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ERRORS STATISTICS PROCESSING OF AN AVIATION OPERATOR FOR RELIABILITY PREDICTION

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Abstract**—***This paper deals with unmanned aerial vehicle operator's analytical model as the basis of estimation of operator's errors distribution. The mail goal is to alignment of statistical series and determine whether the theoretical curve f(t) matches the processing of the histogram f*(Δt, t) using Pearson's chi-squared test.*

Index Terms—operator's error, analytical model, model of dependability, statistics of error*s*.

I. Introduction

Organization of aviation operations, maintenance is the complex task in modern conditions, considering human and organizational factors, it is directed to minimization of negative processes occurrence, such as flight accidents and air crashes [6].

That is exactly why it is important to evaluate the reliability aviation equipment and systems correctly; moreover, it is impacted by the reliability of operators who operate these systems.

Furthermore, it should be remarked that we can determine several types of operators, depending on the type of aviation equipment: air traffic controllers, pilots, aircraft maintenance technicians.

The quantified value of performance reliability of any operator described above can be defined as a probabilistic evaluation of these operators' successful performance of any operation or any given task on the given stage of system operation within certain time ranges.

That is why the efficiency and reliability of aviation operator's operation can vary within grate ranges in normal and special situations. It should also be noticed that without consideration of aviation operator's reliability, the aviation reliability can't be quantified with complete certainty.

The lack of scientific development of aviation operators' reliability issues and the great importance that they attached to the flight safety in general, determine the topicality of this article.

II. Peculiarity of Aviation Operator Errors Range of Problems

Human error is a major contributor to flight incidents, with some reviewers suggesting that the human error contribution is in the order of 90% or more [6]. The aim of this paper is therefore to increase knowledge and understanding of aviation operator performance mechanisms and the human errors with which they are associated. While investigation of incidents in this environment often conclude human error as the main causal factors, investigation of the human performance factors aims to go beyond this category alone, analysing the different facets of the situation and trying to understand the mechanisms and context which led to the error [7].

Modeling of an adequate analytical model of the reliability is possible when it is based on the input aviation operators' error statistics. The alignment of statistical series to treat the statistics and to choose the distribution model of the operator's errors to describe it can be used.

III. Alignment of Statistical Series

Solution of the alignment of the statistical series involves choosing the theoretical distribution $f(t)$, i.e., mathematical model of the distribution of errors that best describes the operational statistics of errors.

Theoretical distribution $f(t)$ is selected on the basis of analyzing of the laws of physical processes, which lead to errors and is considered as random processes and/or in accordance with the appearance probability density histograms error $f(\Delta t, t)$, and the error rate $\lambda(\Delta t, t)$ obtained as a result of statistical processing of the existing data on errors of various elements, components, and systems [1].

Method of constructing a histogram probability density errors $f(\Delta t, t)$ (Fig.1) and qualitative analysis of the theoretical distributions $f(t)$.

The function Δ (t), dubbed the "error rate" is not only one of the most important criteria when choosing a theoretical model of the distribution of use errors to $f(t)$. According to [2] $\Delta(t)$, which is also known as a function of resources, including a list of indicators of reliability of technical systems in assessing their reliability at the stage of first refusal to operate.

Analyze the information capabilities of various functions, the most commonly used as models as a strictly probabilistic errors and the probability distributions of physics [3].

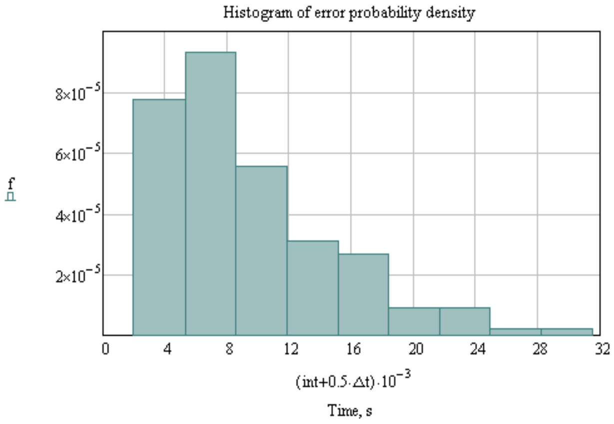

Fig. 1. Histogram of operator's error probability density

IV. Information Capabilities of Various Functions

Functions $R(t)$ (1) and $F(t)$ (2) are the integral characteristics of the density distribution $f(t)$ (3).

