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INFLUENCE OF THE PILOT'S PSYCH OPHYSIOLOGICAL PRESSURE ON THE QUALITY OF THE FLIGHT PILOTING TECHNIQUE

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Abstract*—This article deals with issues related to assessing the impact of the pilot's psychophysiological pressure on the quality of the flight piloting technique. The quality of the aircraft control technique was evaluated by changing one of the flight parameters, namely the pitch angle during the landing approach. The analysis of the autocorrelation functions of the controlled parameter and their spectra were used to conduct the research. The proposed mathematical apparatus makes it possible to track the moment the pilot's psychophysiological pressure increases to a state of emotional instability, build a function of its influence on the quality of the flight piloting technique, and develop an effective method of anti-stress training for crews.*

Index Terms—Autocorrelation functions; human factor; spectrum analysis; flight simulator; flight piloting technique.

I. INTRODUCTION

The problem of flight safety is one of the key problems in the aviation industry. Safety issues must be brought to the fore, and flight safety technologies must be constantly improved. Since the lives of the entire crew and passengers on board the aircraft depend on safety, awareness of the importance of safety and its efficiency issues in aviation is the main driving force for its continuous development.

According to statistics, the cause of 80% of aviation incidents and disasters is the human factor. Therefore, it is significant to study all the factors influencing a person and to be able to manage the emotional component of the aviation crew. A person can be unpredictable in his actions and emotions. To acquire skills to deal with stressful factors, an aircraft pilot needs experience that can provide such countermeasures.

The main goal in the analysis and research of the human factor is to find out the human operator's physical, psychological and other capabilities and limitations in certain conditions and environments. In the future, the obtained research results will help to understand how to avoid aviation incidents caused by the human factor and, in particular, to improve the professional training of pilots with the help of unique methods developed to prevent these incidents. Another aspect of using the results of such studies is the creation of conditions for comfortable, safe and effective human work in the energy system.

To understand the effectiveness of a pilot as an operator when controlling an aircraft at various stages of its flight, it is necessary to assess the quality of its flight piloting technique. This procedure allows for a deeper analysis of flight information and to identify the most dangerous areas of the flight. Also, it helps to create measures to counter negative factors that come out when piloting an aircraft.

This article examines the impact of changes in flight parameters, namely changes in the pitch angle, on the quality of aircraft control techniques. For an in-depth description of flight parameter changes, the analysis of the autocorrelation function and its spectra is used.

II. PROBLEM STATEMENT

The purpose of this work is to assess the quality of the aircrew flight piloting technique in the ergatic system.

The papers [1], [2] considered the issue of assessing the quality of the piloting technique in the horizontal plane by the angle of roll in the director control mode [3]. The studies were carried out on the flight simulator An-148 and B-737-500.

In this paper, we analyze the data from the transcripts of real flights of the B737NG, An-148 and the An-148 full flight simulator in the vertical plane along the pitch angle on the glide path. To do this, a spectral analysis of the autocorrelation functions of the pitch angle is carried out. A block diagram of the aircrew training is developed taking into account the results obtained.

III. PROBLEM SOLUTION

The autocorrelation function makes it possible to characterize the degree of correlation between individual elements of a time series presented as a random process. In our case, such elements are pitch angle amplitude values.

In the case of the analysis of flight parameters, in particular, changes in the pitch angle, the autocorrelation function provides a complete description of random processes and makes it possible to track at which moment the pilot's psychophysiological pressure increases. Flight analysis with the help of the autocorrelation function significantly expands the possibility of obtaining statistical data about the flight.

The first negative values of amplitudes by modulus indicate that the pilot's stress level is increasing. Such a change is dangerous and can cause the pilot's movements to become hasty and imprecise or completely uncontrolled, which in turn can cause critical angles of attack to be reached and cause the aircraft stalling.

