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METHODS OF TRAINING OF MODERN AIRCRAFT FLIGHT CREWS FOR INFLIGHT ABNORMAL CIRCUMSTANCES

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Abstract

Purpose: *The purpose of this article is the theoretical justification of the existing methods and development of new methods of training the crews of modern aircraft for inflight abnormal circumstances.* ***Methods:*** *The article describes the research methods of engineering psychology, mathematical statistics and analysis of the correlation functions.* ***Results:*** *The example of the two accidents of aircraft with modern avionics is shown in the problem statement. The pilot made a sharp movement of the steering wheel while go-around, which has led to a sharp diving and impossibility of coming out of it. It was shown that the developed anti-stress training methods allow crews to train a human operator to prevent such events. The theoretical solution of the problem of optimization of the flight on the final approach, considering the human factor, is suggested to solve using the method of analysis of the autocorrelation function.* ***Conclusions:*** *It is necessary to additionally implement methods of teaching the counteracting of factorial overlaps into the training course using the complex modern aircraft simulators. It is enough to analyze a single pitch angle curve of the autocorrelation function to determine the phenomena of amplification of integral-differential motor dynamic stereotype of the pilot.*

Keywords: correlation function; dynamic stereotype; glide path; negative factors.

1. Introduction

Ensuring the flight safety is very important component of the civil aircraft operation. For modern aircraft high level of modern airplane safety depends primarily on the features of the airplane and the training and experience of the flight crew. The functional efficiency of aircraft is determined by its structural and operational excellence, stability, handling and maneuverability, as well as high operational workability of the airframe, engine and equipment. The functional efficiency of the flight crew depends on the theoretical training, knowledge of aircraft and the rules of its operation under regular and extreme conditions, as well as the discipline and diligence of captain and his crew. Statistical analysis of aircraft accidents shows that most of them are caused by the fault of human factor.

2. Problem statement

Let us consider two accidents of the Boeing 737 aircraft during night operations under adverse weather conditions.

Aircraft accident of «Tatarstan» airlines Boeing 737-500 during landing, had place on November 17, 2013 in Kazan International Airport. There was heavy rain with snow and wind gusts of 7 m / s to 16 m / s depending on the altitude, with visibility of 10 km.

Aircraft accident of FlyDubai airlines Boeing 737-800, flying from Dubai (United Arab Emirates), which has crashed at the airport of Rostov-on-Don during the second approach in difficult weather conditions, with a strong side wind and rain.

In both cases the captains made a sharp and disproportionate movements using the steering wheel while go-around, which caused the airplane to dive sharply. In both cases we deal with the problem of controlled flight into terrain (CFIT).

This brings up the question of working out the situation using the complex flight simulator (CFS) to secure the persistent flight crew skill. Of course, it should be done. As much as possible situations are required to be worked out using CFS. But the programs of simulator training are based on the condition of ordinariness, when only one failure is put in from the instructor control panel. In practice it sometimes happens in a different way i.e. we can have 2^Noptions, which deal with the right or wrong action, and N – the number of negative factors, which influence the flight crew. So considering all the situation is almost impossible.

The problem of improving the quality of flight is currently the subject of many scientific publications [1-6].

The purpose of this work is the theoretical justification of application of existing methods of modern aircraft crew training for special conditions of flight and the development of new such methods.

3. Solution for the problem using complex airplane simulator by methods of engineering psychology and mathematical statistics

Now let's investigate the reason of disproportionate integral-differentiated motive actions of human operator. The experiment was carried out using CFS of Tu-154 B2 by staff of Kyiv Institute of Civil Aviation Engineers (National Aviation University nowadays) at the training detachment in 1980-1990. We used the CFS not to work out concrete action (the necessity of this procedure, we do not deny in any case) but to improve the skill of countering the factor overlays (FO), which were simulated by simultaneously acting failures. It was determined that initially 80% of the pilots had no opposition to factor overlays. Recommendations for pilots were based on the theory of the process analysis and factor transitions phenomenon, introduced by Khokhlov E. M., phenomenon of "factor resonance", introduced by Korneyev S. V. (further research was continued by Polozhevets A. A.), where the area with the greatest amplitude of the flight parameter and phenomenon of amplification of integral-differentiated motive dynamic stereotype (PAIDMDS) was examined by Hryshchenko Y. V. It should be noted that these techniques allowed to successfully train pilots to counter FO, but their further implementation has been stopped due to lack of funding.

