Minimax decision for solution of the problem of aircraft and airline reliability processing results of acceptance full-scale fatigue test of airframe

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Probability of Failure (PF) of fatigue-prone AirCraft (AC) and Failure Rate (FR) of AirLine (AL) for specific inspection program can be calculated using Markov Chains (MC) and Semi-Markov Process (SMP) theory if parameters of corresponding models are known. Exponential approximation of fatigue crack size growth function, $a(t) = a_0 \exp(Qt)$, where a_0, Q are random variables, is used. Estimation of the parameters of the distribution functions of these variables and the choice of final inspection program under condition of limitation of PF and FR can be made using results of observation of some random fatigue crack in full-scale fatigue test of the airframe. For processing of acceptance type test, when redesign of new aircraft should be made if some reliability requirements are not met, the minimax decision is used. The process of operation of AC is considered as absorbing MC with $(n + 4)$ states. The states $E_1, E_2, ..., E_{n+1}$ correspond to AC operation in time intervals $[t_0, t_1), [t_1, t_2), ..., [t_n, t_{SL})$, where n is an inspection number, t_{SL} is specified life (SL), i. e. AC retirement time. States E_{n+2}, E_{n+3}, and E_{n+4} are absorbing states: AC is descarded from service when the SL is reached or fatigue failure (FF), or fatigue crack detection (CD) takes place. In corresponding matrix for operation process of AL the states E_{n+2}, E_{n+3} and E_{n+4} are not absorbing but correspond to return of MC to state E_1(AL operation returns to first interval). In the matrix of transition probabilities of AC, P_{AC}, there are three units in three last lines in diagonal, but for corresponding lines in matrix for AL, P_{AL}, the units are in the first column, corresponding to state E_1. Using P_{AC} we can get the probability of FF of AC and the cumulative distribution function, mean and variance of AC life. Using P_{AL} we can get the stationary probabilities of AL operation $\{\pi_1, ..., \pi_{n+1}, \pi_{n+2}, ..., \pi_{n+4}\}$. Here π_{n+3}defines the part of MC steps, when FF takes place and MC appears in state E_{n+3}. The FR, λ_F , and the gain of this process, g, are calculated using the theory of SMP with reword, taking into accout the reword of succesful operation in one time unit, the cost of acquisition of new AC after SL, FF or CD take place,... If the gain is measured in time unit then $L_{n+3} = g/\pi_3$ is a mean time between FF; the intensity of fatigue failure $\lambda_F = 1/L_{n+3}$. The problem of inspection planning is the choice of the sequance $\{t_1, t_2, ..., t_n, t_{SL}\}$ corresponding to maximum of gain under limitation of AC intensity of fatigue failure. In a numerical example the minimax decision, based on observation of some fatigue crack during acceptance full-scale fatigue test of airframe, is considered.