When calculating the autocorrelation function, we used graphs of real flights on a modern Boeing 737 NG aircraft. To calculate the autocorrelation function, we first determined the pitch angle change amplitude during four flights. After that, the normalized autocorrelation function was calculated using the formula:

$$K(t)=\frac{1}{\sigma N}\sum_{i=0}^{N-t-1}\left[(\theta_i-m)(\theta_{t+1}-m)\right],$$

where N is the number of observations in the time series t, θ_i is the pitch angle amplitude, i = 1, 2, 3; m is the mathematical expectation, σ is the mean square deviation.

And then calculate the unnormalized autocorrelation function according to the formula:

$$\psi(t)=\frac{1}{N-t+1}\sum_{i=0}^{N-t-1}\left[(\theta_i-m)(\theta_{t+i}-m)\right].$$

To calculate the spectrum of autocorrelation functions θ for discrete values, we use the Fourier integral formula:

$$S_t=\sum_{i=1}^{N-1}K_i e^{\frac{-i2\pi it}{N}}.$$

We will analyze the autocorrelation functions of four flights in the airline on the Boeing 737 NG aircraft.

Let's analyze the autocorrelation functions of the pitch angle. Figure 1 shows the full calculations of the normalized and unnormalized autocorrelation functions for flight parameters #1.

So, first, let's consider the spectrum calculations for flight #1:

On Figure 2 shows the calculation of the spectrum of normalized and unnormalized autocorrelation functions for flight #1. The maximum values of the amplitudes of the spectra of normalized and unnormalized autocorrelation functions are equal to 2.6755, 9.108, respectively.

The next step is to calculate the spectrum of autocorrelation functions for flight #2. The maximum values of normalized and unnormalized autocorrelation functions are equal to 1.7532, 5.462 (Fig. 3).

During the spectral analysis of flight parameters #3, it became known about its maximum values, which are equal to 1.3185, 5.1336 (Fig. 4).

Data from the analysis of normalized (y1) and unnormalized (y2) spectra of autocorrelation functions of the pitch angle during landing approach of B-737 NG under normal flight conditions are presented in Table I.

These data indicate the good quality of the flight technique of the aircrews. Pilot 3 has a slightly better piloting technique.

Next, an analysis of the real flight without failures of the An-148 aircraft on the glide path is carried out according to the autocorrelation function (Fig. 5) and its spectrum (Fig. 6), which is 0.40339, 3.1291.

There is an approximate correspondence between the data of flights without failures of the B-737NG and An-148 aircraft.

Now let's consider the negative effect of complex failures on the psychophysiological pressure of the crew on the full flight simulator An-148.

Next, an analysis of the real flight without failures of the An-148 aircraft on the glide path is carried out according to the autocorrelation function (Fig. 7) and its spectrum (Fig. 8), which are equal to 1.7885, 70.893.

The maximum values of the unnormalized spectra of autocorrelation functions during a real flight on the An-148 without failures and with complex failures on the An-148 full flight simulator differ in 22.656 times.

To avoid such phenomena, it is necessary both to prepare the crews for special cases on the full flight simulator and to prompt the crew for actions in flight.

$n := 27 \quad i := 1..26 \quad j := 1..25$

$\theta_i :=$

1.8
1.7
1.9
2.6
3
1.5
4
5.1
3.9
3.6
2.2
0.2
−1
−2
1.9
1
0.2
2.4
0
2.6
0.2
2.7
0.5
2.3
1
0.2
2.7

$\text{mean}(\theta) = 1.611$

$t := 0..66$

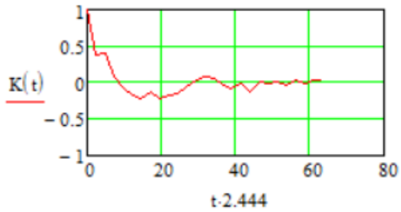
$\text{var}(\theta) = 2.548$

$\Delta t := 66 \div 27 = 2.444$

$$\frac{\sum_{i=0}^{26} \theta_i}{27} = 1.611$$

$$K(t) := \frac{1}{\text{var}(\theta)\cdot(27)} \cdot \sum_{i=0}^{27-t-1} \left[(\theta_i - \text{mean}(\theta))(\theta_{t+i} - \text{mean}(\theta))\right]$$

