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Initial considerations for the multi-optional doctrine implementation to the aircraft airworthiness support effectiveness estimations

The first part of the generalization for the degrading state maximal probability determination in the framework of the hybrid-optional functions entropy conditional optimality doctrine was presented in the report. The issue will be continued with a following sequence of reports.

Introduction. Aeronautical engineering maintenance technologies are purposed upon the aircraft airworthiness support [1]. Through its own operation an engineering unit, possibly sometimes, goes into damaged and after that into failure state. Reliability is a very significant factor [1-3]. Even if it is not just, also, for instance, functional coatings applications [4]. In order to prevent those negative consequences periodical maintenance is carried out [1-3, 5, 6]. The optimal periodicity of aeronautical engineering units' maintenance is an important parameter [1].

State of the problem. The optimal periodicity is designated, prescribed, and scheduled in accordance with various subjectively preferred requirements [1, 7]. One of such strategies envisages the optimal periodicity predetermined and established by the probabilities of the aviation engineering devices acceptable states [1, pp. 162-174, Chapter 15, especially Sub-Chapter 15.4, pp. 169, 170]. The states dynamical characteristics with the maximum probability of a non-failure state can sometimes be considered as a proper criterion for the optimal periodicity of the aeronautical engineering units' maintenance [1, Chapter 15, pp. 170-172, especially Sub-Chapter 15.4, p. 172, Fig. 15.2].

The character of all the three (normal, damaged, failure) situations probability changes is shown in [1, p. 172, Fig. 15.2]. At the optimal periodicity t_{opt} determination one should follow the requirement that the probability of failure $P_{DF}(t)$ is not higher than the predetermined (prescribed) one $P_{DF}(t)_{req}$, [1, p. 171].

Purpose of the paper. The proposed approach (doctrine) likewise in [8-16] is based upon the Jaynes' principle [17-19] and subjective entropy maximum principle [7, 20-23]. It resembles [24], however in actual fact follows [8-16]. A first step to a generalization has to be done with the use of mathematics [25] in order to opportunely reconsider the problems of [26-34] in the framework of the discussed concept.

Problem setting. Considering a simplified system of the possible discrete states, randomly changed in time, deemed to be a continuum [24], the corresponding marked graph of the states and transitions of such system is shown in Figure 1, it is proposed to find the maximum of the probability through the multi-optional hybrid functions entropy conditional optimization doctrine.

Here, in Figure 1, "0" designates the up state of the system; "1" – damage; "2" – failure. The corresponding values of the worsening rates λ_{ij} and restoration rates

μ_{ji} will determine the process going on in the system. For the substantiated reasons, for the state of "2" to be a state without an "exit", it has to be satisfied the conditions of $\mu_{20} = \mu_{21} = 0$. Then, it, the state of "2", will be a real failure.

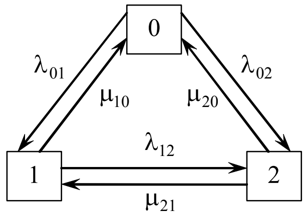

Fig. 1. Graph of the three states of an aeronautical engineering unit

Traditional concept. Elements of the Markovian processes and mass service theory [24] can be applied to the reliability problems solving. For example, considering a Markovian random process with discrete states and continuous time, for the general case with the three states we have the graph shown in Figure 1 [24].

The corresponding, to the graph of Figure 1, system of ordinary linear differential equations of the first order by Erlang will have the view of [24]:

$$\left.\begin{aligned} \frac{dP_0}{dt} &= -(\lambda_{01} + \lambda_{02})P_0 + \mu_{10}P_1 + \mu_{20}P_2; \\ \frac{dP_1}{dt} &= \lambda_{01}P_0 - (\lambda_{12} + \mu_{10})P_1 + \mu_{21}P_2; \\ \frac{dP_2}{dt} &= \lambda_{02}P_0 + \lambda_{12}P_1 - (\mu_{20} + \mu_{21})P_2, \end{aligned}\right\} \tag{1}$$