$$R(t) = 1 - Q(t). \tag{1}$$

$$F(t) \equiv Q(t). \tag{2}$$

$$R(t) = 1 - F(t) = 1 - \int_0^t f(t)dt. \tag{3}$$

Density function of mean time to error $f(t)$ characterizes the various properties of the distribution (location of range of possible values on the time axis, the presence and location of most probable values, the degree of scattering symmetry, and others). Thanks to these qualities, the function $f(t)$ is most often used in the graphical representation of a distribution law. During choosing the alleged error distribution model (or competing models) in appearance histogram density models the theoretical curves the density distribution of time to error should be presented on a background of the histogram distribution density of the initial error statistics (Fig. 2).

The error rate $\lambda(t)$ is a generalized description of the distribution, which carries information about the two functions at once $f(t)$ and $F(t)$. So $f(t)$ is the most expressive feature of the distribution law. Laws of $f(t)$ functions are substantially different from a number of laws, although the latter have a relatively similar functions $F(t)$ and $f(t)$.

So, for the most common time to error distribution (Weibull distribution, logarithmic) curve of the density distribution $f(t)$ are asymmetric, looks very similar, but the behavior of the error rate at the ends of the distribution function itself, that is asymptotically is significantly different.

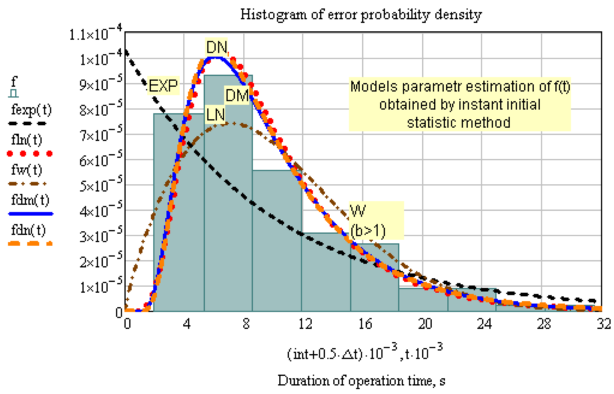

Fig. 2. Histogram of error probability density and theoretical curves of density distribution of time to error models

Thus the function $\lambda(t)$ is one of the most important criteria when choosing a theoretical model of distribution of time to error.

The choice of the alleged error distribution model (or competing models) in appearance histogram $\lambda^*(\Delta t, t)$ theoretical curves resource function should be presented on a background of the histogram of the original error rate statistics (Fig. 3).

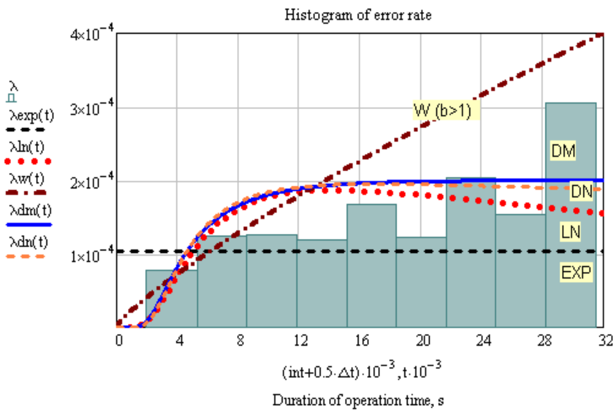

Fig. 3. Histogram of error rate and theoretical curves of models

V. Fitting Criterion for Histogram and Distribution Model of Errors Density

Unfortunately, in some cases at processing of operators' errors statistics there is a problem related to the discrepancy between the theoretical curve $f(t)$ and the histogram $f^*(\Delta t, t)$. These differences may be random in nature and to be associated with a limited number of observations. But the same problem may be connected with the selected curve that aligns the received statistical distribution poorly.

The consent criterion can be used in order to determine whether the theoretical curve $f(t)$ matches the processing of the histogram $f^*(\Delta t, t)$.

The idea of using goodness of fit is as follows. Based on statistical material we have to test the hypothesis H consists in the fact that the random variable t is subject to some given distribution law.

In order to confirm or refute the hypothesis H, it is necessary to establish a measure of discrepancy z between the theoretical statistical distributions. This measure differences and there are criteria consent; it is also a random value having its own distribution law [4].