$A_i := i \qquad \text{corr}(A, \theta) = -0.271 \qquad K(2) = 0.388$



$$\Psi(t) := \frac{1}{27 - t + 1} \cdot \sum_{i=0}^{27-t-1} \left[(\theta_i - \text{mean}(\theta))(\theta_{t+i} - \text{mean}(\theta))\right]$$

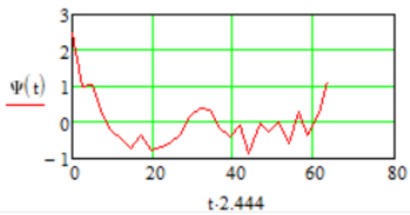
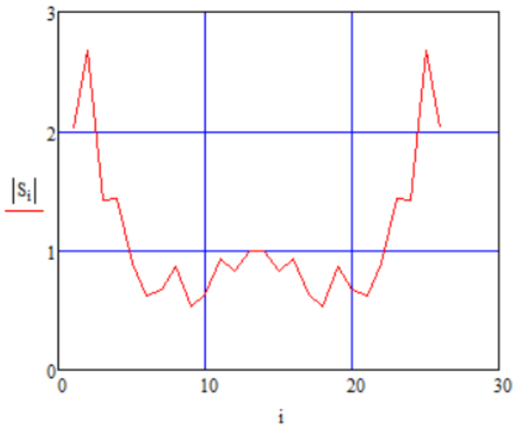


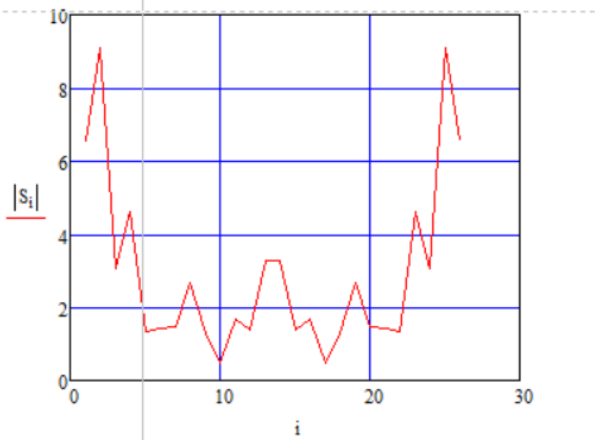
Fig. 1. Listing of the calculation of normalized and unnormalized autocorrelation functions

$$S_t := \sum_{i=0}^{26} \left(K_i \cdot e^{\frac{-i\cdot 2\cdot \pi \cdot i \cdot t}{27}} \right)$$



$y1 := 2,6755$

$$S_t := \sum_{i=0}^{26} \left(\Psi_i \cdot e^{\frac{-i\cdot 2\cdot \pi \cdot i \cdot t}{27}} \right)$$



$y2 := 9.108$

Fig. 2. Listing of the spectrum calculation of normalized and unnormalized autocorrelation functions for flight #1