Here, in the system of equations (6), P_0 , P_1 , and P_2 – probabilities of the corresponding states (see Fig. 1); t – time. In accordance with [25, Chapter XIII, § 30, pp. 108-113], the characteristic equation for system (1) will be similarly (likewise) [25, Chapter XIII, § 30, p. 109, (5)]:

$$\begin{vmatrix} -(\lambda_{01} + \lambda_{02}) - k & \mu_{10} & \mu_{20} \\ \lambda_{01} & -(\lambda_{12} + \mu_{10}) - k & \mu_{21} \\ \lambda_{02} & \lambda_{12} & -(\mu_{20} + \mu_{21}) - k \end{vmatrix} = 0 . \tag{2}$$

Determinant (2) yields

$$\begin{gathered} [-(\lambda_{01} + \lambda_{02}) - k][-(\lambda_{12} + \mu_{10}) - k][-(\mu_{20} + \mu_{21}) - k] + \lambda_{01}\lambda_{12}\mu_{20} + \\ + \lambda_{02}\mu_{10}\mu_{21} - \{\lambda_{02}[-(\lambda_{12} + \mu_{10}) - k]\mu_{20}\} - \{\lambda_{01}\mu_{10}[-(\mu_{20} + \mu_{21}) - k]\} - \\ - \{[-(\lambda_{01} + \lambda_{02}) - k]\lambda_{12}\mu_{21}\} = 0 . \end{gathered} \tag{3}$$

From (8) it can be found the roots of $k_{1,2,3}$. For each root k_i of Eq. (2), (3), namely k_1 , k_2 , k_3 we will write down the system of linear uniform (homogenous) algebraic equations with respect to their coefficients $\alpha_1^{(i)}$, $\alpha_2^{(i)}$, $\alpha_3^{(i)}$, [25, Chapter XIII, § 30, p. 108, (3)]. The system derives from an assumption of a partial solution existence in the view of [25, Chapter XIII, § 30, p. 108, (2)] for the system of Eq. (1). Since having three roots in the stated problem setting, we obtain, [25, Chapter XIII, § 30, p. 109], the solution of the system of Eq. (1).

The other method of the system of Eq. (1) **solution** is represented with the *Laplace transformations* in the *operational calculus* [25, Chapter XIX, pp. 400-432].

For example, in case of Laplace transformations at the initial conditions of $P_0\big|_{t=t_0} = 1$, $P_1\big|_{t=t_0} = P_2\big|_{t=t_0} = 0$, $t_0 = 0$, for the Laplace transformants (images) F_i of the corresponding initial functions, or originals, of the probabilities of P_i, one has

$$F_0 = \frac{p^2 + pa_1 + b_1}{p\left(p^2 + pe_1 + b_1 + c_1 + d_1\right)}, \qquad (4)$$

where p is the complex parameter (variable) of the Laplace transformation;

$$a_1 = \mu_{20} + \mu_{21} + \lambda_{12} + \mu_{10}, \quad b_1 = \lambda_{12}\mu_{20} + \mu_{10}\mu_{20} + \mu_{10}\mu_{21}, \qquad (5)$$

$$e_1 = \mu_{20} + \mu_{21} + \lambda_{12} + \mu_{10} + \lambda_{01} + \lambda_{02}, \quad c_1 = \lambda_{01}\mu_{20} + \lambda_{01}\mu_{21} + \lambda_{02}\mu_{21}, \qquad (6)$$

$$d_1 = \lambda_{01}\lambda_{12} + \lambda_{02}\lambda_{12} + \lambda_{02}\mu_{10}, \qquad (7)$$

$$F_1 = \frac{p\lambda_{01} + c_1}{p\left(p^2 + pe_1 + b_1 + c_1 + d_1\right)}, \quad F_2 = \frac{p\lambda_{02} + d_1}{p\left(p^2 + pe_1 + b_1 + c_1 + d_1\right)}. \qquad (8)$$

The consideration for probabilities and further generalization steps in the following (1)-(8) ideas [8-10, pp. 23-29, (6)-(38)] will appear in the next report.

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