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ASSESSMENT OF THE FLIGHT QUALITY IN VERTICAL PLANE

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Abstract*—This article discusses the problem of the quality assessing of the crew An-148 piloting technique, taking into account the human factor. The calculations showed that the statistical distribution of the pitch angle does not contradict the normal distribution. It is known that the normal law of the distribution of parameters indicates a good quality piloting technique. An analysis of autocorrelation functions and its spectrum is proposed to quickly solve this problem. The assessment of the quality of the piloting technique by analyzing the autocorrelation function of the pitch angle and its spectrum is consistent with the estimation method according to the distribution laws. A good technique was established for piloting the An-148 pilot under normal piloting technique. It also offers a scheme of a warning system for failures of systems for displaying the values of the angle of attack or speed and an algorithm of actions in such cases.*

Index Terms—Autocorrelation functions; indicated air speed; human factor; parameter amplitude; autocorrelation functions; spectrum analysis.

I. INTRODUCTION

Safety issues occupy one of the main places in the air transport system. Most often, there is deterioration in the quality of piloting techniques in the event of special cases in flight. Usually, in this case, the crew flies in the director mode of control of the aircraft. Accidents take improbable character due to equipment malfunctions and failures. The human operator exacerbates the negative situation in most cases due to the stress state. Therefore it is necessary to prepare crews for flights in special cases. We suggest evaluating the quality of piloting techniques by autocorrelation functions and its spectra. This method is appropriate for further automation of this process. In addition, it is necessary for a trained crew to report on their psychophysiological tension. Despite the fact that the pilots are prepared for action in special cases in flight on the complex simulators of the aircraft, but all situations cannot be foreseen. Therefore, they must be prepared for adequate action in a state of psychophysiological tension. Action algorithms are needed for reproducing the position of the aircraft in space for other flight instruments in case of failures (malfunctions) in the speed indicator system. The relevance of the work lies in the fact that there were air crashes during failures in the air pressure receivers of the speed indicator system. A warning system for the failure of the angle of attack or speed indicators is required. All of the above methods, system and methods are aimed at improving flight safety.

II. PROBLEM STATEMENT

Aim. The aim of this work is to improve the quality of the ergatic aircraft control system.

Earlier, methods were obtained for assessing the quality of the crew piloting technique by autocorrelation functions and the laws of roll angle distribution [1] – [4]. The normal distribution law and small values of the coefficients of autocorrelation functions indicate a good quality piloting technique.

In this paper, it is proposed to consider the autocorrelation function, its spectrum and the distribution law of the pitch angle of the real flight of the An-148 aircraft.

There are cases when pilots in a state of stress allow unacceptable values of the angle of attack and at the same time do not control the readings of other instruments, according to which it is possible to restore the spatial orientation. Not less than three cases are known in case of a failure in the speed indication system, when the actions of the pilots led to air crashes. Therefore, it is necessary to prescribe an algorithm for the pilot's actions in such a situation.

III. Problem Solution

A. Analysis of the law of distribution

Large pitch angles, which are associated with the psychophysiological state of the pilot, affect the quality of flight in a horizontal plane. Let us analyze the flight quality in the horizontal plane in pitch in the real flight of the An-148 aircraft from the end of the second turn to landing.

We construct a histogram of the distribution of the pitch angle when approaching the pilot after the 2nd turn (excluding pitch during turns) before landing (Fig. 1). We also select the corresponding theoretical distribution.

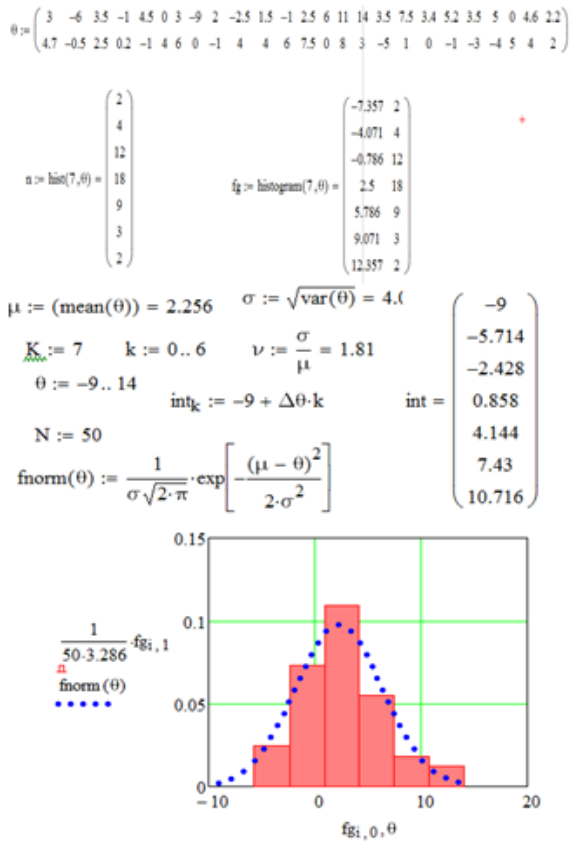

Fig. 1. Listing of the construction of a histogram of the values of the pitch angle (ϑ), its approximation by the normal distribution law

Let us verify the correspondence of the theoretical normal distribution to the statistical one according to the Pearson agreement criterion (Fig. 2).

