ARTIFICIAL INTELLIGENCE SYSTEM IN A PROBLEM OF A PILOTING OF THE HELICOPTER.

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The present report is dedicated to some problems control of helicopters of a general purpose with allowance for the requirements safety flight.

By the managing document in Russia for fulfilment of flights serve airworthinees code of helicopters, which one determine the requirements at contact flight and instrument flight.

The basis for fulfilment of secure flights serve computational the operation conditions, which one include:

- state parameters and effects on the helicopter of an environment;
- operational parameters;
- flight parameters.

State parameters and effects on the helicopter of an environment include:

- barometric pressure, density, temperature and air humidity;
- parameters of motion of a wind;
- electrical effect and other not predictablis factors.

The operational parameters include:

- structure of crew of the helicopter;
- condition of aerodromes;
- weight and balance data of the helicopter;
- operational modes of engines;
- safe life of the helicopter;
- geographic and temporary features of application of the helicopter.

The flight parameters includes:

- altitude of flight;
- projection of speed of the helicopter;
- overload;
- angles of slide, roll and pitch;
- profile of standard flight.

From the point of view of a eeting the requirements of safety of concrete flight, the maiden two conditions are unguided - the third condition it is possible to operate.

Recommended flight phases - modes inside area instituted by operating limits, are established Aircraft Flight Guide (AFG).

It is necessary to mark three relevant circumstances, which one largely determine a flight safety:

- not all flight-navigation parameters are measured;
- not all measured flight-navigation parameters have indispensable accuracy;
- the solution in composite situations is received only by crew it is ground of the analysis of the numerous factors.

On these causes, and also in connection with a poor training standard crew to work in extreme situations, take place emergencies and debacles of helicopters.

In modern conditions to helicopters is presented a series of new operational requirements, namely:

- fulfilment of flight at any time of day in composite meteorological conditions;
- making a landing on the non-equipped aerodromes and on mobile objects.

Thus the requirements on an air safety are not reduced.

Here it is necessary to mark, that flights in composite meteorological conditions is, in main, instrument flight and requirement to veracities of flight-navigation parameters (speciall on modes of take-off and the landings) are much higher, than at fulfilment contact flight.

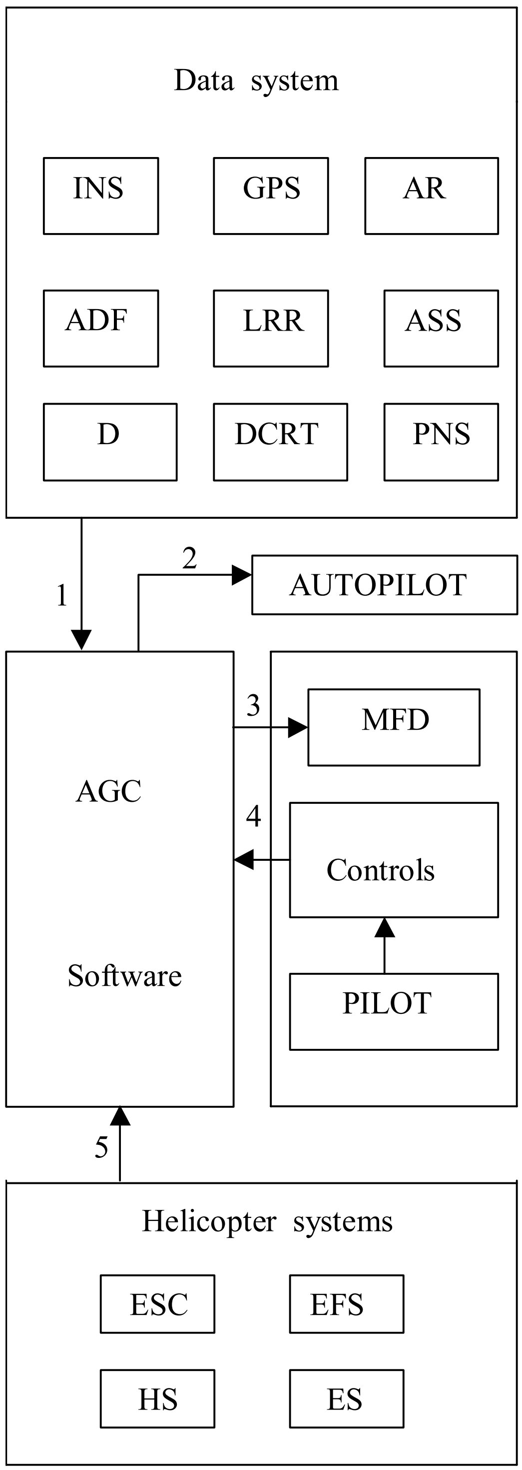

Fig. 1 Frame AEC of the helicopter.

