is impotent also for UAV or aircraft with low thrust-to-weight ratio, i.e. in case when $\mu = P/G << 1$ (P is the thrust and G –is the UAV weight), to improve the safety of their flight at low speeds may be useful an additional special device for automatic stabilization of the UAV angular position.

The task of this work is to develop a stabilization system (SS) of the angular position of the UAV at low flight speeds and check functionality such system. To solve this task may by using application in UAV construction features so called "Hybrid drones" [2]. Hybrid versions combine the advantages of fixed wing models, such as longer flight times, with the advantages of propeller-based models (VTOL), such as the ability to hover. Hybrid aircraft designs have been designed since the 1960s, but have not been very successful. However, with the advent of a new generation of sensors (gyroscopes and accelerometers), the hybrid design has received a new life and development direction.

Constructively such propeller-based models are attached to the pylons under the wings of the UAV (or aircraft) or specially made holes on the wings of the aircraft and its fuselage as it's shown in Fig. 1.

As stabilizing power devices, it is proposed to use fans with low-power, in contrast to powerful (such fans can provide VTOL) ones, which, for example, are used in the design of the XV-5 Vertifan aircraft [3]. The structural placement of the three lifting fans of this aircraft next:

1) one of them is mounted in the fuselage forward part (Fig. 1.a);

2) two in the wings (Fig. 1.b).

Fans in this design played the role of not only lifting power units, but also load-bearing ones, moreover, the traction force was created at deviation of the air flow from the fan due to the control surfaces. Modern version of propeller-based models, consisting of four fans installed on UAV with aircraft type, are shown in Fig. 2.

a b

Fig. 1. Appearance of the XV-5 Vertifan aircraft [3]: a - on the runway, b - in the air

Let us modeling the work of the angular stabilization system on example of the UAV with characteristics similar to UAV M -7 «Sky Patrol". In this UAV the speed of flow disruption is $V_{st} \approx 27$ *m/s*.

Let control force F_B directed down as it is shown on Fig. 3 and the fan is installed along the longitudinal axis of the UAV. The controlling moment of forces created by one fans installed along the longitudinal axis of the UAV will be written in the form

$$M_B = F_B \times r_p, \quad (1)$$

where F_B is the force created by fan; r_p is the distance from the point of force application to the center of mass.

Fig. 2. Model of the designed hybrid UAV Airbus "Zelator-28" [2]

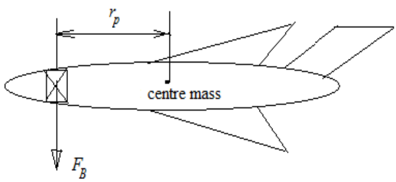


Fig. 3. Control force F_B

A linear model of longitudinal short-period motion in dimensionless form can be written [4]:

$$\dot{\Theta} + a_y^{\alpha}\alpha = f_y^{dis};$$

$$\dot{\omega}_z = a_{m_z}^{\alpha}\alpha + a_{m_z}^{\omega_z}\omega_z = a_{m_z}^{\delta_E}(\delta_B + \delta_B^f); \quad (2)$$
$$\dot{\alpha} - \omega_z - a_y^{\alpha}\alpha = \dot{\alpha}_W .$$

The system of equations (2) in our case it is necessary to correct due to the fact that these equations describe the movement of an aircraft controlled by aerodynamic rudders, but, at small speed of flight aerodynamic rudders are not effective. At small values $\dot{\Theta}$ and a_y^{α} first equation in system (2) can neglect and consider only second and third equations. In this case 2-nd equation describes the dynamics of the angular controlled motion of the UAV in the vertical plane and 3-rd equation it's the kinematics.

For the numerical solution of system (2), it is convenient to write its as

$$\dot{\vartheta} = \omega_z ;$$
$$\dot{\omega}_z = a_{m_z}^{\alpha}\alpha + a_{m_z}^{\omega_z}\omega_z + a_f \ , \quad (3)$$

where $a_f = M_z/I_z$ is dimensionless parameter, I_z is UAV moment of inertia.

The following initial data were selected for debugging the program:

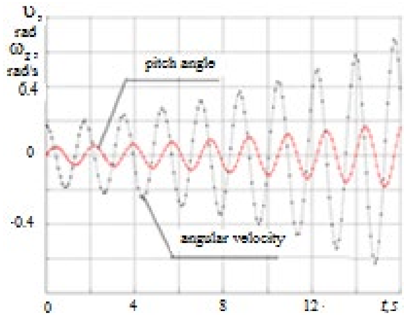
- UAV speed $V(t=0)$= 30 m/s,
- the angle of inclination of the velocity vector to the horizon $\theta_T=\theta(t=0)=0$,
- variants of the initial angular velocity: 1) $\omega_z(t=0) = \omega_{z0} = 0.174$ rad/s; 2) $\omega_{z0} = 0$,
- variants of the initial pitch angle: 1) $\vartheta(t=0)=\vartheta_0=0$; 2) $\vartheta_0=0.174$ rad,
- flight height $H(t=0) \approx 0$.

The distance from the point of application of the control force to the UAV center of mass (r_p) is assumed to be equal to half the fuselage length, i.e. r_p =2.85 m.

Modeling the work of such type stabilization system in Math lab is provided.

The results of the calculations of the angular motion of the UAV without taking into account the control force (without term a_f) are shown in Fig. 4. As it follows from the calculations, there is a gradual increase in the pitch angle of the UAV and its angular speed over the entire range of the considered time interval (16 s).

When closing the angular velocity feedback with account term a_f, the transient process, with a stepwise influence on the oscillatory system, fades out within 10 seconds (Fig. 5).



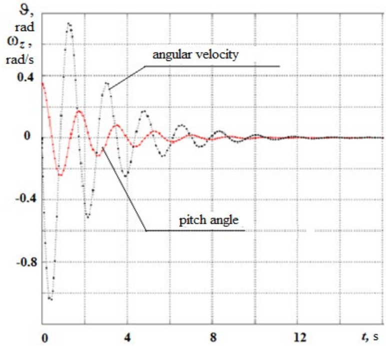


Fig. 4. Dependences of angle ϑ and angular velocity ω_z from time at F_B=0

Fig. 5. Dependences of angle ϑ and angular velocity ω_z from time at $F_B \neq 0$

So, such type stabilization system allows reduce the value of the UAV's the speed of flow disruption, as a result of which the aircraft will begin to plan, maintaining its angular position. Also distance of runway of UAV may decrease.

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