A density of the form characterizes known mathematical statistics distribution

$$R(t) = 1 - F(t) = 1 - \int_0^t f(t)dt.$$

$$f(z) = \begin{Bmatrix} 2^{\frac{r}{2}} \Gamma\left(\frac{r}{2}\right) z^{\frac{r}{2}-1} \exp\left(-\frac{z}{2}\right) & \text{if } z > 0 \\ 0 & \text{if } z < 0 \end{Bmatrix},$$

where r is a parameter of the distribution; $\Gamma\left(\frac{r}{2}\right)$ is a gamma-function from the table.

The value χ^2 is the distribution of the sum of squares r of independent random variables, each of which is subject to the normal law, with $\mu = 0$ and $\sigma = 1$. Pearson's criterion can be written as

$$z = \chi^2 = N \sum_{k=1}^{K} \frac{\left(f_k(\Delta t, t)\Delta t - Q_k^T(\Delta t, t)\right)^2}{Q_k^T(\Delta t, t)},$$

where $f_k(\Delta t, t)$ is the empirical probability density on kth interval Δt denying obtained after processing as a result of tests; $Q_k^T(\Delta t, t)$ is the theoretical probability of error on the k – the interval Δt, determined by the area under the curve $f(t)$:

$$Q_k^T \cdot (\Delta t, t) = \int_{\text{int}_k}^{\text{int}_{k+\Delta t}} f(t)dt,$$

where int_k are boundaries of the intervals of the histogram density distribution time to error.

Distribution Pearson's chi-squared test χ^2 depends on the number of degrees of freedom of the model under investigation, i.e. the parameters of the r.

VI. Number of Degrees of Freedom for Error Distribution Model

Number of degrees of freedom r is equal to the number of intervals of the statistical distribution of errors $K = (t_n - t_1) / \Delta t$ minus the number æ of independent conditions or relations imposed theoretical model of error $f(t)$.

These conditions are following:

$$\int_0^\infty f(t)dt = 1.$$

1. Normalization condition density distribution time to error t.

2. First initial moment of the theoretical distribution is equal to the arithmetic mean time between errors.

$$T_0 = \int_0^\infty t\, f(t)dt = 1 = \alpha_1' = \sum_{k=1}^{K} \left[Q_1' t_1\right].$$

3. The second central moment of the theoretical distribution is equal to dispersion of statistical distribution.

$$D = \int_0^\infty (t - T_0)^2 f(t)dt = D' = \sum_{k=1}^{K} \left[Q_1'(t_1 - \alpha_1')\right].$$

It is obvious, æ = 2 for a one-parameter exponential distribution, æ = 3 for a two-parameter exponential distribution [1].

VII. Work with a Table of χ^2 Distribution

For distribution Pearson's chi-squared test χ^2 there are special tables that for each combination of values χ^2 and r, you can determine p the likelihood that due to purely accidental causes measure differences will not be less than the actual observed value.

If the probability p is very small, so small that an event with a probability can be considered to be virtually impossible to reject the hypothesis H and to recognize that the statistical series and selected for him no statistically model is not consistent. Statistical distribution of random values of use is not subject to the theoretical model $f(t)$.

Let's assume, that when testing the hypothesis derived measure differences $\chi^2 = 25.6$ if $r = 7$.

According to the table χ^2 is a value of probability p, value corresponding to the value of the goodness of fit, it is less than 0.001. It means that at the expense of random reasons the divergence between theoretical and statistical distributions, has very small probability $p = 0.01$.

Consequently, the discrepancy χ^2 is not due to accidental causes, and it should be recognized that the chosen model error distribution is not consistent with the experimental data, a poor description of error statistics. Thus, the hypothesis, that the statistical and theoretical distributions, is rejected.

If the value p is relatively large, is to know the difference between the theoretical and experimental distributions insignificant and take it due to accidental causes, that is, it can be assumed that the experimental distribution is described by the selected model errors. For practical calculations hypothesis considered plausible (or at least does not contradict the experimental data) if $p \geq 0.10$.

If $p < 0.1$, it is recommended to repeat the experiment (if it is possible) and if significant differences appear again, try to find a more suitable to describe the statistical error model. in some cases, you should consider several hypotheses about the form of a theoretical model of error (several competing distribution function of the operating time *t*). In this case, the test of the hypothesis of conformity carried out for each of the competing distribution.