It should be noted that the above mentioned aircraft pilots would not have made a disproportionate and sharp actions using steering wheel of the aircraft with a high probability in the case of passing the training techniques which were mentioned above [7,8].

Also it was noticed that the burst of accidents has periodic nature each 10 years. This peak takes place this year [8].

The general nature of the industrial cycles is the development of large scale machine industry, such as aviation, is studied in detail by economists. And although economists do not have a single point of view, there are about 500 different points of view about mechanisms and the nature of the industrial cycles, but the fact of existence of these cycles is not already under discussion.

Delta is taken as flight safety level in the conception proposed in work [8], as level for various modal (volumetric) air transportation market indicators (number of flights, takeoffs and landings, the volume of passenger traffic, cargo handling, mail, etc.)

Delta level of flight safety (FS, surplus safety) is a differentially difference level that fixes the positive effect of flights and shows the difference (increment) between the total effect of the flights and the negative effects from them in absolute and relative forms. Of course, the maximum negative effect of flights is an accident and the positive one is flights without remarks.

In other words, unlike established flight safety assessment approaches, this concept offers accounting not only security as a systemic property of the air transport system by the level of danger, but assessment of the increment of flight operation, which provides the result of transportation (delta - safety).

Central strategic goal of scientific research, which controls decisions, can only be decrease of the danger of flights (DF). Such decrease of DF level may be carried out in two phases:

- system method by increasing the decrement of oscillations damping of DF level in cycles of 10 years till "sustainable" level;
- process methods by a factor transition from "sustainable" level of danger to drift near "zero level of accident rate" over human factor.

Process analysis which is based on the general theory of processes, the general theory of statistics is based on the theory of limits, qualitative theory of uncertainties and other theories of process concepts. Knowledge and understanding of the dialectical law of transition from disordered to ordered science is important for understanding the general nature and general points of transition from system to process research, as a general new scientific strategy for the areas of human factors.

Civil aviation companies are complex automated manufacturers. The scale of air transportation, the number of people and equipment that are involved in this type of transport are increasing every year. One of the major problems of civil aviation is ensuring the high level of flight safety. This problem has many aspects as flight safety depends on complex factors, including the level of technical dependability of the aircraft and its systems, level of professional staff training, organization of work of flight, technical and medical services, discipline of flight and technical staff, human interaction with technology and among themselves, intensity and conditions of flights and many other things.

The problem of improving the flights safety is complex and can be solved by consistent efforts of flight, engineering, medical staff, as well as scientists, designers and specialists from other professions. However psychophysiology knowledge is essential for improving the flights safety.

Depending on the level of automation of process management there are two main processes: automatic and ergatic. In ergatic process human operator is a center that receives information, processes it, makes decisions and carries out specific actions on management. But the full automation of the production process in aviation cannot always be done, or is not always needed. This significantly causes that ergatic production processes are very extensive class of processes and ergatic systems are essentially the main processes in aviation.

Let us consider glide path with taking into account PAIDMDS.

4. The theoretical solution for the problem of optimization of the flight on the final approach with taking into account the human factor

Let us define integral difference between the set and realized flight paths.

Flight path deviation from the intended course is characterized by the correlation function between the set and realized flight paths [9, 10]. The physical sense of the correlation function is analyzed in this work. Relationship of correlation function with the difference between scheduled and actual flight paths is determined.