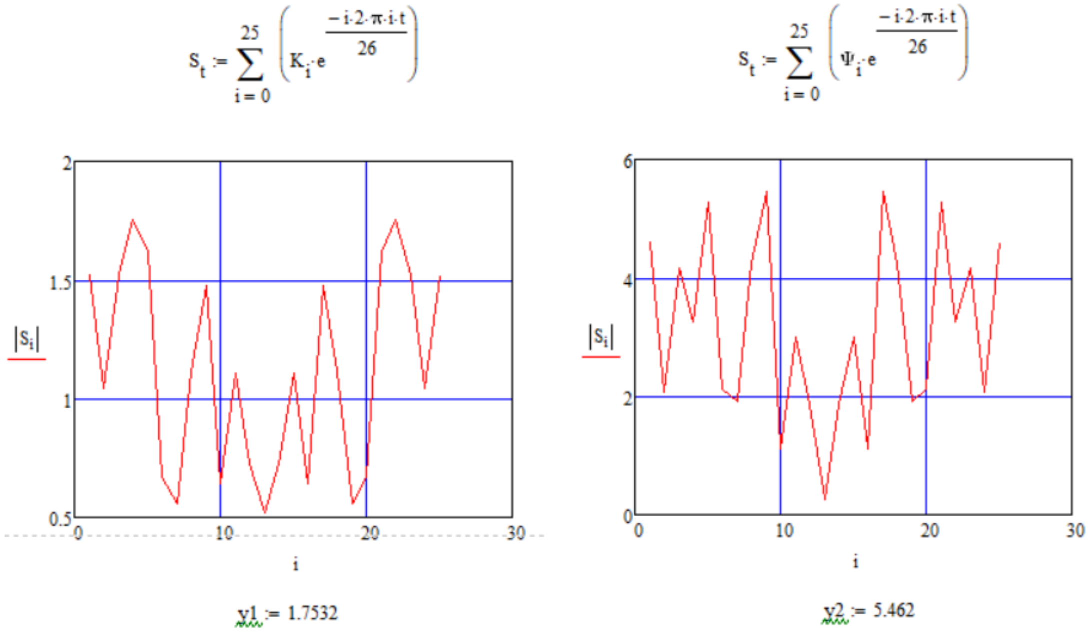


Fig. 3 Listing of the spectrum calculation of normalized and unnormalized autocorrelation functions for flight #2

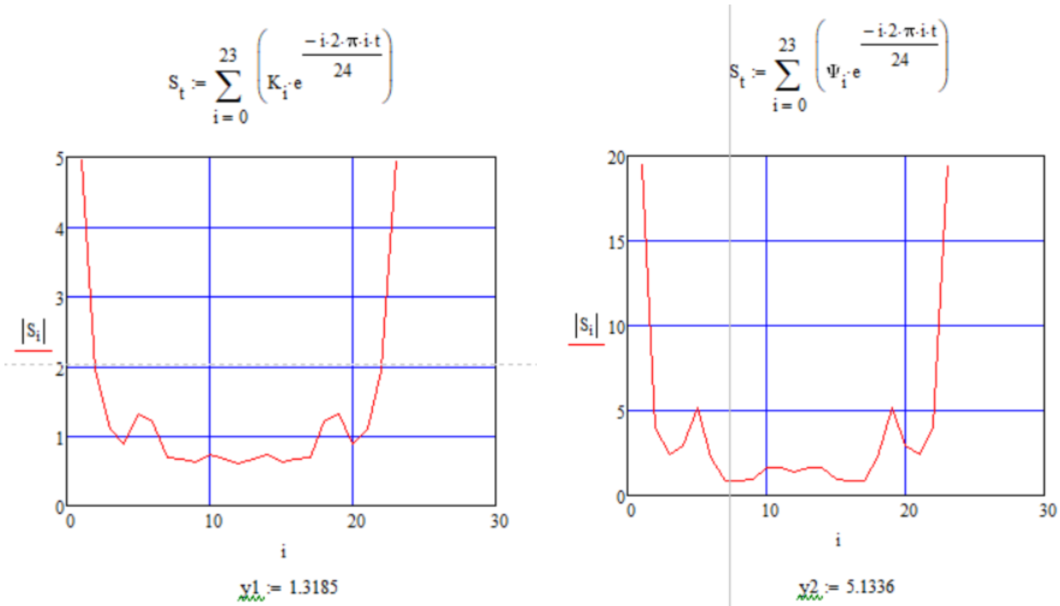


Fig. 4. Listing of the spectrum calculation of normalized and unnormalized autocorrelation functions for flight #3

