Software-Hardware Complex of Qualification Evaluation of Mi-171 Helicopter Simulator

Urgency of the research. Flight safety is an actual practical issue which solving influences the future of Ukraine as a transport state. As a consequence of technical progress aviation technology is becoming more and more sophisticated and reliable. However, the intensity of the impact on a person caused by various adverse factors, including information overloads, is constantly increasing. Statistics show that up to 80% of accidents and disasters occur due to pilot errors. The reason for about 35% of these errors is lack of professional training, and about 40% of the errors are caused by inexperience of the crew.

Target setting. The cost of aircraft, crew training and the "price" of error increase simultaneously. Cost of professional training of helicopter crews on complex flight simulators is an order of magnitude lower than on real helicopters. Therefore, today the focus of increasing the safety of flights is to improve the level of flight training and flight experience via the use of flight simulators with a high level of information adequacy to a real helicopter.

Actual scientific researches and issues analysis. In order to ensure the possibility of the trained crew to obtain the appropriate official documents stating their professional training level, the simulator must be certified according to national and international requirements, i.e. the adequacy of its handling qualities to the appropriate qualities of a simulated helicopter must be guaranteed.

Uninvestigated parts of general matters defining. The equipment allows simulating the conduct of the helicopter in all flight modes, including critical ones: control failure, landing in the mode of main lift rotor autorotation, etc., developing practical recommendations for the flight crew, as well as to train the flight crew to find ways out of emergencies. Receiving information about the flight mode, the parameters of the onboard systems, the external environment, etc., the crew envision the information flight model. The information model of the simulator should be as similar as possible to the information model of the real helicopter. Consequently, the basic components of the simulator are the imitation systems providing the influence of the information creating the adequate picture of the flight on sense organs of the crew, including eyesight – a visualization system, flight control equipment, etc.: hearing – a system of aviation noise simulation; vestibular apparatus – a motion generation system; tactile channel – a system for loading control levers.

The research objective. The listed systems form the informational model of the simulator, which should be coordinated with the movement of the helicopter. A mathematical model of the helicopter movement dynamics and the models of the mentioned systems provide this coordination. To provide the operation of the complex flight simulator, nonlinear mathematical models of helicopter dynamics based on the modified discrete vortex method have been developed. The models describe the flow of the volumetric design of the propeller apparatus and allow simulating a real-time flight in different modes, including "post-stall" condition.

The statement of basic materials. The principles and approaches to the qualification evaluation of complex flight helicopter simulators in accordance with the requirements of the EU (CS-FSTD (H)) and ICAO (Doc 9625) are analyzed. The performance capabilities of a complex full-flight Mi-171 helicopter simulator created by SPA "AVIA" are described. The necessity of certification of flight simulators in compliance with international standards is substantiated. The analysis of the validation procedure is performed. The structure and functioning of the software complex designed to automate validation tests are described.

Conclusions. An algorithm for obtaining a conclusion on the test result for one of the tests is presented.

Keywords: flight safety; pilot error; flight simulator; information model; validation tests.

Fig.: 1. Table: 1. References: 12.
The research objective. In order to enable helicopter training crews to receive high-level professional training, SPA “AVIA”, Kremenchuh developed and produced a complex full-flight simulator (FSTD) of the Mi-171 helicopter type V (by classification [2]), or level FFS(D) (by classification [3]). The equipment allows simulating the conduct of the helicopter in all flight modes, including critical ones: control failure, landing in the mode of main lift rotor autorotation, etc., developing practical recommendations for the flight crew, as well as to train the flight crew to find ways out of emergencies.

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The statement of basic materials. The guidance on the criteria for qualifying flight simulators [2] designates the following levels of adequacy: "N (None or Not Applicable)" – not required; "G (Generic)" – basic; "R (Representative)" – typical; "S (Specific)" – high. For instance, the high level of adequacy S means that a helicopter of the specific type is being simulated, and initial and periodic validation tests should be made on the basis of objective comparison of the data of the simulator with the approved data of the helicopter.