The square of the integral difference between flight paths (scheduled and real) in the specific area equals

$$\Delta = \int_{x_1}^{x_2} \left[Z_s(x) - Z_r(x) \right]^2 dx , \qquad (1)$$

where $Z_s(x)$ is scheduled flight path,

$Z_r(x)$ is real flight path.

Flight path takes place in a plane $y = const$. Coordinate Z depends on x, Z(x), i.e. it is the height of flight path in the Cartesian coordinate system.

x_1, x_2 are starting and ending points of reference of flight path in the horizontal plane.

Let's compute the expression (1)

$$\Delta = \int_{x_1}^{x_2} Z_s^2(x)dx - 2\int_{x_1}^{x_2} Z_s(x)Z_r(x)dx + + \int_{x_1}^{x_2} Z_r^2(x)dx , \qquad (2)$$

Let us designate the components of the equation (2):

$$\Delta = \int_{x_1}^{x_2} Z_s^2(x)dx = L\rho_3 ,$$

$$\int_{x_1}^{x_2} Z_s(x)Z_r(x)dx = L\rho_{3p} ,$$

$$\int_{x_1}^{x_2} Z_r^2(x)dx = L\rho_r ,$$

where $L=x_2 - x_1$, functions ρ_s, ρ_{sr}, ρ_r are respectively autocorrelation function of the scheduled flight (ρ_s), function of correlation between the scheduled path and the real path (ρ_{sr}) and ρ_r are autocorrelation function of actual flight path. In this case expression (1) takes the form

$$\Delta = L\rho_s - 2L\rho_{sr} + L\rho_r , \qquad (3)$$

Autocorrelation functions ρ_s and ρ_r are approximately equal to each other. Let's consider the case, where

$$\rho_s \approx \rho_r \approx \rho_A , \qquad (4)$$

and ρ_A is autocorrelation function of scheduled and implemented process. That is, when the correlation function of the scheduled and realized the flight path differ insignificantly.

Let's rewrite formula (3) with considering (4)

$$\Delta = 2L(\rho_A - \rho_{sr}) , \qquad (5)$$

$$\rho_{sr} = \rho_A - \frac{\Delta}{2L} .$$

From (5) it is clear that if the paths are same Δ=0, then $\rho_{sr}= \rho_A$.

Integral error value per unit of length $\frac{\Delta}{L}$ equals to the difference of the function of autocorrelation ρ_A and correlation ρ_s. Let us calculate these three functions for different types of paths.

5. Flight paths on the glide path

Let us consider Flight paths on the glide path (fig. 1), which is defined by the equation

$$Z_s(x) = h - \frac{h}{L}x , \quad (6)$$

where h is initial altitude of flight on the glide path, L is the length of flight on the glide path.

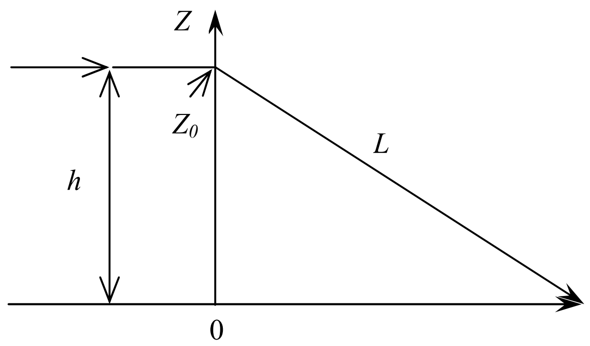

Fig. 1. Glide path trajectory.

L is the glide path length (l≈12000,00002m), h is the initial altitude at the moment of landing.

Let us consider the special case of delay of landing trajectory.

$$Z_p = h - \frac{h}{L}(x-\chi) . \quad (7)$$

Where χ is value of the delay.

