HELICOPTER AS AN OBJECT OF ACCIDENT INVESTIGATION

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Abstract

The well-known helicopter's peculiarities stipulated primarily by availability of rotor and tail rotor with flapping elastic blades manifest themselves not only at designing and piloting but at investigation of air accidents – the most formidable challenge for corresponding experts, who must have special knowledge, experience and training exactly in helicopter's emergencies not common aircraft accidents.

There are some important heuristics of the functional dependence between failure indications and parameters of the damaged helicopter condition and causes of air accident, also the domain of decisive indications of the serviceable or fault operational condition of the helicopter units at an impact on the ground. There is a similar domain of indications for the human factor analysis.

The enumerated features have been systematized into the emergency-oriented base of knowledge and expert system – user-friendly interactive software for the exchange of information between a computer and expert.

Introduction

Helicopters of all types are widely operated in military and civil aviation, however they are involved in a number of flight incidents and accidents. Note should be taken that, as a rule, the accident rate of helicopters is some higher than plane's one mainly due to a combination of two basic groups of factors.

First, helicopters feature in certain unfavourable peculiarities at piloting, such as:

- lack of the stability and control margins under some flight conditions;
- some unfavourable combinations of flight speed and altitude are fraught with an unsafe forced landing in case of the failure of an engine;
- .the rotor speed depends on the serviceability of the powerplant, rate of the controls deflection, and the intensity of the manoeuvring;
- a danger of the blades hitting against an obstacle or the fuselage.

Second, one should take into account unfavourable specificity of the helicopter operation:

- helicopters are often based on unprepared fields, aircraft carriers, etc.;
- terrain flights;
- unscheduled maintenance, agricultural operations, installations, etc.;
- external load transporting;
- flights among mountains, piloting in adverse weather conditions, etc.;
- helicopters have to perform mainly the contact flights.

Generally, air accident investigation is a ramified process comprising heterogeneous activities yet pursuing a single goal of revealing:

- serviceability and operating condition of the main aircraft systems at emergency or collision with an obstacle;
- the fault operational system, subassembly, unit or component and the reason(s) for the failure;
- a breach of the assigned operational limits or piloting/maintenance errors;
- environmental effects, their nature and consequences;
- the primary cause of the air accident and attendant ones;
- recommendations and requirements imposed to prevent similar air accidents.

Eventually, the true unambiguous cause for the accident should be established in the shortest possible time, as a rule in the field conditions near the crash site, which requires a complex of approved scientific techniques and sophisticated

facilities, highly skilled specialists, and considerable expenditures.

Air accident investigation is both very complicated and demanding activity for it results in costly preventive measures, such as modifications of the design or maintenance/operation, elaboration of the manufacturing technology and repair, education and training of the crews and engineering personnel.

So an investigation of air accidents is the most formidable challenge for corresponding experts. As an accident takes place, no matter how serious are the consequences, it must be properly investigated and classified in order to analyse its causes and prevent them in future.

Peculiarities of helicopter's accidents

Long-term Russian and international practice of accidents and serious incidents investigation, especially on the site of crash or emergency landing, shows that key experts of the investigation team must have special knowledge, experience and training exactly in helicopter's emergencies not common aircraft accidents. The point is that helicopter's accident investigations are the most complicated due to the following factors:

- ground collisions of the helicopters do not feature in high speeds and G-loads (in comparison with airplanes), and travelling components of the helicopter units usually do not get stuck strictly in the positions they were at collision;
- some key damages of helicopter's structure are being caused by blade's strokes but no ones knows where – in flight or during collision against ground obstacles;
- a fire often follows the crash of a helicopter, which later complicates examination of the operational status of the damaged aircraft and its assemblies;
- it is difficult (sometimes impossible) to restore objective data of the helicopter operational parameters at emergency afterwards because the flight data recorders available are not good enough, or in serviceable condition, or damaged as well.

On the other hand, there is a number of circumstantial evidence to reconstruct operational conditions of the aviation machinery, pilots poses and control actions at an impact on the ground: the crashed aircraft position on the ground, burned or destroyed vegetation and soil, condition of the operational systems adjacent to that under examination and so on.