The implementation of a put problem is possible on the basis of following the factors:

- intrusion in Airborne Eguipment complex (AEC) of helicopters new Data System (DS);
- usage modern Airborne Guidanse Computer (AGC);
- mining software, permitting to supply support to crew in extreme situations (Fig . 1).

The following notations are in figure adopted:

INS - inertial navigation system;
GPS - global position system;
D - Doppler;
LRR - low-range ratio;
ASS - air signals system;
ADF - automatic direction finder;
DCRT - digital card of a relief of terrain;
PNS - pilot night system;
AR - airborne radar;
ECS - engine control system;
EFS - engine fuel system;
HS - hydraulic system;
ES - electrical system;
MFD - multifunction display;

1 - measurement of flight-navigation parameters;
2 - signals of automatic control (δ^a_x, δ^a_y, δ^a_z, δ^a_h control in longitudinal, travelling, cross-sectional and high-altitude channels);
3 - parameters of indication MFD;
4 - signals manual control (δ_x, δ_y, δ_z, δ_h control in longitudinal, travelling, cross-sectional and high-altitude channels);
5 - parameters helicopter systems.

Software of the helicopter is intended
84.2 fulfilment problems:

organization of control of the helicopter in manual and automatic modes during takeoff (landing) and navigating on selected flight routing;

- inspection Data System and Helicopter Systems;
- airborne trial.

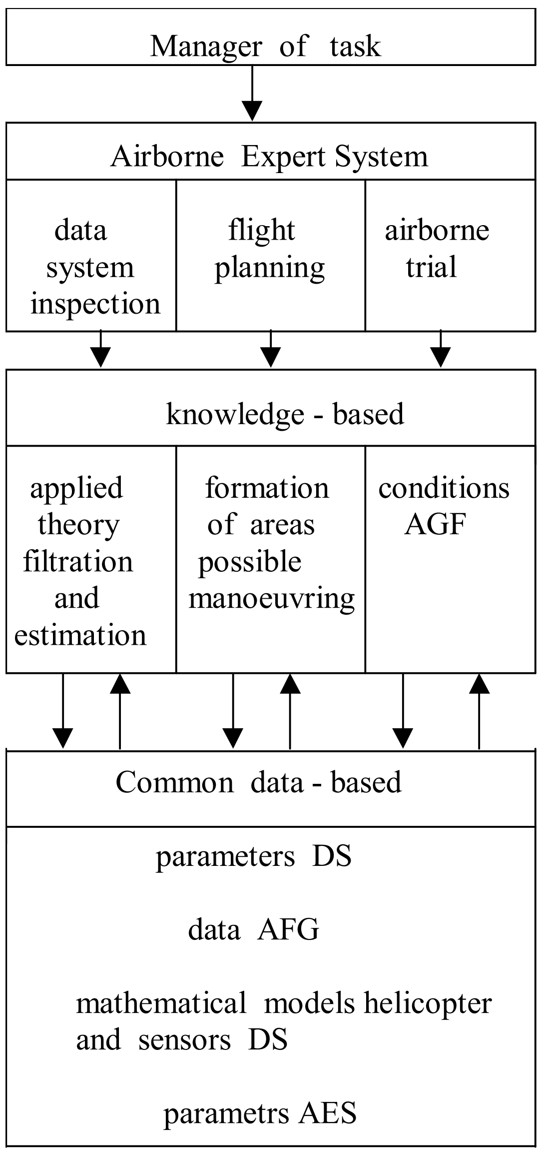

Fig. 2 Software AEC helicopter.

It is necessary to mark, that airborne trial does not change means terraneous opening-up and training, and is intended for a constant trainings of an aircrew at fulfilment instrument flight.

AEC of modern flight vehicles on problems and frame it is possible to categorize as artificial intelligence system, definite in concrete area, namely, as Airborne Expert System (AES).

Primary goal AES - assistance to crew of the helicopter or functional replacement of crew in extreme conditions.

It is possible to categorize parameters deliverable AEC, as data-based, and logical conditions of indispensable calculuss and formations the informations for crew can be categorized as knowledge-based.

Further we shall consider frame software AEC of the helicopter,
the flowchart is shown to which one in figure 2.

Manager of task management is intended for:

- selection of a mode of a piloting;
- selection of a mode of indication on MFD;
- selection of actuation AES.