The calculations showed that the statistical distribution ϑ does not contradict the normal distribution with a probability of approximately 0.7.

B. Analysis of the autocorrelation function and its pitch angle spectrum

We use the analysis of autocorrelation functions [5] to assess the quality of the flight from the end of the second turn to the fourth and after it until landing (excluding turns). We consider only the amplitude of the parameters. Using normalized autocorrelation functions, we calculate the coefficients of its first negative values y_1 (Fig. 3).

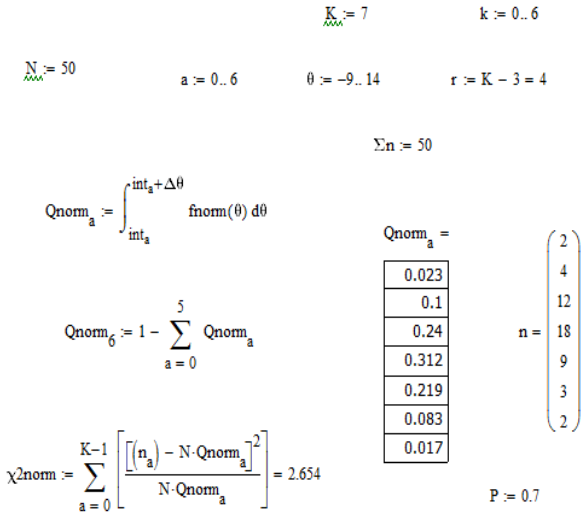

Fig. 2. Listing of verification of compliance of the theoretical normal distribution with the statistical one according to the criterion of agreement χ^2

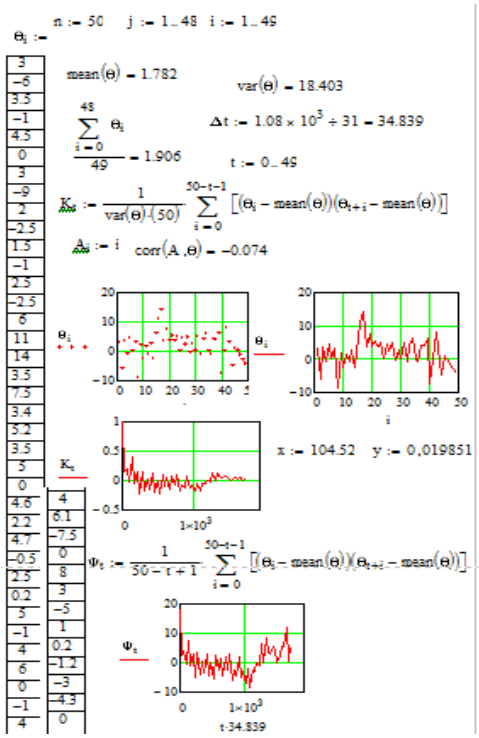

Fig. 3. Listing of the calculation of the normalized autocorrelation function of the pitch angle (y_{norm}= 4.453)

Let us calculate the spectrum of the unnormalized autocorrelation function of the pitch angle (Fig. 4). Listing a fragment of a function implementation.

Based on the obtained values of y_{norm} = 4.453 and y_{unnorm} = 63.28 and relying on studies on the angle of roll, we conclude that the quality of the piloting technique is good. This also confirms the normal distribution law.

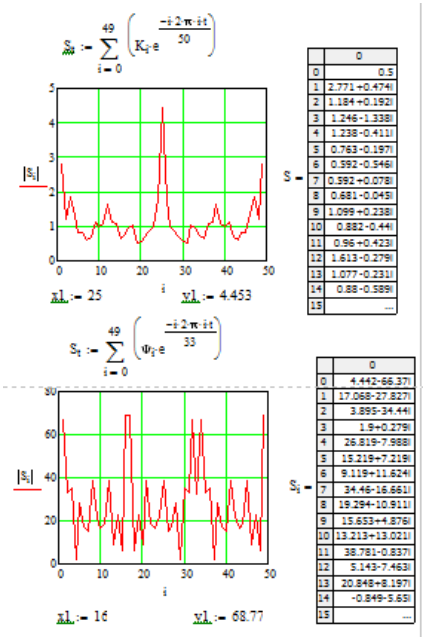

Fig. 4. Listing of the calculation of the spectrum of the unnormalized autocorrelation function of the pitch angle (y_{unnorm} = 68.77)