Some of these circumstantial evidences are typical exactly of a helicopter due to availability of rotor and tail rotor with flapping elastic blades, for example crash with fault/shutdown engines seem appropriate to mention:

- hollows left by the tail boom and (or) tail rotor blades, which were the first to hit the ground;
- crash position, i.e. on the wheels or capsized on the left (for Russian helicopters) side;
- damage or destruction of the tail boom, landing gear attachments, skin, structural members of the tail rotor pylon and tail boom, fuselage spine fairing;
- damage to the tail rotor blades:
- scatter of the tail rotor blade tips should not exceed ~50m;
- separated parts of the helicopter do not scatter on the ground;
- the blade spars and drag hinge aft stops are intact;
- spline couplings of the tail rotor drive system are intact.

The enumerated circumstantial external features point to the helicopter emergency landing with its engines shutdown or fault, yet they must be thorougly analysed in combination with diagnostics of the onboard recorders and data obtained from examination of the engines.

There is a similar domain of indications (in terms of gnosiology) for the human factor analysis. They enable reconstruction of the pilots' poses and injury (death) causes at an impact on the ground or an obstacle.

One should emphasize that according to extensive statistics poor performance of the pilots entails over 70% of serious flight incidents and accidents in both Russian and world aviation, whereas approximately 20% caused by in-flight failures of aviation machinery could have been managed but uncoordinated, untimely or wrong actions of the pilots and air traffic officers under the circumstances.

As it well known emergencies that lead to in-flight incidents and accidents are the result of:

- adverse environmental conditions;
- improper pre-flight maintenance;
- piloting errors or breaches of the flight rules;
- heavy psycho-physiological loads that result in worse efficiency of the crew;
- unfavourable peculiarities of the aircraft aerodynamics, controllability and aeroelasticity.

Each standard stage and specific condition of helicopter flight have typical rather limited totality of combinations of the enumerated factors. For instance, during the vertical takeoff there exist the following typical piloting errors or breaches of the flight rules, aggravating by known unfavourable peculiarities of the helicopter's aerodynamics and controllability:

- errors in account of wind speed and direction;
- an extremely sudden rise in the rotor collective pitch to take helicopter off;
- excessive and sharp push of the control stick to start the takeoff acceleration;
- rollout on the selected heading at inadmissible bank angle while executing the takeoff acceleration into the wind;
- neglect of the unfavorable influence the underlying surface exerts on rotor thrust and visibility.

Possible consequences of the considered emergencies are spontaneous rotation and descent of the helicopter, involuntary descent and collision with the ground with determined peculiarities of damaged aircraft.

This reasoning has given an impetus to development of an evolving helicopter emergency-oriented information system, which would comprise long-term experience and profound knowledge of the experts, and on the other hand, would amplify and supplement the specialists rather than replace them.

Database on the helicopter's accidents

These domains of typical reiterated pilots errors and standard indications of crashed helicopters state have been systematized from the analysis and generalization of the data obtained from air accidents investigations in the former Soviet Union, and later in Russia and CIS countries, as well as from special ground and flight experiments carried out both in the course of the investigations and intended for working out preventive safety measures. In particular, there is a computer database on the accident rate of the Mi-2, Mi-6, Mi-8, Mi-14, Mi-17, Mi-24, Mi-26 civil and military helicopters flown both in Russia and in foreign Air Forces and companies during the latest thirty years.

This database comprises all air accidents and serious incidents, including the following information:

- the type of the helicopter involved in an air accident, its registration number, manufacturer and date of manufacturing, belonging, date of the last repair and maintenance, operating time and hours flown after the last repair;
- the pilot's data, such as his age, rating, overall flying hours, and hours flown on this helicopter and as a pilot-in-command;
- number of passengers and presence of a supervisor on-board the helicopter;
- the flying task or combat mission;
- the underlying surface at the air accident scene;
- flight stage and regime at the emergency;
- weather conditions (clouds, visibility, wind speed and direction, pressure and humidity of the air, natural phenomena);
- data of the flight recorders and cockpit voice recorders;
- helicopter gross mass and e.g. position at emergency;
- crashed aircraft position (on the wheels, capsized, on the right/left side);
- directional rotation at the moment of crash;
- symptoms of in-flight or ground fire;
- maximum scatter of the helicopter heavy and light fragments;
- indications of the rotor and tail rotor blades impacts on foreign objects or helicopter body;
- data on the spar destructed sections and damage to the blade tips;
- kinking in the engine drive shafts and tail rotor drive system shafts;
- powerplant and electric equipment serviceability at the impact on an obstacle/ground;
- occurance and development of the emergency:
- classification of the air accident (a fatal accident, a non-fatal accident, or a failure);

