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THE PROBLEM OF UNCOORDINATED AIRCRAFT TURN ON SMALL FLIGHT SPEED

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Abstract—This article addresses the issue of deteriorating flight quality when receiving a crew. Provision is made for the use of a crew warning system for a possible collection of data on the speed and speed of air traffic. It is proved that a decrease in the area of correlation fields indicates a non-coordinated reversal. With sufficient speed, uncoordinated turns are not so dangerous. Therefore, we reviewed the indications for the correlation fields of the coefficients of the angle of attack and instrumental velocity. A method has been developed for calculating the area of correlation fields above the existing parameters. It is based on the least squares method. The proposed quantitative characteristics determine the quality of flight depending on the area of the correlation fields.

Index Terms—Correlation field; flight path; glide path; human factor; parameter amplitude.

I. INTRODUCTION

One of the most complex and intense flight phases is landing. This is due to the fact that it requires high accuracy of angular control and trajectory-based parameters of the flight, taking into account the speed of the aircraft and the incident air flow. Low altitude and speed during landing help to reduce crew's decision time. It should also be noted that at this stage, the occupancy of the pilot and crew members increases with additional functions of different character: connection with ground services, change of operating modes of engines, issue of chassis and flaps, control of extracabin space and others. Simultaneous control and analysis of many parameters and factors of flight requires the crew of increased concentration of attention.

The approach to landing the aircraft consists of the following stages: the output of the aircraft in the area of the aerodrome, the expected maneuvering, the event in the garden on the glide path, alignment, landing and mileage.

One of the main tasks of the pre-shunting maneuvering of the aircraft is to ensure its entrance to a given point of the airspace in such a way that the plane was on the extension of the runway axis with a given height and range. If this problem is solved and the plane is in a given small area of the air space, then the parameters of the spatial position of the airplane and its speed are estimated. If these parameters satisfy the specified requirements, then the precondition for a successful approach is formed and the crew is made to decide on the continuation of the landing process – the entrance to the glide path on the seized signal of the glide path radio beacon. If the above conditions are not respected, the crew decides to leave for the second course.

II. PROBLEM STATEMENT

The purpose of this work is to increase the reliability of the ergatic control system of the aircraft in case of failures in avionics systems.

On modern aircraft digital avionics systems. Despite the high reliability of modern element base, in such systems there are failures. The crew may have difficulty rebooting such systems or they may receive false information.

Earlier in article [1], the possibility of determining a noncoordinated reversal by the parameters of the angles of attack and roll was considered. However, with sufficient speed, such an error in the piloting technique does not pose a big threat. Thus, the greatest danger is the loss of speed. With a constant engine thrust speed is directly related to the angle of attack. From this it follows that in case of incorrect indications of instrumental speed, this could be determined by changing the angle of attack and vice versa, if proceeded from the condition of ordinariness. Therefore, in this article will be considered the possibility of determining the correlation between the velocity and the angle of attack by the correlation field.

III. PROBLEM SOLUTION

When performing complex flight tasks, the pilot needs operational information on the quality of the

airplane control system. On aircraft, even in the flight mode, mismatch between the angle of attack and the instrument speed, as well as uncoordinated evolution, should not be allowed. But sometimes these systems and control systems fail.

The term "failure" refers to a sudden technological failure or suddenly disappearing, which is generally not diagnosed by on-board and ground-based controls. Such negative random cyclic processes can occur in the electronic security control systems themselves.

Under the correlation field is understood not a table or a matrix, but a group region in which there are contour shapes (contours) over which any groups of transformations up to free can occur.

Approaches focused on contour analysis, as shown N. Wiener (the terms "contours", "contour figure" applies as synonyms, correlation field in the two-dimensional region), sharply reduce the amount of unused information and focus attention on the analysis of contours of figures.