Then correlation and autocorrelation functions are equal to

$$\rho_s = \frac{1}{L}\int_0^L \left(h - \frac{h}{L}x\right)^2 dx = \frac{h^2}{3} , \quad (8.1)$$

$$\rho_{rs} = \frac{1}{L}\int_L^0\int_0^L \left[\left(h-\frac{h}{L}x\right)\left(h-\frac{h}{L}(x-\chi\right)\right]dx =$$

$$= \frac{h^2}{3} + \frac{h^2}{2L}\chi , \quad (8.2)$$

$$\rho_k = \frac{1}{L}\int_L^0 \left[h - \frac{h}{L}(x-\chi)\right]^2 dx =$$

$$= \frac{h^2}{3} + \frac{h^2}{L}\chi + \frac{h^2}{L^2}\chi^2 . \quad (8.3)$$

Further we denote $\rho(-\chi)$.

Substitute values of (8.1, 8.2, 8.3) into formula (3) and we find the integral difference between the two paths

$$\Delta = L\frac{h^2}{3} - 2L\frac{h^2}{3} - h^2\chi + \frac{h^2L}{3} - \frac{h^2}{L}\chi^2 + h^2\chi^2 =$$

$$= \frac{h^2}{L}\chi^2 , \quad (9)$$

while χ=0, Δ=0, $\chi=L$, $\Delta=h^2L$. (9.1)

Let us write (9) in such a way

$$\Delta = h^2 L\left(\frac{\chi}{L}\right)^2 . \quad (10)$$

The formula (8) shows that with increasing of χ from 0 to L the value of Δ increases.

Outrunning flight path on the glide path equals

$$Z(x+\chi) = h - \frac{h}{L}(x+\chi) . \quad (11)$$

Let us split the range (0, L) into two parts (0, $L-\chi$) and (0, $L+\chi$). Outrunning function at part ($L-\chi$, L) equals zero: $Z(x+\chi)=0$. Consequently, the outrunning correlation function is determined by integrating only in the interval of (0, $L-\chi$)

$$\rho_{sr} = \rho(+\chi) = \frac{1}{L}\int_0^{L-\chi}\left(h-\frac{h}{L}x\right)\cdot\left[h-\frac{h}{L}(x+\chi)\right]dx =$$

$$= \frac{h^2}{3} - \frac{h^2}{2L}\chi . \quad (12)$$

By comparing the expressions (8.2) and (12)

$$\rho(-\chi) - \rho(+\chi) = \frac{h^2}{L}\chi .$$

It can be concluded that

$$\rho(-\chi) > \rho(\chi)^* .$$

Autocorrelation function of outrunning path is equal to

$$\rho_k(+\chi) = \frac{1}{L}\int_0^L\left[h - \frac{h}{L}(x+\chi)\right]^2 dx =$$

$$= \frac{h^2}{L}\int_0^L\left[1-\frac{x+\chi}{L}\right]^2 dx = \frac{h^2}{3} - \frac{h^2\chi}{L} + \frac{h^2}{L^2}\chi^2 . \quad (13)$$

$\rho(-\chi) - \rho(+\chi)=0$ as long as $\chi = 2L$, that is unreal condition when the aircraft has not landed.

If L»χ, the delay value is much less than the length of the glide path, which is quite real, the autocorrelation function is equal to the outrunning path

$$\rho_k(+\chi) = \frac{1}{3}h^2 \quad (14)$$

Let us substitute values ρ_s, $\rho_k(+\chi)$ and $\rho_{sk}(+\chi)$ into the equation (3) and get (fig. 2):

$$\frac{\Delta}{L}=\frac{1}{3}h^2-\frac{2h^2}{3}+\frac{h^2}{L}\chi+\frac{h^2}{3}+$$
$$+\frac{h^2}{L^2}\chi-\frac{h^2}{L}\chi+\frac{h^2}{L^2}\chi=\frac{h^2}{L^2}\chi\,.$$