The implementation of functional problems AEC of the helicopter can is made with usage three AES:

- data system inspetction (AESDSI), determining current availability index of product Data System and Helicopter Systems with issue of the information to crew;
- flight planning and automatic control (AESFP) on all phases of application of the helicopter (take-off, route, landing);
- airborne trial (AESAT), permitting to conduct preflight opening-up of crew.

It is necessary to mark, that generally in software can be AES of an estimation of external situation, in which one the information will be used from day-night survey systems (AR and PNS), but this a subject separate researches and in frameworks of the present report does not enter.

On time of usage AESDSI works permanently on a extent all flight, AESFP in a part of automatic control at will the pilot, AESAT in a mode of terraneous training.

Let's consider the concrete contents tendered AES.

The problems AESDSI consist of giving the next parameters to crew on MFD:

- preventing state information of helicopter systems (ECS, EFS, HS, ES);
- course of the helicopter;
- instrumental speed;
- pressure altitude;
- bank angles and pitch;
- vertical velocity;
- angle of slide;
- line of a flight routing at fulfilment of a mode of navigating;
- label of a position of the helicopter.

Knowledge-based AESDSI is reshaped on the basis of the applied theory filtration and estimation.

The problems AESFP consist of giving the next parameters to crew on MFD:

- preventing information on critical values flight-navigation parameters (bank angles and pitch, vertical velocity, instrumental speed, deviation from a command altitude, dangerous approach with ground);
- signals of automatic control of the helicopter.

Knowledge-based AESFP is grounded on formation of areas possible manoeuvring instituted by the requirements AFG and estimations of flight-navigation parameters.

The modern requirements to AEC of helicopters determine a problem maximum automation of control procedures on all phases of flight.

The algorithms of automatic control of the helicopter are reshaped on the basis of parameters of a planned trajectory.

The control law by the helicopter is set by the way of repetitive process formations a component of a command vector at phases from take-off before landing with allowance for of assumptions and limitations in automatic control mode on value and speed signals controls in the conforming control channels δ_{im}, $\Delta\delta_{im}$ i = 1 - 4 it is possible to present by following ratio:

$$k_i = x_i / \delta_i ;$$

$$\Delta \dot{\delta}_{i1} = - f_i / k_i ;$$

$$\Delta \delta_i = \Delta\delta_{i1} \quad \text{if} \quad |\Delta\delta_{i1}| \le \Delta \dot{\delta}_{im} ;$$

$$\Delta \delta_i = \Delta \delta_{im} * \text{sign}\, \Delta \delta_{i1} \quad \text{if} \quad |\Delta\delta_{i1}| > \Delta \delta_{im} ;$$

$$\delta i1 = \delta_i + \Delta \delta_i ;$$

$$\delta_i = \delta_{i1} \quad \text{if} \quad |\delta_{i1}| \le \delta_{im} ;$$

$$\delta_i = \delta_{im} * \text{sign}\, \delta_i \quad \text{if} \quad |\delta_{i1}| > \delta_{im} ; \qquad (1)$$

In (1) the following notations are adopted:

x_i = 1 – 4 value (ω_x, ω_y, ω_z, h_1) projection angular rate of the helicopters in a bound coordinate system (BCS) and vertical velocity of the helicopter in earth coordinate system (ECS) accordingly.

The values f_i are determined as follows:

$$f1 = \omega_x - \omega_{xm};$$

$$f2 = \omega_y - \omega_{ym};$$

$$f3 = \omega_z - \omega_{zm};$$

$$f4 = h_1 - h_{1m}; \qquad (2)$$

here:

- ω_{xm}, ω_{ym}, ω_{zm} acceptable values of angular rate the helicopter in BCS, and – h_{1m} acceptable value vertical the speeds of the helicopter in ECS, which one are determined as functions:
- current and given bank angles, pitch and course of the helicopter;
- current and command altitude of flight.

The expressions (1), (2) determine algorithm automatic control of the helicopter.

Conducted in State Research Institute of Aviation Systems mathematical and seminatural simulation on modes of take-off and the landings of the helicopter completely have confirmed his high the functional characteristics.

The problems AESAT consist in maintenance:

- formation of a mode of practice flight;
- objective control of a degree of a training standard of crew.

Knowledge-based AESAT is grounded on positions AFG in a part of fulfilment by crew of indispensable operating in nominal and contingencies. Common data-based includes estimations flight-navigation parameters and data AFG:

- data array (limitations) on a taking – off and landing of helicopters by maximum, I and II of categories;- indispensable to the logician of a crew effects in nominal and contingencies.