FSTD characteristics important for training, testing and checking flight crewmembers need evaluating. They include the reactions of FSTD in the longitudinal and lateral motion directions; flight technical characteristics while taking-off, hovering and moving, climbing, cruising flight, downgrading, landing approach, power-on landing and landing in autorotation; while performing all-weather flights, as well as checking control systems; and, if necessary, checking the functions performed at the pilots and the instructor’s workplaces. To guarantee the correct functioning, the performance of the systems simulating acceleration, vibrational, visual and sound effects is also evaluated.

The performance data, flying qualities, and other necessary parameters recorded on a helicopter by means of calibration system of data accumulation with sufficient resolution and experimentally proved accuracy that allow forming a set of corresponding parameters, which can be compared with similar FSTD parameters are considered validation data of flight tests.

The approved data is the performance data of the helicopter, collected through the application of the appropriate engineering practice and accepted by the National Aviation Administration, which is responsible for the qualification for use. The best sources of such data are helicopter producers, although the data from other competent sources may also be considered. For instance, the validation tests of the simulator by SPA "AVIA" rest on the data obtained in the flight tests [4, 5], agreed with the National Aviation Administration and [6] which states, that “The Mi-171, Mi-8AMT, Mi-172 and Mi-8MTV helicopters have the same flight performance and operational characteristics”.

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In order to compare the performance data of the helicopter with one of the helicopter simulator in [2, 3], a system of tests in the form of the table of validation tests is given. The requirements of one of the tests for comparing the balancing curves of the helicopter and the simulator in the horizontal flight are given in Table 1.

Table 1

| TESTS                        | TOLERANCE                                      | FLIGHT CONDITIONS | FSTD LEVEL | COMMENTS                                           |
|------------------------------|------------------------------------------------|-------------------|------------|----------------------------------------------------|
| Flight Performance           | Torque ± 3%                                    | Cruise stability  | FSTD A B C | Two combinations of gross weight /kg and at least two speeds (including Vy and maximum cruise speed) within the flight envelope. May be snapshot tests. For FNPT level 1 changes in kg are not required. For FNPT (any level), only one stability augmentation case is required. |
| and Trimmered Flight         | Pitch angle ± 1.5º                              | Stability         | FSTD C T M |                                                   |
| Control Position             | Sideslip angle ± 2º                             | augmentation      | FSTD C T M |                                                   |
|                              | Longitudinal control position ± 5%             | on or off         | FSTD C T M |                                                   |
|                              | Lateral control position ± 5%                  |                   | FSTD C T M |                                                   |
|                              | Directional control position ± 5%              |                   | FSTD C T M |                                                   |
|                              | Collective control position ± 5%               |                   | FSTD C T M |                                                   |

The resulting balancing curves should be within the limits of the tolerances with the results of flight tests.

To automate the validation tests, the software package TSFlightChart (Fig. 1) has been developed. It allows making the following processes operational:

- receiving real time flight parameters of the simulator and displaying their diagrams on the flight control officer’s monitor;
- managing recording of flight parameters (recording, stopping, pausing, putting custom labels, etc.);
- saving flight information records;
- graphing flight parameters changes in time;
- editing diagrams (changing the set of displayed parameters, cutting out the desired areas, changing the scale, etc.);
- saving the edited records in digital and graphic formats;
- processing flight information in accordance with the tasks of a particular test;
- generating a formal report on the results of the test.

The examples below demonstrate a fragment of the content of the flight task and a general algorithm for forming the conclusion about the result of the test 1.f. Level flight Performance and Trimmed Flight Control Positions.
For a comparison test of balancing curves on the simulator, flights with the minimum and maximum flight mass and with the extreme front and the extreme rear centering are performed. In the horizontal flight phase without sideslip with the autopilot turned off and on, several speeds within the permitted range for 10 ... 15 seconds are recorded. The following algorithm processes the obtained records.

1. Generating a values array of the parameters to be evaluated.
2. Preparing the zones where the constant test speed was maintained during the test. Determining the beginning and end reference numbers of the zones (according to the labels placed during the test), their quantity and length.
3. Calculating medium speed on each of the zones. Generating an array of speeds, which were kept constant during the test.
4. Calculating the average parameter value for each of the zones. Generating an array of average parameter values for each zone.