TABLE I. ANALYSIS DATA OF NORMALIZED (Y1) AND UNNORMALIZED (Y2) SPECTRA OF AUTOCORRELATION FUNCTIONS OF THE PITCH ANGLE

Flight number	**y1**	**y2**
1	2.6755	9.108
2	1.7532	5.462
3	1.3185	5.1336

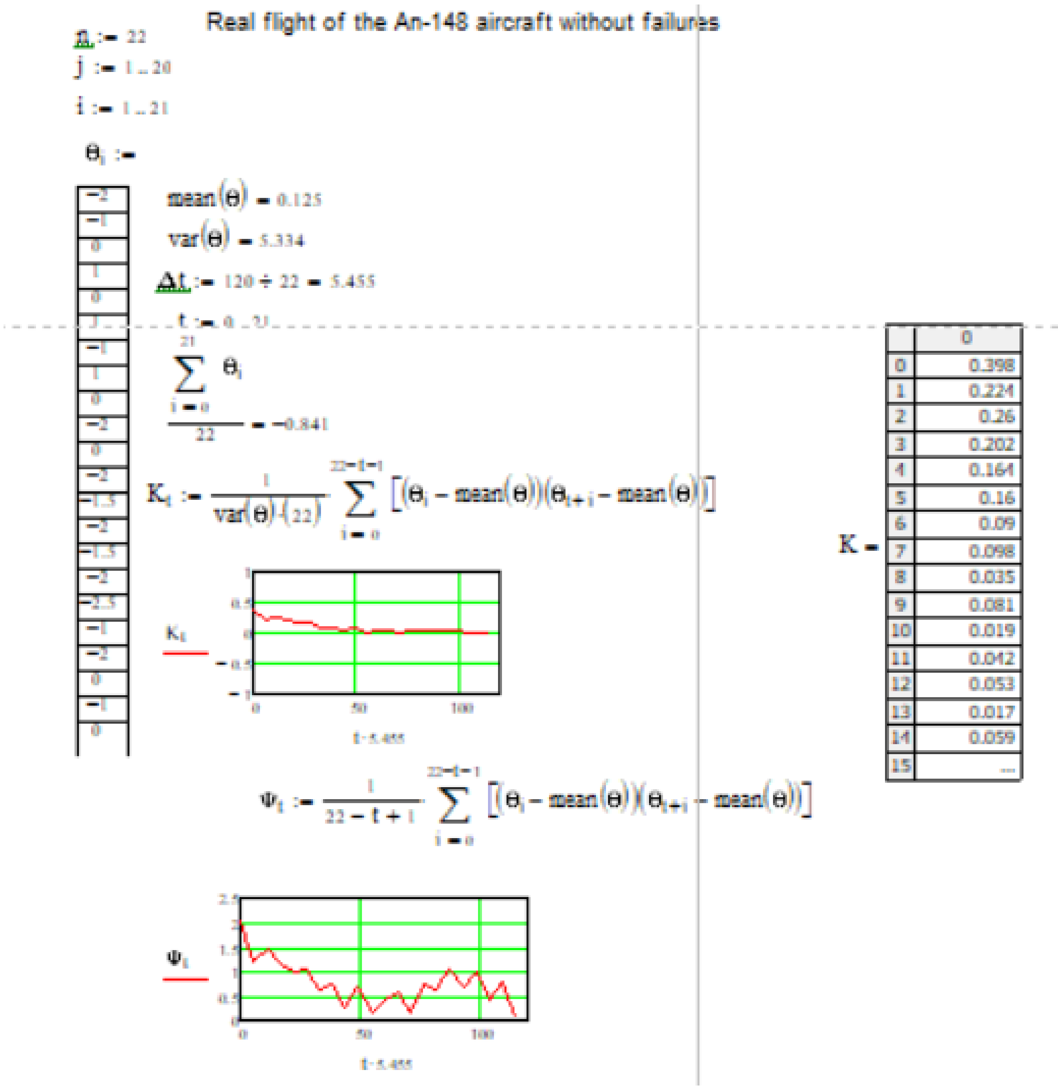


Fig. 5. Listing of the analysis of normalized and unnormalized autocorrelation functions