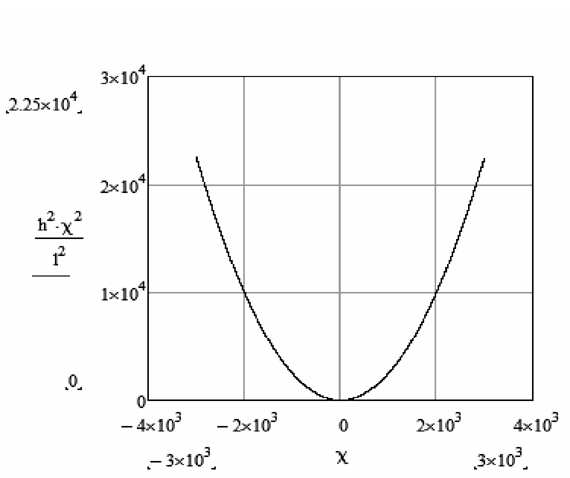

Fig. 2. Graph of relation between $\frac{\Delta}{L}$ and χ (χ is within the range from -3000 m to 3000 m).

This figure shows that in the case of the glide path entrance delay, the probability of hitting the threshold level of runway increases.

The probability of the preconditions for occurrence of aircraft accident increases. Therefore measurement error will be less than this one.

6. Conclusions

1. It is necessary to further implement a training course using CFS training methodology of countering FO.
2. To determine PAIDMDS enough for the pilot to have analysis of one curve of the autocorrelation function on the glide path during "flight" using CFS.
3. To implement the proposed method it is necessary to develop and create the equipment for comparing the predetermined and realized glide paths. Most likely polarimetric devices will be used, allowing to register the above mentioned the glide paths and analyze quickly and accurately.

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Методи підготовки екіпажів сучасних літаків до особливих ситуацій польоту

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Мета: Метою даної статті є теоретичне обґрунтування застосування існуючих і розробки нових методів підготовки екіпажів сучасних літаків до особливих ситуаціям польоту. **Методи:** У статті розглянуто методи досліджень інженерної психології, математичної статистики та аналізу кореляційних функцій. **Результати:** При постановці завдання наведено приклад двох катастроф літаків із сучасною авіонікою. При виході на друге коло пілот допустив різкі рухи штурвалом, що призвело до різкого пікірування і неможливості виходу з нього. Показано, що розроблені методи антистресової підготовки екіпажів дозволяють навчити людину-оператора недопущенню таких подій. Теоретичне рішення задачі оптимізації польоту на глісаді з урахуванням людського чинника запропоновано вирішити методом аналізу автокореляційної функції. **Висновки:** На комплексних тренажерах сучасних літаків необхідно додатково вводити в курс підготовки методики навчання протидії факторним накладкам. Для визначення явища посилення інтегро-диференційованого рухового динамічного стереотипу у пілота досить провести аналіз однієї кривої автокореляційної функції тангажу.

Ключові слова: глісада, функція кореляції, динамічний стереотип, негативні чинники.

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Методы подготовки экипажей современных самолетов к особым ситуациям полета

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Цель: Целью данной статьи является теоретическое обоснование применения существующих и разработки новых методов подготовки экипажей современных самолетов к особым ситуациям полета. **Методы:** В статье рассмотрены методы исследований инженерной психологии, математической статистики и анализа корреляционных функций. **Результаты:** При постановке задачи приведен пример двух катастроф самолетов с современной авионикой. При уходе на второй круг пилот допустил резкие движения штурвалом, что привело к резкому пикированию и невозможности выхода из него. Показано, что разработанные методы антистрессовой подготовки экипажей позволяют обучить человека-оператора недопущению таких событий. Теоретическое решение задачи оптимизации полета на глиссаде с учетом человеческого фактора предложено решить методом анализа автокорреляционной функции. **Выводы:** На комплексных тренажерах современных самолетов необходимо дополнительно вводить в курс подготовки методики обучения противодействию факторным накладкам. Для определения явления усиления интегро-дифференцированного двигательного динамического стереотипа у пилота достаточно провести анализ одной кривой автокорреляционной функции тангажа.

Ключевые слова: глиссада, функция корреляции, динамический стереотип, негативные факторы.

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