As our studies of the parameters of the piloting technique have shown, it perfectly characterizes the effect of preservation of orthonormalization of on-board coordinates. It is precisely this figure that is observed during processing. The peculiarity of such figures of any form is the presence of the area as a mathematical value and as an invariant of the correlation field. Lack of space creates the effect of breaking orthonormalization, which happens when extremely complex.

The analyzing the flight information information [2] from the angle of attack and the instrument speed before the failure and after the failure of the warning system. It is introduced the dimensionless values of the angle of attack and the instrument speed:

$$\Delta\alpha_j = \left(\alpha_i - 1\right)/1, \qquad \Delta V_j = \left(V_i - 1\right)/1,$$

where 1 is the minimum allowable error value when reading flight information; α is the angle of attack, and V is the instrument speed.

For an ideal system, that is to say, to ensure that the operator is fully airborne and that the airplane is perfectly error-free while processing information about the flight path, the aircraft manages a fully-specified flight program $I(t)$ and the aircraft without any error gives information about the flight $I(t)$.

The specified trajectory and information about the actual flight path, coming from the instrumentation of the aircraft, will be the same. Any deviation of these two information, that is, the deviation from the given flight mode is immediately processed by the operator. The operator compares the information coming to the first and second channels and will work to zero the difference about the information of the real and given trajectory.

In order not to operate the aircraft on distorted information on the angle of attack and speed, it is suggested comparing the correlation fields $\Delta\alpha_j = (\alpha_i - 1)/1$ and $\Delta V_j = (V_i - 1)/1$, as well as α and γ to obtain information on the coordination of the turn. This information is transmitted from the sensors, the digital converter is transmitted to the unclear, and then the correlation fields are compared in the calculator. The pilot takes measures for correction of distorted by other means of displaying information (Fig. 1).
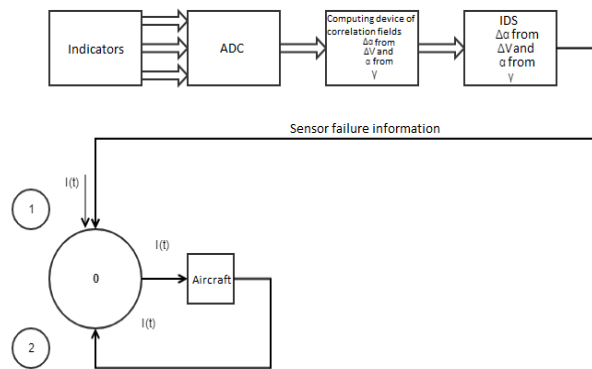

Fig. 1.   Scheme for obtaining information on the failure of one of the sensors (angle of attack or speed)

To implement the work of this scheme, it is offered the following method.

The values of relative areas indicate that the flight quality of the parameters ΔV and $\Delta\alpha$ in flight of the aircraft during the failure is much worse than before the failure. The deterioration of quality is 2.5 times.

Let the correlation field have a value: x_1, x_2, ..., x_n, which correspond to the magnitudes y_1, y_2, ..., y_n (Fig. 2).
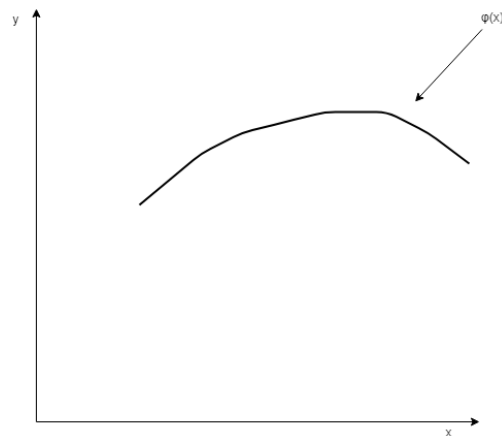

Fig. 2.   Approximation of given points by a function

Combine multiple points with functional dependence φ(x). It is made a choice on the basis of

theoretical measurements or on the basis of how the points are located on the correlation field. In order to as accurately as possible, the process of approximation should be selected in the selected function $y = \varphi(x, a, b, c, \ldots)$ numerical parameters a, b, c, ... To solve this problem could be applied a known method of least squares.