C. Installation of an additional piloting alert system in case of failure of angle or speed sensors

Cases of inappropriate actions of pilots during failures in speed indicator systems have been recorded. The failure in the systems connected with the lack of heating of the full pressure pipelines or the ingress of ice particles into the air pressure receiver. There were at least three such cases ended in an exident. In the absence of any action on the part of the pilots, there would be no exident. During take-off and improper operation of the speed indicator, the pilot turned the plane into a dive from which he could not exit. On the flight level, the pilots pulled in one case the steering wheel, in the other the joystick towards themselves, which led to a stall. If the angle of attack indicator in the system failed due to its freezing, the pilots could not establish an error in the autopilot. It reads the indications from the angle of attack sensor. This led to the stall in the spin and, as a result, to an exident.

When developing the aircraft operation manual, tables are entered there that can be used to determine the correct dependence of speed on the angle of attack. If this dependence is incorrect, then it is necessary to signal the crew (Fig. 5).

Consider the algorithm of the crew actions in case of failure in the systems for indicating the angle of attack or speed (Fig. 6).

Figure 6 illustrates the signal path from accepting different parameters to indicate on the display [6], [7]. This value is further implemented through the actuator displayed on the interface (displays).

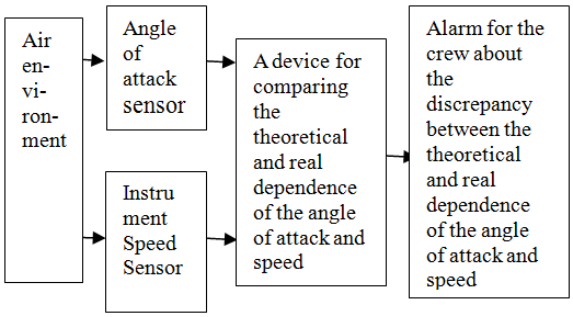

Fig. 5. The alarming system about a failure in the indication systems of the angle of attack or speed

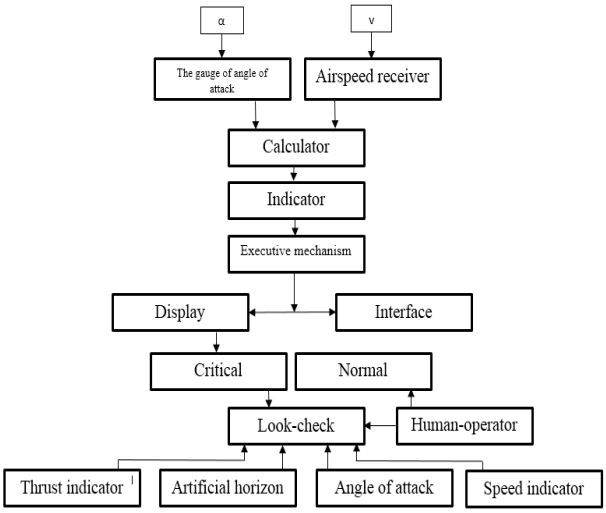

Fig. 6. Scheme of the algorithm of actions of the crew at the alarm signaling in case of failure in systems of indication of angle of attack or speed

If an incorrect mismatch is detected, then one of the sensors will probably fail.

The crew action algorithm in this case is as follows:

1. Move the look to the horizon and compare its changes with the angle of attack indicator.
2. When correlating them, suspicion falls on a malfunction in the instrument speed indicator system.
3. Verify proper engine thrust.
4. After confirming the suspicion of a malfunction (failure) in the instrument speed indicator system, focus on the indicator of the horizon, engine thrust and angle of attack.
5. If there is a failure in the system of indicating the angle of attack, check the correlation between the indicators of the horizon and the angle of attack.
6. Next, focus on the horizon, engine thrust and speed.
7. If there is a natural horizon, check actions on it.

The methods, systems and recommendations proposed above are advisable to apply in combination. The main result of the above studies should be an increase in safety in case of failures in avionics systems.

IV. CONCLUSIONS

The assessment of the quality of the piloting technique by analyzing the autocorrelation function of the pitch angle and its spectrum is consistent with the estimation method according to the distribution laws. A good technique was established for piloting the An-148 pilot under normal flight conditions.

The scheme of a warning system for failures of the instrument speed indicator or angle of attack indicator has been developed. Recommendations on the actions of pilots in such situations are developed.

