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TESTS OF ULTRALIGHT AND VERY LIGHT HELICOPTERS ON THE CRITICAL MODES

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Abstract

The purpose of the research was to create a simplified method of designing automatic control systems for unmanned helicopter tests on critical modes. Research methods included flight tests and mathematical modeling. The results showed that the developed methodology and equipment can be used for flight research of little helicopters.

Keywords: Coaxial helicopter, flight tests, automatic control system.

INTRODUCTION

The tests of helicopters allowing to define the limits of their applicability are complicated task with the risk of the pilot's life. In this regard, it is proposed to do design tests of ultralight and very light helicopter (ULH & VLH) in two phases. In the first phase to perform functional tests on hovering and forward flight speed less than 0,7 Vmax. In the second part of the tests to confirm the calculated limiting parameters of the aircraft – the maximum air speed, static ceiling, dynamic ceiling, verification of the recovery system and the definition of the fatigue capacity-processing of individual units.

Fig. 1. Coaxial ULH & VLH which appeared in recent years.
a – "Rotorfly" (Russia), b –"Flip-2" (Germany),

Fig. 1. Coaxial ULH & VLH which appeared in recent years.
c – "Berkut" (Russia), d – "Brat" (Belorussia-Russia)

The second phase is very dangerous for the pilot. Automatic control system (ACS) without human intervention may be used in order to eliminate this threat. It has become particularly urgent because coaxial ULH & VLH begin to appear, the blades of which can intersect in any flight modes (Fig. 1). Also, manufacturers try to use parachute recovery systems (Fig. 2). It is impossible to check this system with a pilot.

Fig. 2. Installing of parachute recovery system under the tail boom of ULH „Rotorfly" (a) and above the rotor hub of VLH AK1-5 (b)

The ACS of ULH & VLH is a very difficult system, primarily from the instability of this type of aircraft. According to it, the main problem of autopilot adapting to the ULH & VLH is the helicopter stabilization. Quick and safe creation of ACS is possible if it executes the synthesis of algorithms based on the identification of the helicopter flights.

This work can be divided into 3 stages:

- measurements of the dynamic performance of the helicopter and synthesis of the helicopter control algorithms,
- manufacturing, mounting and testing of ACS ULH & VLH in an manned mode,
- testing ULH in an unmanned mode.

The same tests were done on Russian ULH „Rotorfly."

HELICOPTER AND MEASURING EQUIPMENT

Two seats coaxial helicopter "Rotorfly" were done by "OKB Rotor" firm from Russia. It has an empty mass about 240kg but the maximal take-off weight (MTOW) 490 kg. According with Russia requirements (MTOW 495 kg) this helicopter is classified as ultralight. "Rotorfly" has carburetor engine "Rotax 912" by power 100hp.

Identification of the flight performance of a helicopter was done by a measuring system which determines the flight of the helicopter with the addition data on the position of control rods. In accordance with the requirements of the tests in manned and unmanned modes was developed a complex of registration of dynamic parameters (RDP). It was optimized for ULH & VLH. RDP had small sizes, modular and easily expandable structure and supply voltage 12V, typical for ULH & VLH (Fig. 3).

The system allows to measure and record the following parameters:

- ground speed;
- vertical airspeed;
- angles of yaw, pitch and roll;
- barometric altitude;
- airspeed;
- atmospheric pressure;
- ambient temperature;
- magnetic direction;
- torque of rotor shafts;
- RPM shafts;
- displacements of hand control system;
- oil, cylinder heads and engine exhaust temperature;
- engine oil pressure.