Consider the sum of the squares of the difference of values y_2 and function φ ... at the appropriate points. The function of the sum is denoted $F(a, b, c, \ldots)$.

$$F(a,b,c,\ldots) = \sum_{i=1}^{n}\left(y_i - \varphi(x_i,a,b,c,)\right)^2.$$

For the sum function it is necessary to select numerical parameters a, b, c, ..., so that it is the smallest, that is: $F(a,b,c,\ldots) = \min$.

To determine the minimum of the sum function, one must consider equations with partial derivatives:

$$\frac{\partial F}{\partial a} = 0, \frac{\partial F}{\partial b} = 0, \frac{\partial F}{\partial c} = 0, \ldots$$

It is represented these equations in the form of a system:

$$\begin{cases} \sum_{i=1}^{n}\left(y_i - \varphi(x_i,a,b,c,)\right)\dfrac{\partial\varphi(x_i,a,b,c,\ldots)}{\partial a} = 0, \\[2mm] \sum_{i=1}^{n}\left(y_i - \varphi(x_i,a,b,c,)\right)\dfrac{\partial\varphi(x_i,a,b,c,\ldots)}{\partial b} = 0, \\[2mm] \sum_{i=1}^{n}\left(y_i - \varphi(x_i,a,b,c,)\right)\dfrac{\partial\varphi(x_i,a,b,c,\ldots)}{\partial c} = 0. \end{cases}$$

The solution of such a system of equations when substituting their values x_i and y_i will have numerical parameters a, b, c, ... , which will best minimize the sum function $F(a, b, c, \ldots)$.

If another function is defined in the correlation field in the same way $y = \varphi(x)$, then if necessary you can calculate the area of the curvilinear figure, between these curves on a certain interval $x \in [x_1, x_2]$, (Fig. 3).
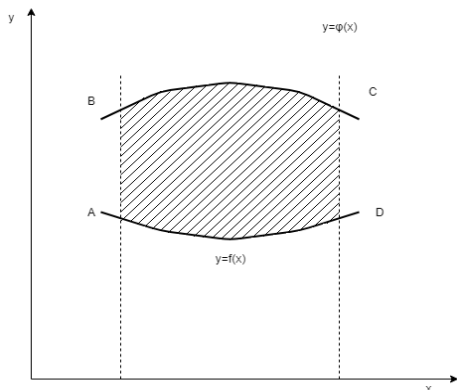

Fig. 3. Determination of the area of the curvilinear figure

$$S_{a,b,c,d} = \int_{x_1}^{x_2}\left(\varphi(x) - f(x)\right)dx.$$

If in a correlation field a function that approximates the given values is not constructed for certain reasons and it is necessary to determine the area of the polygon formed by the given points (Fig. 4), then in this case it is necessary to determine the functional dependence of each link of the polygon.
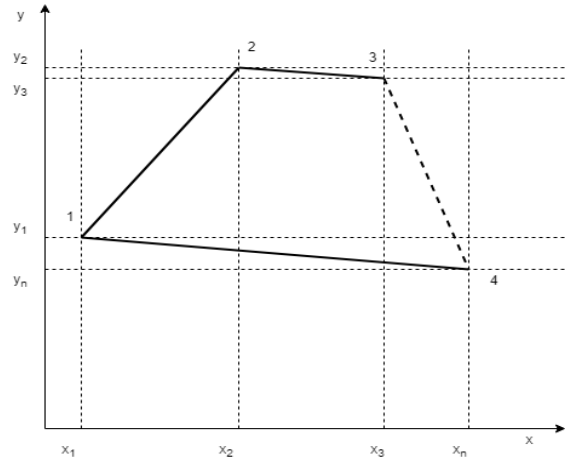