The scheme of an alarming system for failures of the instrument speed indicator or angle of attack indicator has been developed. Recommendations on the actions of pilots in such situations are developed.

The crew's erroneous actions occur when they have increased tension (stress). The proposed methods for assessing the quality of piloting techniques should be applied on an integrated simulator of an airplane. It is also advisable to work on the simulator actions in case of failure in the system of indicating the angle of attack or instrument speed according to our recommendations.

REFERENCES

[1] Y. V. Hyshchenko, "Autocorrelation functions in determining the signs of the phenomenon of strengthening the dynamic stereotype of a pilot," Academy Scientific Papers: Issue V, Part 1, State Flight Academy of Ukraine, DLAU, 2000, pp. 226–231. (in Russian)

[2] Y. V. Hryschchenko, "Training pilots for flights in special situations, taking into account the phenomenon of strengthening the dynamic stereotype," Cybernetics and computer engineering, NAS of Ukraine, 2003, vol. 139, pp. 81–85. (in Russian)

[3] Y. V. Hryschchenko, "Analysis of changes in the dynamic stereotype of pilots during flight training on an integrated simulator of an airplane," Cybernetics and computing engineering, NAS of Ukraine, 2004, vol 142, pp. 35–40. (in Russian)

[4] V. D., Gulenko, Y. V. Hryschchenko, and V. M. Gribov, "Modeling and estimation of visual loss of roll angle by flight crews based on modular distributions of flight parameters," Cybernetics and computing engineering, NAS of Ukraine, 2010, vol. 160, pp. 43–56. (in Russian)

[5] M. Zaliskyi, O. Solomentsev, R. Odarchenko, and S. Gnatyuk, "Research of Energy Characteristics of QAM Modulation Techniques for Modern Broadband Radio Systems," Electronics and Information Technology: IEEE International Conference, 23-27 May 2016, Proceedings, Odesa, 2016, pp, 53–58. https://doi.org/10.1109/ICEAIT.2016.7500991

[6] Y. V. Hryschchenko and I. V. Kravets, "Signaling methods about deteriorating quality of aircraft flight," Scientific and Technical Conference "Problems of Development of Global Communications, Navigation, Observation and Organization of Air Traffic CNS/ATM", 21-23 of November, 2018, 66 p.

[7] Y. V. Hryschchenko, I. V. Kravets, "Signaling methods about deteriorating quality of aircraft flight and training of pilots," XIV International Scientific and Technical Conference "Avia-2019". Section 15 – State and prospects of avionics development, 2019, pp. 15.1–15.5.

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Ю. В. Грищенко, С.В. Павлова, Д. М. Піпа, І. В. Кравець. Системи оцінювання якості техніки пілотування у вертикальній площині

У даній статті розглянуто проблему оцінювання якості техніки пілотування екіпажем Ан-148 з урахуванням людського фактора. Розрахунки показали, що статистичний розподіл кута тангажу не суперечить нормальному розподілу. Це свідчить про хорошу якість техніки пілотування. Для оперативного вирішення цієї проблеми пропонується аналіз автокореляційних функцій і її спектрів. Оцінка якості техніки пілотування методом аналізу автокореляційної функції кута тангажу і її спектра узгоджені з методом оцінки за законами розподілу. Встановлено хороша техніка пілотування пілота Ан-148 під час польоту нормальних умовах. Запропоновано схему системи попередження про відмови (збої) систем відображення значень кута атаки або швидкості і алгоритм дій в таких випадках.
Ключові слова: автокореляційна функція; амплітуда параметра; людський фактор; приладова швидкість; спектральний аналіз.

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Ю. В. Грищенко, С. В. Павлова, Д. М. Пипа, И. В. Кравец. Системы оценки качества техники пилотирования

В данной статье рассмотрена проблема оценки качества техники пилотирования экипажем Ан-148 с учетом человеческого фактора. Расчеты показали, что статистическое распределение угла тангажа не противоречит нормальному распределению. Это свидетельствует о хорошем качестве техники пилотирования. Для оперативного решения этой проблемы предлагается анализ автокорреляционных функций и ее спектров. Оценка качества техники пилотирования методом анализа автокорреляционной функции угла тангажа и ее спектра согласованы с методом оценки по законам распределения. Установлена хорошая техника пилотирования пилота Ан-148 при полете нормальных условиях. Предложена схема системы предупреждения об отказах (сбоях) систем отображения значений угла атаки или скорости и алгоритм действий в таких случаях.

Ключевые слова: автокорреляционная функция; амплитуда параметра; приборная скорость; спектральный анализ; человеческий фактор.

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