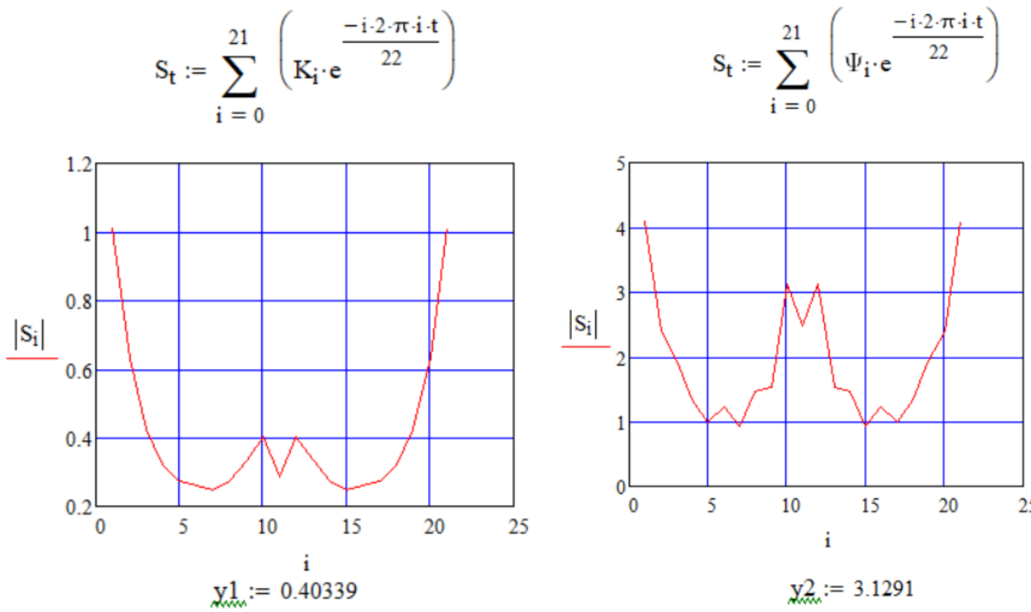


Fig. 6. Listing of the spectrum calculation of normalized and unnormalized autocorrelation functions