Fig. 4. A polygon formed by given points

Let the given polygon be convex. The equation is straight in sections $1 - 2, 2 - 3 \ldots, n - 1 - n, 1 - n$:

$$\frac{x - x_1}{x_2 - x_1} = \frac{y - y_1}{y_2 - y_1}, \text{ or } y_{1-2} = k_1 x + b_1,$$

$$\frac{x - x_2}{x_3 - x_2} = \frac{y - y_2}{y_3 - y_2}, \text{ or } y_{2-3} = k_2 x + b_2,$$

$$\ldots\ldots\ldots\ldots \qquad\qquad \ldots\ldots\ldots\ldots$$

$$\frac{x - x_{n-1}}{x_n - x_{n-1}} = \frac{y - y_{n-1}}{y_n - y_{n-1}}, \text{ or } y_{n-1-n} = k_n x + b_n,$$

$$\frac{x - x_1}{x_n - x_1} = \frac{y - y_1}{y_n - y_1}, \text{ or } y_{1-n} = k x + b_1.$$

The area of the polygon is determined by the formula:

$$S_{1-2-3-n} = \int_{x_1}^{x_2}\left(y_{1-2} - y_{1-n}\right)dx + \int_{x_2}^{x_3}\left(y_{2-3} - y_{1-n}\right)dx$$

$$+ \ldots + \int_{x_{n-1}}^{x_n}\left(y_{n-1-n} - y_{1-n}\right)dx.$$

Determine the area of the polygon, which is constructed according to the data in Table I and is depicted in Fig. 5. It represents the functional dependence of the angle of attack $\Delta\alpha$ of the flight speed ΔV in relative units.

Points on the graph number from 1 to 9. Line 1–9 is assumed to be imaginary. It binds to one integer the start and end of a sampling of the values of the velocity ΔV and the angle of attack $\Delta \alpha$. Real flight on this site was not carried out.

For each plot of the graph, it is defined the linear dependence and the data obtained will be reduced to Table II.

For each of the sites could be defined the subinterlacial function and leave the results of calculating them foregone in Table III.

The resulting total value of the polygon polygon area of the aircraft can be represented in relative units within $S \in [0; 1]$. To do this, could be defined the limit values for ΔV and $\Delta \alpha$:

$$\Delta \alpha_{ri} = 20.8 - 12 = 8.8, \qquad \Delta V_{ri} = 411 - 364 = 47.$$

Area in relative units:

$$S_{B1} = \frac{S_1}{\Delta \alpha_{ri} \Delta V_{ri}} = \frac{219.74}{8.8 \cdot 47} = 0.531.$$

When $S_B = 0$ this means that the flight did not take place for certain reasons. When $S_B = 1$ the sampling of the flight parameters of an airplane forms a rectangle or a square on a coordinate plane.

Similarly, it is processed a sample of airplane flight parameters during a malfunction. The sample data are presented in Table IV and are depicted in the form of a polygon in Fig. 6.

Polygon on figure 6 has 7 plots. Plot 1–7 is imaginary. For each plot, determine the linear dependence and get the results put in Table V.

TABLE I.   DATA TO DETERMINE THE AREA OF THE POLYGON

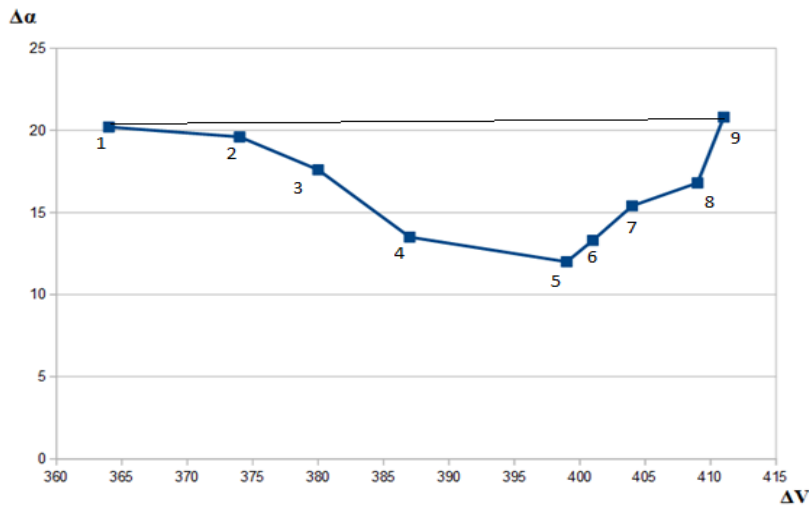| α	21.2	20.6	18.6	14.5	13	14.3	16.4	17.8	21.8
V	365	375	381	388	400	402	405	410	412
$\Delta \alpha$	20.2	19.6	17.6	13.5	12	13.3	15.4	16.8	20.8
ΔV	364	374	380	387	399	401	404	409	411