5. Approximating the discrete dependencies of mean values of the parameters of the results obtained on stage 4 from average speed by power polynomials with increasing degree till obtaining a sufficiently large coefficient of approximation reliability.

6. Obtaining continuous balancing curves by spline-interpolation of discrete dependences obtained on stage 5.

7. Comparing the results of the balancing curves obtained on stage 6 with those obtained in the flight tests. Identifying the maximum deviation of the simulator. Making conclusion about the test result.

Adjusting the actual performance data of the simulator in accordance with the tolerance limits determined by the requirements of validation tests CS-FSTD(H) is used as a method for refining the parameters of the mathematical model of the complex helicopter simulator.

Determining the list of available (obtained as a result of flight tests) characteristics of stability and control, performance data and field performance for refining the parameters of the mathematical model of the complex helicopter simulator is performed by comparing the list of required characteristics and parameters contained in CS-FSTD(H) with corresponding characteristics and parameters contained in the Helicopter Test Acts.

**Conclusions.** Thus, the developed training complex is certified according to the rules of CS-FSTD, implemented in batch production of SPA "AVIA" and accepted for supply by the Armed Forces of Ukraine, in accordance with the Order of the Minister of Defense of Ukraine. To make validation tests automatic, the software package TSFlightChart has been developed. The next stage of the software and hardware complex development should be the development and implementation of an automatic flight control system, enabling automatic validation tests. This, in turn, will significantly accelerate validation tests and reduce their cost.

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ПРОГРАМНО-АПАРАТНИЙ КОМПЛЕКС КВАЛІФІКАЦІЙНОГО ОЦІНЮВАННЯ ТРЕНАЗЖЕРА ВЕРТОЛІТА Мі-171

Актуальність теми дослідження. Безпека польотів є актуальною практичною проблемою, від вирішення якої залежить майбутнє України, як транспортної держави. В результаті технічного прогресу авіаційна техніка стає все більш досконалою і надійною. Однак, постійно збільшується інтенсивність впливу на людину різноманітних...
Введення недосліджених раніше частин загальної проблеми. Інформаційна модель тренажера повинна якомога менше відрізнятися від інформаційної моделі реального вертольота. Відповідно, базовими компонентами тренажера є системи імітації, що забезпечують вплив на органі відчуття екіпажу інформації для створення адекватної картини польоту, у тому числі: зір – система візуалізації, пілотажно-навігаційні прилади, тощо; слух – система імітації акумулятивних шумів; вестбулярний апарат – система реалізації; тактичний канал – система завантаження важельв корупції. Для забезпечення роботи комплексного льотного тренажера розроблено нелінійні математичні моделі динаміки вертольота, на основі мінімізованого методу дискретних вихорів, які описують обмініння екіпажу, штатному компонуванню гвинтокрилого апарату і дозволяє моделювати експлутацію реальних систем будь-якої складності.

Виділення недосліджених раніше частин загальної проблеми. Інформаційна модель тренажера повинна якомога менше відрізнятися від інформаційної моделі реального вертольота. Відповідно, базовими компонентами тренажера є системи імітації, що забезпечують вплив на органі відчуття екіпажу інформації для створення адекватної картини польоту, у тому числі: зір – система візуалізації, пілотажно-навігаційні прилади, тощо; слух – система імітації акумулятивних шумів; вестбулярний апарат – система реалізації; тактичний канал – система завантаження важельв корупції. Для забезпечення роботи комплексного льотного тренажера розроблено нелінійні математичні моделі динаміки вертольота, на основі мінімізованого методу дискретних вихорів, які описують обмініння екіпажу, штатному компонуванню гвинтокрилого апарату і дозволяє моделювати експлутацію реальних систем будь-якої складності.

Аналіз основних досліджень і публікацій. Були розглянути останні дослідження, принципи та підходи до кваліфікаційного оцінювання комплексних льотних тренажерів відповідно до вимог ЄС (CS-FSTD(H)) та ІКАО (Doc 9625).

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Висновки відповідно до статті. Наводиться алгоритм отримання висновку про результат проходження для одного з тестів.

Ключові слова: безпека польотів; помилки пилota; льотний тренажер; інформаційна модель; валідаційні випробування.

Рис.: 1. Табл.: 1. Бібл.: 12.