Distinctive feature common data-based is usage of mathematical models of the helicopter (with the autopilot), kinematics parameters and sensors DS, which one execute following functions:

- estimation of veracity of flight-navigation parameters;
- calculation of parameters of automatic control;
- maintenance flight simulation of the helicopter in airborne trial.

For example one of version may be equations of motion of the helicopter in dextral bound coordinate system look like:

longitudinal motion

$$\dot{\nu}_x = x(\nu) - x^{\upsilon}(\nu) * \upsilon + x^{\delta_z}(\nu) * \delta_z + \nu_y * \omega_z + \Delta x;$$

$$\dot{\nu}_y = y(\nu) + y^{\nu_y}(v) * \nu_y + y^{\varphi}(\nu) * \delta_h + \nu_x * \omega_z + \Delta y;$$

$$\dot{\omega}_z = m_z(\nu) + m_z^{\omega_z}(\nu) * \omega_z + m_z^{\delta_z}(\nu) * \delta_z + \Delta m_z;$$

collateral motion

$$\dot{\nu}_z = z(\nu) + z^{\gamma}(\nu) * \gamma + z^{\delta_x}(\nu) * \delta_x + z^{\nu_z}(\nu) * \nu_z + \nu_x * \omega_y - \nu_y * \omega_x + \Delta z;$$

$$\dot{\omega}_x = m_x(\nu) + m_x^{\omega_x}(\nu) * \omega_x + m_x^{\nu_z}(\nu) * \nu_z + m_x^{\delta_z}(\nu) * \delta_x + m_x^{\delta_y}(\nu) * \delta_y + \Delta m_x;$$

$$\dot{\omega}_y = m_y(\nu) + m_y^{\omega_y}(\nu) * \omega_y + m_y^{\nu_z}(\nu) *$$

$\nu_z + m_y^{\delta_x}(\nu) * \delta_x + m_y^{\delta_y}(\nu) * \delta_y + \Delta m_{y};$

where:

- ν_x, ν_y, ν_z component of vector speeds;
- ω_x, ω_y, ω_z component of vector angular rate;
- Δx, Δy, Δz, Δm_x, Δm_y, Δm_z signals for implementation of off-gauge condition of flight and balancing of equanions;
- $x(\nu)$, $y(\nu)$, $m_z(\nu)$, $z(\nu)$, $m_x(\nu)$, $m_y(\nu)$ functions describing change of forces both moments at an alteration of speed and altitude flight instituted on the formulas:

$$x(\nu) = - [x^{\upsilon}(\nu) * \upsilon_0 + x^{\delta_z}(\nu) * \delta_{zo}];$$

$$y(\nu) = - [y^{\nu_y}(\nu) * \nu_{yo} + \delta_h(v) * \delta_h];$$

$$z(\nu) = - [z^{\gamma}(\nu) * \gamma_o + z^{\delta_x}(\nu) * \delta_{xo}];$$

$$m_x(\nu) = [m_x^{\delta_x}(\nu) * \delta_{xo} + m_x^{\delta_y}(\nu) * \delta_{yo}];$$

$$m_y(\nu) = [m_y^{\delta_x}(\nu) * \delta_{xo} + m_y^{\delta_y}(\nu) * \delta_{yo}];$$

$$m_z(\nu) = [m_z^{\delta_z}(\nu) * \delta_{zo}];$$

where – υ_o, γ_o, v_{yo}, δ_{zo}, δ_{yo}, δ_{xo} balance values of a flight parameters and control signals in a function of speed and altitude of the helicopter.

The mathematical model of the autopilot is determined by concrete phylum the helicopter.

Mathematical models of flight-navigation sensors are under construction on mathematical models of the helicopter and kinematics parameters.

The mission models of the helicopter with calculus of reference values flight-navigation parameters. The models of sensors are reshaped on usage of values of the conforming parameters from models the helicopter and kinematics parameters with attachment of some values, the indications, instituted by prior errors, of sensors in low frequency and high frequency ranges.

The tendered approach was tested in State Research Institute of Aviation Systems at realization of seminatural improvement AEC of helicopters and at creation of helicopter simulators.

In summary present report can be approved, that tendered frame of creation software by Airborne Expert System allows potentially to raise the level of safety piloting by the helicopter in composite conditions for the score:

- increase of veracity of estimations flight-navigation parameters;
- automation of a piloting;
- training standards of crew to work in extreme conditions.