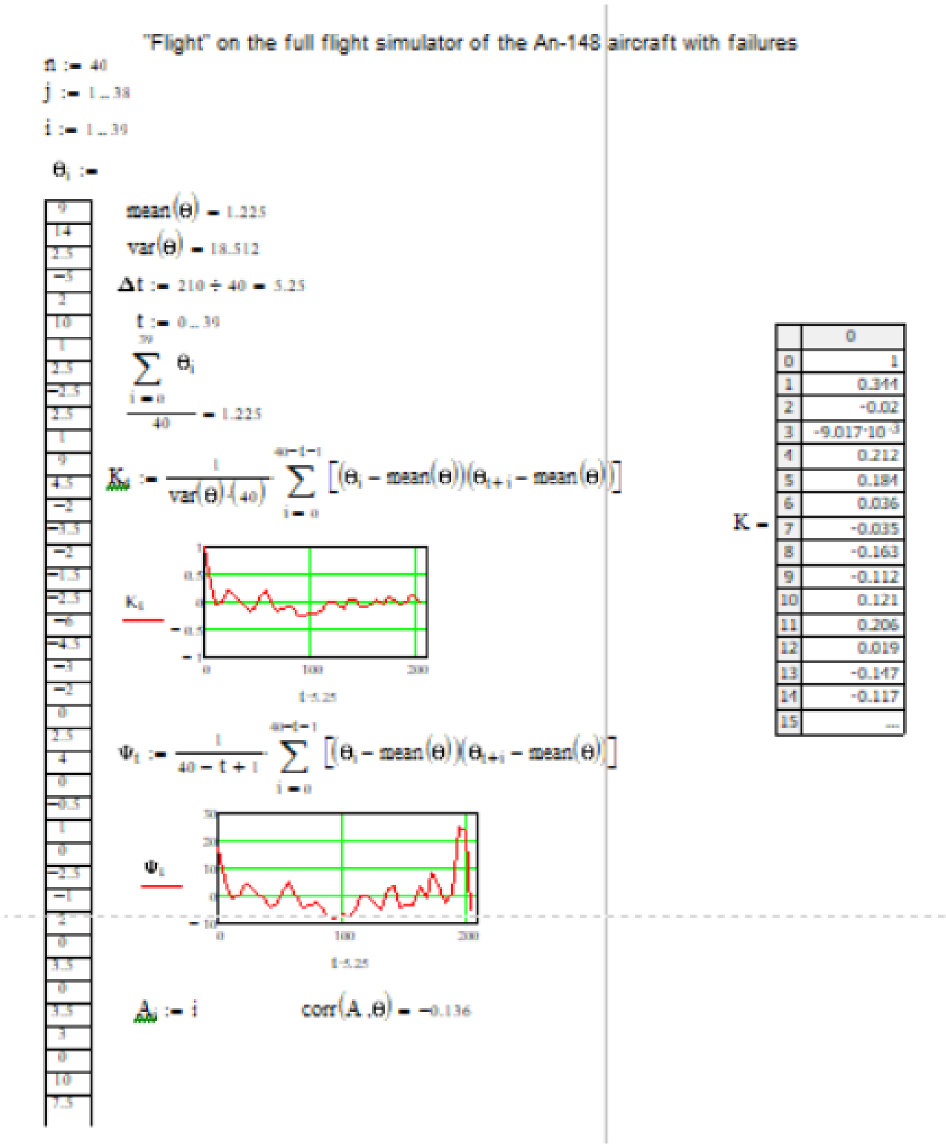


Fig. 7. Listing of calculation of normalized and unnormalized autocorrelation functions

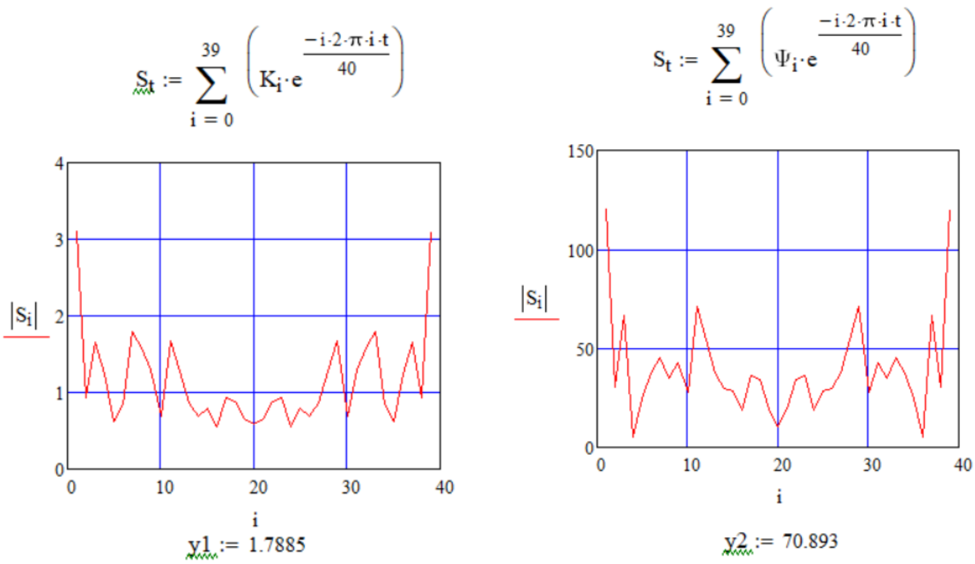


Fig. 8. Listing of calculation of the spectrum of normalized and unnormalized autocorrelation functions

The increase in the amplitudes of the aircraft parameters is directly related to the change in the psychophysiological state of the pilot.

A comprehensive analysis of the function, where the flight parameters are presented, can help determine the psychophysiological state of the pilot and show his level of training (Fig. 9).