Fig. 5. Flight to failure

TABLE II.   LINEAR EQUATIONS OF SITES

Section Number	Initial Equation of the Plot	The Final Equation of the Plot
1–2	$\dfrac{\Delta V - 364}{374 - 364} = \dfrac{\Delta \alpha - 20.2}{19.6 - 20.2}$	$\Delta \alpha_{1-2} = -0.06 \Delta V + 42.04$
2–3	$\dfrac{\Delta V - 374}{380 - 374} = \dfrac{\Delta \alpha - 19.6}{17.6 - 19.6}$	$\Delta \alpha_{2-3} = -0.33 \Delta V + 144.069$
3–4	$\dfrac{\Delta V - 380}{387 - 380} = \dfrac{\Delta \alpha - 17.6}{13.5 - 17.6}$	$\Delta \alpha_{3-4} = -0.585 \Delta V + 270.17$
4–5	$\dfrac{\Delta V - 387}{399 - 387} = \dfrac{\Delta \alpha - 13.5}{12 - 13.5}$	$\Delta \alpha_{4-5} = -0.108 \Delta V + 55.22$
5–6	$\dfrac{\Delta V - 399}{401 - 399} = \dfrac{\Delta \alpha - 12}{13.3 - 12}$	$\Delta \alpha_{5-6} = -0.65 \Delta V + 247$

6–7	$\dfrac{\Delta V - 401}{404 - 401} = \dfrac{\Delta\alpha - 13.3}{15.4 - 13.3}$	$\Delta\alpha_{6-7} = -0.7\Delta V + 267$
7–8	$\dfrac{\Delta V - 404}{409 - 404} = \dfrac{\Delta\alpha - 15.4}{16.8 - 15.4}$	$\Delta\alpha_{7-8} = -0.28\Delta V + 97.72$
8–9	$\dfrac{\Delta V - 409}{411 - 409} = \dfrac{\Delta\alpha - 16.8}{20.8 - 16.8}$	$\Delta\alpha_{8-9} = -2\Delta V + 801.2$
1–9	$\dfrac{\Delta V - 364}{411 - 364} = \dfrac{\Delta\alpha - 20.2}{20.8 - 20.2}$	$\Delta\alpha_{1-9} = -0.0127\Delta V + 16.15$

TABLE III.   CALCULATING THE AREA

Section Number	Integral to Determine the Area	Land Area
1–2	$\int_{364}^{374}(0.0727\Delta V - 25.89)d(\Delta V)$	9.36
2–3	$\int_{374}^{380}(0.342\Delta V - 127.91)d(\Delta V)$	6.144
3–4	$\int_{380}^{387}(0.597\Delta V - 224.02)d(\Delta V)$	34.5
4–5	$\int_{387}^{399}(0.121\Delta V - 39.07)d(\Delta V)$	101.79
5–6	$\int_{399}^{401}(-0.6373\Delta V - 263.15)d(\Delta V)$	16.46
6–7	$\int_{399}^{401}(-0.687\Delta V + 283.15)d(\Delta V)$	19.89
7–8	$\int_{399}^{401}(-0.267\Delta V + 113.87)d(\Delta V)$	26.67
8–9	$\int_{399}^{401}(-1.987\Delta V + 817.25)d(\Delta V)$	5.16
Total		**219.974**