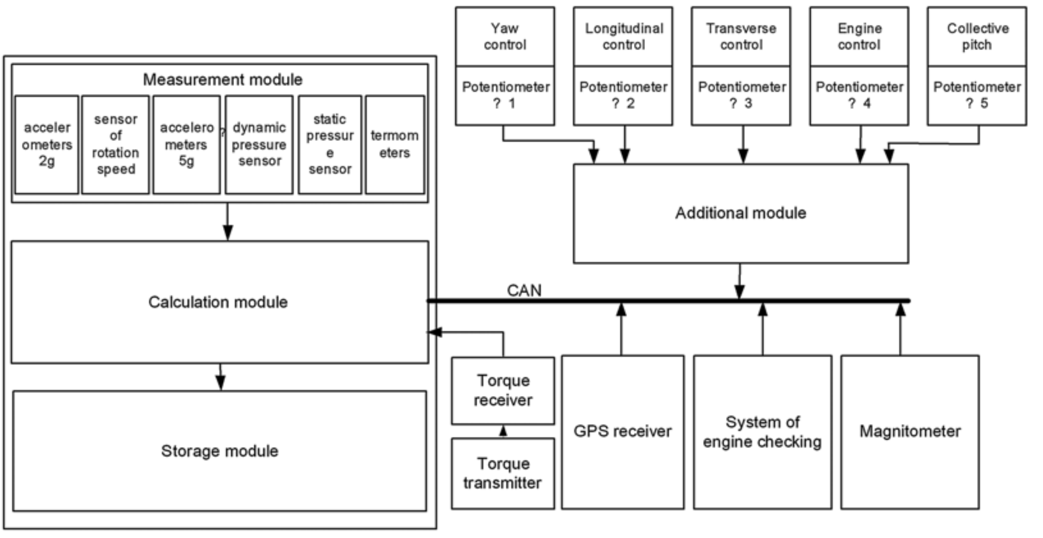

Fig. 3. The scheme of RDP complex

System had a few original devices. The engine control module played the role the device of constant RPM supporting. A device of torque measurement with a digital radio transmitter was fixed directly to the rotating shaft. Torque receiver was mounted inside the fuselage.

DETERMINATION OF THE TRANSFER FUNCTIONS OF THE AUTOMATIC CONTROL SYSTEM

Primary determination of the transfer function was done after 3 test flights. That was enough for algorithm founding and beginning helicopter tests with ACS. Approximating transfer functions in the control channels pitch, roll and yaw angles for „Rotorfly" helicopter were obtained by standard pocket of MATLAB. The result of comparative mathematical modeling of identified transfer function and flight experiment data is shown on Fig. 4. As it can be seen from the graphs founding, transfer function which relates the yaw angular velocity and the position of the yaw control, well reflects the real physical process of manual control of the helicopter.

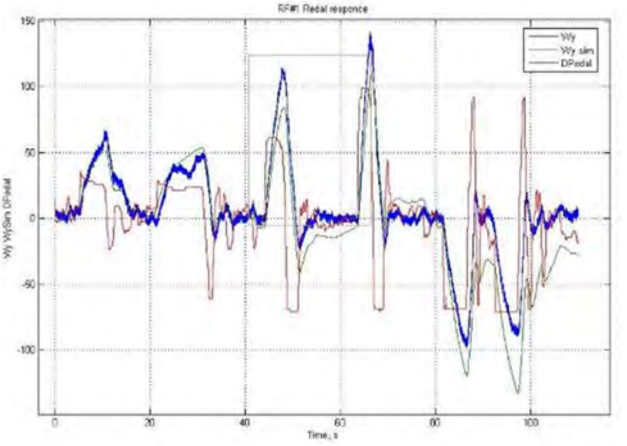

Fig. 4. Comparative modeling of the measured (Wy, degree / sec)
and the synthesized signal of yaw angular velocity rate (Wy Sim, degree / sec),
the yaw control signal is given as a percentage of displacement (Dpedal,%).

After founding a model of short periodic movement ULH „Rotorfly” experiments with ACS began. During the next flight tests an original model was developed. As a result, a model of spatial movement is shown on Fig. 5.