- results obtained from special examinations of the fault aviation machinery;
- conclusion drawn on the cause of the air accident and provoking factors that had served to aggravate the emergency;
- comments and recommendation to the flying and engineering personnel and manufacturers on taking measures to ensure flight safety.

This database with its exhaustive information on the air accidents, in which a particular type of aircraft have ever been involved, combined with an aggregate of operational conditions reconstructed for the helicopter units and assemblies and data on the crew at the impact on an obstacle together with the particular domain of gnosiology (descriptions, manuals, reports, scientific papers, layouts, photos, etc.) and friendly user interface all together form an expert system, which allows objective analysis, generalization and establishing of the air accident probable causes, drawing conclusions and their thorough substantiation.

The expert system

An expert system is software, information carrier competent at symbol reasoning in a particular area of knowledge, solving complex problems and substantiating the found solutions. Such systems fall in the category of artificial intellegence working in direct connection with experts. A pattern of the knowledge representation is of essential importance for any expert system; it should enable statement of the problem being analysed so that it can be solved in the simplest possible way. A fundamental analysis the authors have carried out testifies in favour of so-called "if…(condition), go to… (action) pattern, i.e. when the situation being analysed satisfies the left-side scenario, then actions described in the rignt side are fulfilled. Applying sequentally, this rule results in a deduction chain; the investigators employing two opposite conceptions - the direct and inverse deduction chains.

The base of knowledge for the expert system comprises the following:

- a control system for the database on the Russain single rotor helicopters both civil and military;
- heuristics of the functional dependence between failure indications and parameters of the damaged helicopter condition and causes of the air accident, e.g. correlation between the engines serviceability before an impact on the ground and positions of the automatic fuel management system actuators, condition of the drive shafts and transmission shafts, flapping hinge stops and rotor blades, as well as the crashed helicopter attitude on the ground;
- the domain of decisive indications of the serviceable or fault operational condition of the helicopter units and parts at an impact on the ground (obstacle);
- the domain of decisive indications of the crew postures and causes for the injury/death at an impact on the ground (obstacle);
- the statistical distribution laws for the characteristic parameters typical of helicopter collisions with ground obstacles, such as distribution laws for the roll and pitch angles depending on various typical causes of air accidents;
- heuristics of experienced experts reasonings accumulated at air accidents investigation during examining the damaged helicopters and drawing conclusions of the accidents' causes.

The proposed expert system is user-friendly interactive software for the exchange of information between a computer and user, the initiative being taken by the computer. Users need not to be any particularly good at computer programming, the dialog is constructed in such a way as to alleviate answering the program's questions. The hard limits are literal-free spelling and adopted terminology at inputing data on the sources of information, circumstances of the air accident, etc.

The expert system includes the following main blocks:

- a data acquisition and analysis block;
- a block, which analyses versions of air accident causes;
- a block providing interaction with external databases;
- an explanation block;
- a self-learning block;
- a self-monitoring block;
- an output block.

The expert system employs a user-friendly window interface developed for the Borland Turbo

Vision medium. The window interface ensures simple and descriptive communication with the software, databases and the other blocks. The context reference clarifies the expert system operation, whereas its feature to comment on the procedure and chain of argument makes the investigator trust the system.

These features are of primary importance for the air accident investigation assistance. An ability to supplement the database and relevant base of knowledge while performing an investigation enables gaining experience helpful at further air accident . investigations.

A labour-saving object-oriented programming technology used for development of the expert system blocks allows updating, correction and elaboration of the software.

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