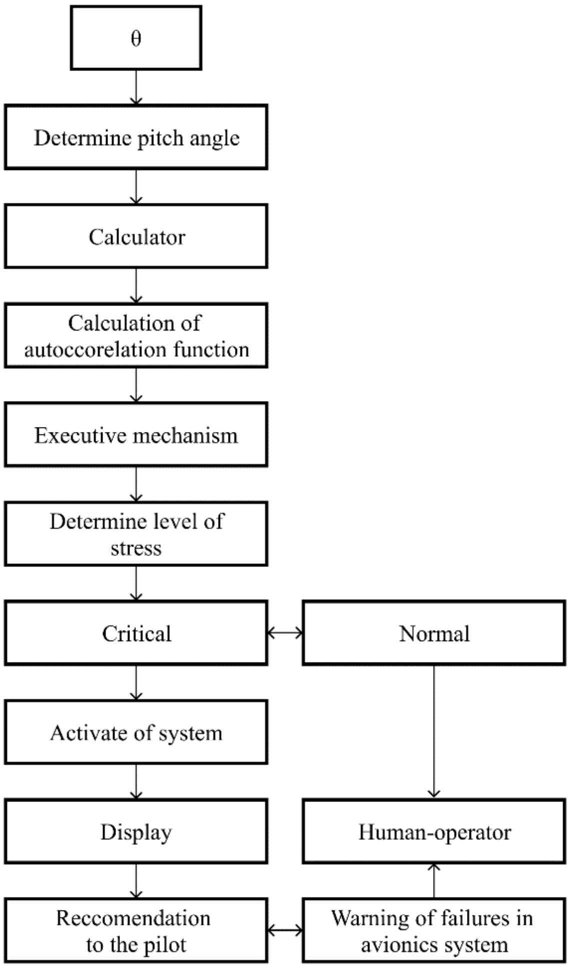


Fig. 9. Scheme of signaling in case of determine psychophysiological pressure of the pilot

The first step in the operation of the system is to determine the pitch angle of the aircraft, the amplitude of changes in its parameters using telemetry data of the aircraft. These indicators directly characterize how smoothly the aircraft moves. To calculate the autocorrelation function, we collect the input data of the flight amplitude. In our case it is the parameters of the pitch angle. As a result of calculating the function, we have graphs that show us in what condition the pilot is. If the calculation of the autocorrelation function results in negative values on the graph, it indicates that the pilot feels tension and his stress level may increase depending on the number and magnitude of negative values. The system defines this indicator as evidence that the pilot-in-command is under psychophysiological tension. In this case, the system works and displays recommendations for reducing stress and directs the pilot's attention to the information that will help him return the aircraft to a safe position.

IV. CONCLUSIONS

Thus, as research has shown, for assessing the quality of piloting techniques, the technique of using autocorrelation functions, depending on the researched random parameter, has a high enough informative capacity, which can give a complete description of this process.

The analysis of autocorrelation functions and their spectra showed that at certain sections of the flight, at appropriate time intervals, the pilot transitions between a normal emotional state and a state of emotional instability. Such an analysis shows the time intervals of flights in which the pilot was maximally exposed to stress and psychophysiological pressure.

During the analysis of changes in the quality of piloting using the oscillograms of Boeing-737-NG flights, it was determined that the random pitch angle function is ergodic and stationary in nature.

Based on the graphs presented above, it can be argued that during the landing approach, if the pilot moved with the smallest deviation from the given glide path, then the pilot's stress level was at its lowest.

Investigating the occurrence of in-flight stress using autocorrelation function analysis can be an essential step to develop aviation safety. By analyzing the autocorrelation functions, it is possible to prevent the negative impact of stress on the technique piloting quality, particularly in the vertical plane.

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Ю. В. Грищенко, Т. О. Пінчук, В. Г. Романенко, О. П. Слободян. Вплив психофізіологічного навантаження пілота на якість техніки пілотування

В даній статті розглянуті питання, які пов’язані з оцінкою впливу психофізіологічної напруженості пілота на якість техніки пілотування літаком. Якість техніки керування повітряним судном оцінювалась за допомогою зміни одного із параметрів польоту, а саме – кута тангажа при заході літака на посадку. Для проведення дослідження використовувався аналіз автокореляційних функціій контрольованого параметра та їх спектри. Запропонований математичний апарат дає можливість прослідкувати у який момент психофізіологічна напруженість пілота зростає до стану емоційної нестабільності, побудувати функцію її впливу на якість пілотування літака, та розробити ефективну методику антистресової підготовки екіпажів.

Ключові слова: автокореляційна функція; людський фактор; спектральний аналіз; комплексний тренажер літака; техніка пілотування.

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