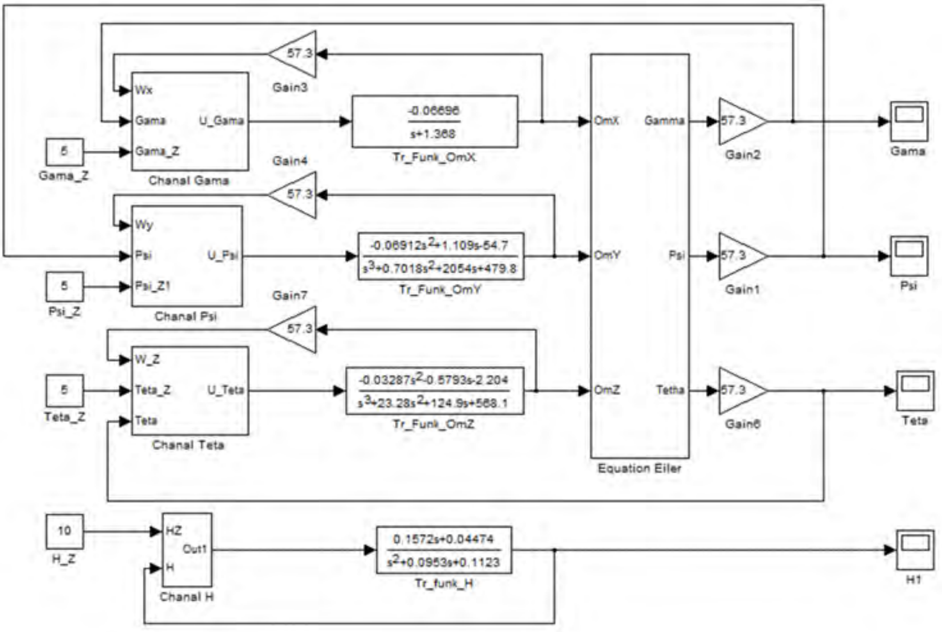

Fig. 5. The model of spatial movement of ACS ULH „Rotorfly”

TESTING OF THE AUTOMATIC CONTROL SYSTEM

In the second stage, ACS was mounted to the board of ULH. The connection of electromechanical servos with a handling control system is a serious problem. It can be solved in different ways. Special clutches are often. We did not use clutches and considered a few types of servos:

- irreversible servos, with the ability to compensate mistaken moving of the servo by the pilot,
- reversible servos with a possibility of mechanical safe disconnection of the drive control system,
- movable servos of controls correction.

After the analysis reversible servos were used in the main channels of control. They connected through two safe rings which were connected by soft rivets. Pilot could move lever of servos by yoke if ACS was de-energized. Pilot could cut off the rivets and mechanical control channel was released from the servo applying a force to the yoke in the case of emergency situations during the working of ACS.

After synthesis of control algorithms ACS was mounted on the board of ULH „Rotorfly". The layout of the equipment ACS is presented on Fig. 6. The main unit 1, which included the controller, display, air pressure sensors were installed in the forward part of the helicopter. Engine control module 13 was situated also there. On the right side of the cabin was installed radiomodem 2. 3 toggle switches enabling to switch on full ACS or separately every control channels were placed on the yoke. An inertial unit was situated near the center of gravity 4. Servos of cyclic 5, 6 yaw 7 and collective pitch 8 mounted to rigid elements of the rear wall of the cabin. Servo of constant RPM 9 hanged directly on a vertical rod of the engine control. At the tail boom was set GPS antenna 10 and magnetometer 12.

Fig. 6. The layout of the ACS equipment on ULH board

Control functions have been added to the display unit. On the dashboard pilot could evaluate the performance of ACS and power plant, change data and corrective parameters through the interface controller. The control of the helicopter was done by four channels - roll, pitch, yaw, step. Rotor speed was maintained at a constant level.

ANALYSIS OF STABILIZATION PERFORMANCE

For evaluation and testing of ACS in stabilization mode were done several flights with different modes of the fly. The effectiveness of each channel was checked while it was alternately turned on. Evaluating the stabilization effectiveness of short-period motion of the helicopter was performed by analyzing the recorded parameters, evaluation of pilots and the fact possibility of ULH „Rotorfly" make steady move in different modes. Fig. 7 shows an example of the automatic control system in the longitudinal control channel. The bottom graph shows the time on and off the channel (1 is on). The graphs show that the helicopter makes a stable flight and the pitch angle and angular velocity of the reflection were treated successfully with a deviation in the angle from -3° pitch to +1°. Rotation speed was maintained within ±100rpm that was sufficient for ULH with the engine Rotax 912 (Fig. 8).