TABLE IV.   THE SAMPLE DATA

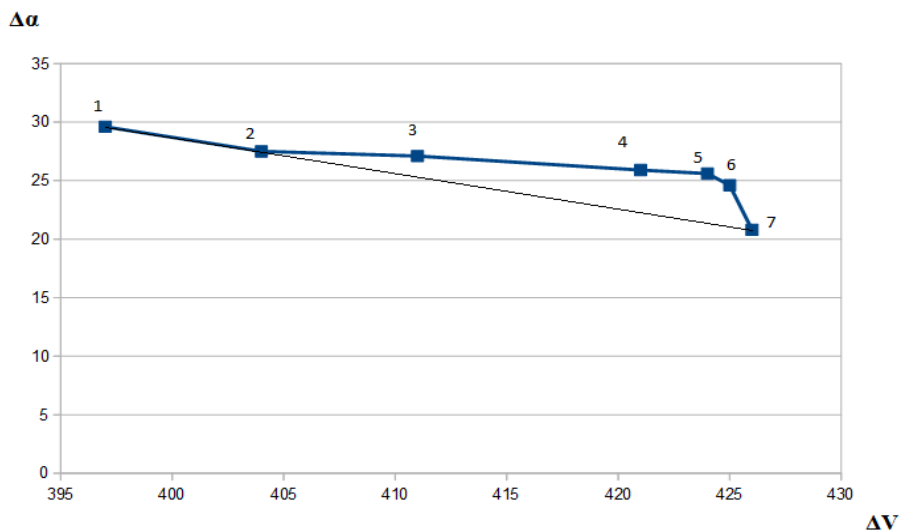| α	21.8	25.6	26.6	26.9	28.1	28.5	30.6
V	427	426	425	422	412	405	398
$\Delta\alpha$	20.8	24.6	25.6	25.9	27.1	27.5	29.6

Fig. 6. Flight during a crash

TABLE V.   CALCULATING THE AREA

Section number	Initial equation of the plot	The final equation of the plot
1–2	$\dfrac{\Delta V - 397}{404 - 397} = \dfrac{\Delta\alpha - 29.6}{27.5 - 29.6}$	$\Delta\alpha_{1-2} = -0.3\Delta V + 148.64$
2–3	$\dfrac{\Delta V - 404}{411 - 404} = \dfrac{\Delta\alpha - 27.5}{27.1 - 27.5}$	$\Delta\alpha_{2-3} = -0.06\Delta V + 50.52$
3–4	$\dfrac{\Delta V - 411}{421 - 411} = \dfrac{\Delta\alpha - 27.1}{29.5 - 27.1}$	$\Delta\alpha_{3-4} = -0.12\Delta V + 76.42$
4–5	$\dfrac{\Delta V - 421}{424 - 421} = \dfrac{\Delta\alpha - 25.9}{24.6 - 25.9}$	$\Delta\alpha_{4-5} = -0.1\Delta V + 68$
5–6	$\dfrac{\Delta V - 424}{425 - 424} = \dfrac{\Delta\alpha - 25.6}{20.8 - 25.6}$	$\Delta\alpha_{5-6} = -\Delta V + 449.6$
6–7	$\dfrac{\Delta V - 425}{426 - 425} = \dfrac{\Delta\alpha - 24.6}{20.8 - 24.6}$	$\Delta\alpha_{6-7} = -3.8\Delta V + 1639.6$
1–7	$\dfrac{\Delta V - 397}{426 - 397} = \dfrac{\Delta\alpha - 29.6}{20.8 - 29.6}$	$\Delta\alpha_{1-7} = -0.296\Delta V + 147.13$

In Table VI are presented the results of calculating the area of the polygon flying an aircraft during a failure.