VIII. Algorithm of Modeling of an Operator's Errors Statistics Histogram and Choosing the Most Relevant Analytical Model of Errors Distribution

To construct the histogram that corresponds to aviation operator's errors and to select an analytical distribution model for his errors, we use computer-aided design Mathcad.

We will represent outputs, which corresponds to the input statistics, using symbols of Mathcad in the following form:

The operational statistics of operators' errors is represented by the following parameters:

– number of intervals;
– length of an interval;
– midpoint of the first interval;
– overall number of errors at intervals.

It is recommended to carry out several experiments and to have as many numbers of statistic data on UAV operators' errors as possible, with the aim to increase the accuracy of the obtained histogram. We should note the fact that they are to be collected at the same external conditions, as well as using identical or similar algorithms of aviation operators' functioning.

Theoretical curves of density distribution model of operation to a error should be represented in front of outputs statistics of density distribution histogram of operators' errors. To do following algorithm:

1. Transport the error vector *n*.
2. Find boundaries for intervals of histogram *int*

$$\mathrm{int}_k = \frac{\tau s1}{2} + \Delta t \cdot k.$$

3. Determine the sum of errors according to output statistics

$$\sum n = \sum_{k=0}^{K-1} n_k .$$

4. Calculate density of operator's error probability:

$$f = \frac{n}{\sum n \cdot \Delta t}.$$

After this, we can obtain histogram of operator's error probability density (see Fig. 1).

To find parameters of analytical errors distribution models we will perform statistical processing for output data, we will:

– calculate the midpoints of histogram intervals;
– obtain a value of mean life to error;
– obtain a value for dispersion of output statistics;
– obtain a value for coefficient of variation for operation to error of output statistics.

Make alignment algorithm for solving initial statistics and describe their actions at each stage of the algorithm.

Justify the choice of the proposed error distribution model in appearance histograms $f^*(\Delta t, t)$ (see Fig. 2), and $\lambda^*(\Delta t, t)$ (see Fig. 3), with the theoretical curves the density distribution models time to error should be presented on a background of the histogram distribution density of error and the error rate of the original statistics.

Then we need to describe the content of the criterion for testing the hypothesis of agreement (compliance) theoretical model given statistics using table of χ^2 distribution (see Fig. 4).

Following which check the hypothesis is consistent with the original statistical non-competing models.

IX. Conclusions

Due to the possibility of constructing an analytical model that is based on the input error statistics of aviation operator, it can further not only predict the frequency and intensity of errors occurrence during the operation of the operator, and to maintain a necessary and sufficient level of reliability.

However, at the time of this model implementation, we should take into account the fact that the statistics histogram and selected analytical error distribution model may differ. To check the precision of the choice you must use the concept criteria.

References

[1] V. Gribov, Y. Kofanov,and V. Strelnikov, *Estimation and prediction of reliability of on-board aerospace*. Monograph. Moscow, National Research University "Higher School of Economics." 496 p. (in Russian)

[2] The system "man-machine". Terms and definitions. GOST 26387–84. Moscow, "IPK publishers of standards". 1985, 6 p. (in Russian)

[3] E. Kozhohina, V. Gribov, and S. Rudas, "Structural reliability operator aeronautical systems." *Materials of XI International Scientific and TechnicalConference "Avia-2013."* 2013, Kyiv: NAU, vol. 2, pp. 37–40.

[4] V. Strelnikov, "Methodological errors of calculation of reliability systems." *Reliability*. 2005, no. 3.(in Russian)

[5] E. Kozhohina, V. Gribov, and S. Rudas, "Analytical model of air navigation system operator reliability." *IEEE 3rd International Conference on Methods and System of Navigation and Motion Control (MSNMC).Proceedings*, Kyiv, 2014, pp. 170–174

[6] G. C. Kinney, M. J. Spahn, and R. A. Amato, The human element in air traffic control: Observations and analyses of the performance of controllers and supervisors in providing ATC separation services. METRIEK Division of the MITRE Corporation: MTR-7655: 1977.

[7] A. Isaac, S. T. Shorrock, R. Kennedy, and B. Kirwan, *Technical Review of Human Performance Models and Taxonomies of Human Error in ATM (HERA)*. 2002, 134 p.

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