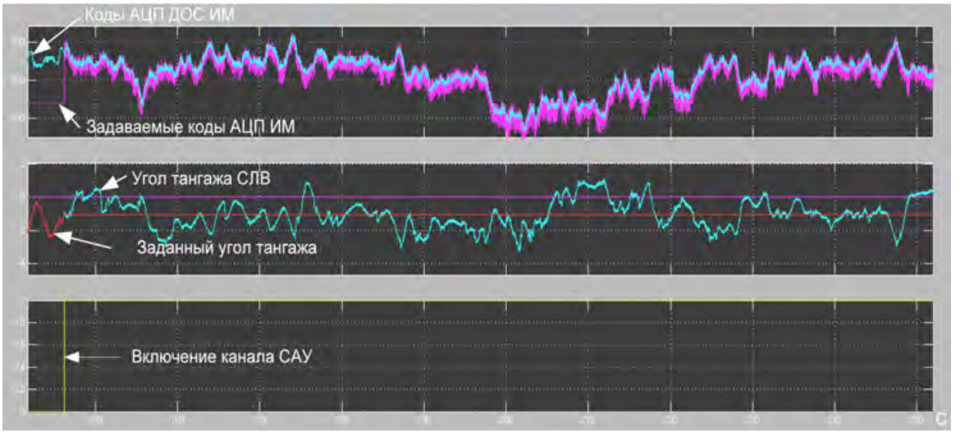

Fig. 7. The work of channel's longitudinal stability ACS ULH „Rotorfly" in time. In the top window are shown the control codes of the servo of this channel and response of the sensor of reverse signals (SRS) servo. In the middle pane are shown graphs of measured and set the pitch angle. The bottom window shows the marks of turning on of the ACS channel

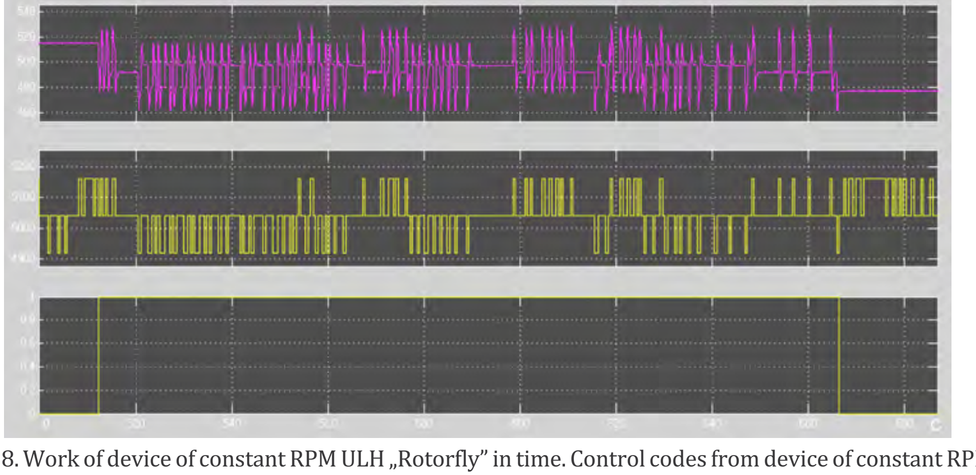

Fig. 8. Work of device of constant RPM ULH „Rotorfly" in time. Control codes from device of constant RPM are shown in the top window. The bottom window shows the level of inclusion of SRS servo of device. The bottom window shows the marks of turning on of the ACS channel

As it can be seen from the data of the ACS ULH „Rotorfly" with the selected dynamic coefficients of the control laws performs spatial stabilization of an acceptable quality in a wide dynamic range, which is sufficient for a fully automatic flight. It can be used not only for unmanned tests but also for producing UAV. In particular, after these experiments were done UAV which were based on "Rotorfly" helicopter (Fig.9).

Fig.9. UAV based on two seats ultralight helicopter "Rotorfly"

CONCLUSIONS

Results of flights show a developed method and equipment that may be used for the organization of critical flight tests in unmanned mode. Using flights with a pilot for autopilot debugging allows to cut costs and time for founding an ACS helicopter. Also this method allows to create UAV which is based on ULH and VLH and is fast.

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