TABLE VI.   CALCULATING THE AREA

Section number	Integral to determine the area	Land area
1–2	$\int_{397}^{404}(-0.002\Delta V + 1.51)d(\Delta V)$	4.963
2–3	$\int_{404}^{411}(0.2388\Delta V - 96.54)d(\Delta V)$	5.397
3–4	$\int_{411}^{421}(0.176\Delta V - 70.71)d(\Delta V)$	25.06
4–5	$\int_{421}^{424}(0.196\Delta V - 79.13)d(\Delta V)$	11.04
5–6	$\int_{424}^{425}(-0.704\Delta V + 302.47)d(\Delta V)$	3.622
6–7	$\int_{425}^{426}(-3.504\Delta V + 1492.47)d(\Delta V)$	1.518
Total		**51.6**

Define the boundary values for ΔV and $\Delta\alpha$:

$$\Delta\alpha_{r2} = 29.6 - 20.8 = 8.6,$$

$$\Delta V_{r2} = 426 - 397 = 29.$$

Area in relative units:

$$S_{B2} = \frac{S_2}{\Delta\alpha_{r2}\Delta V_{r2}} = \frac{51.6}{8.6 \cdot 29} = 0.206.$$

The results are listed in the Table VII.

TABLE VII.   THE RESULTS ARE LISTED

Relative area	Indicator of quality
0–0.29	The quality of piloting is bad
0.29–0,43	The quality is not bad, and not good
0.43–1	The quality is good

The values of relative areas indicate that the flight quality of the parameters ΔV and $\Delta\alpha$ in flight of the aircraft during the failure is much worse than before the failure. The deterioration of quality is 2.5 times.

IV. CONCLUSIONS

The method of determination of mismatch between the angle of attack and the instrument speed in case of failures in avionics systems is developed. Quantitative flight quality indicators are determined. With the help of the developed scheme, according to the proposed method, it is possible to continuously determine the mismatch between the angle of attack and the instrument speed, as well as uncoordinated evolutions in the reversals.

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Ю. В. Грищенко, В. Г. Романенко, А. І. Амеліна. Проблема некоординованого розвороту літака за гранично малих швидкостей польоту

У даній статті розглянуто питання, пов'язане з погіршенням якості польоту при отриманні екіпажу. Передбачено використання системи оповіщення екіпажу про можливе зборі даних про швидкість і швидкості повітряного руху. Доведено, що зменшення площі кореляційних полів свідчить про некоординовані розвороти. При достатній швидкості некоординовані розвороти не такі небезпечні. Тому ми розглянули свідчення у кореляційним полях коефіцієнтів кута атаки і приладової швидкості. Розроблено метод обчислення площі кореляційних полів вище існуючих параметрів. Він заснований на методі найменших квадратів. Запропоновані кількісні характеристики визначають якість польоту в залежності від площі кореляційних полів.

Ключові слова: амплітуда параметра; глісада; кореляційне поле; людський фактор; траєкторія польоту.

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Ю. В. Грищенко, В. Г. Романенко, А. И. Амелина. Проблема некоординированнного разворота самолета при предельно малых скоростях полета

В данной статье рассмотрен вопрос, связанный ухудшением качества полета при получении экипажем недостоверной информации от систем ее отображения. Предлагается система оповещения экипажа о сбое в системах получения данных об угле атаки и воздушной скорости и о выполнении некоординированного разворота. Предыдущие исследования по углам атаки и крена показали, что уменьшение площади корреляционных полей свидетельствует о некоординированном развороте. При достаточной скорости некоординированные развороты не так опасны. Поэтому мы рассмотрели рассогласование показаний по корреляционным полям коэффициентов угла атаки и приборной скорости. Разработан метод вычисления площади корреляционных полей выше указанных параметров. Он основан на методе наименьших квадратов. Предложены количественные характеристики определения качества полета в зависимости от площади корреляционных полей.

Ключевые слова: амплитуда параметра; глиссада; корреляционное поле, траектория полета; человеческий фактор.

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