ВЛИЯНИЕ ПОГРЕШНОСТЕЙ ИЗМЕРЕНИЯ ПАРАМЕТРОВ ТВД PW125B НА ДОСТОВЕРНОСТЬ ДИАГНОСТИКИ СОСТОЯНИЯ ЕГО ПРОТОЧНОЙ ЧАСТИ

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Ключевые слова: турбовинтовой двигатель, термогазодинамические параметры, линейная математическая модель, диагностическая матрица

В докладе рассматривается задача повышения глубины диагностирования двухвального газогенератора турбовинтового двигателя PW125B самолёта Fokker-50, эксплуатируемого в аэропорту «Рига». С этой целью предложено установить в его проточной части дополнительные приёмники давления и температуры. Их необходимое количество теоретически обосновано, исходя из числа переменных, требуемых для решения системы из 16 уравнений разработанной линейной математической модели двигателя. Для большего соответствия полученной модели изменению состояния газогенератора в процессе его эксплуатации в уравнения математической модели введены дополнительные члены, учитывающие смещение характеристик компрессоров и турбин при износе и дефектах проточной части [1].

На основе линейной математической модели двигателя сформирована диагностическая (локализующая) матрица (ДМ), позволяющая путём определения относительных отклонений измеряемых термогазодинамических параметров вычислить отклонения некоторых расчётных параметров. Эти параметры являются критериями (диагностическими признаками) появления дефектов в проточной части таких модулей газогенератора, как компрессоры и турбины.

Для проверки работоспособности ДМ произведено моделирование как одинарных, так и двойных дефектов компрессоров и турбин. Оценка достоверности диагностики состояния модулей двигателя проведена путем численного моделирования статистического разброса значений параметров в диапазоне погрешностей измерений. Это исследование показало достаточную чувствительность разработанной диагностической матрицы к выявлению дефектов узлов турбовинтового двигателя PW125B, что позволит перейти от качественной (выполняемой в настоящее время) к количественной оценке признаков дефектов и накоплению статистики их появления в эксплуатации. Накопленная статистика теоретически обоснованных критериев физического проявления дефектов двигателя позволит эффективно использовать их при разработке нового поколения автоматизированных диагностических систем с элементами искусственного интеллекта типа нейронных сетей [2].

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INSPECTION POLICIES FOR DETECTION OF INITIAL CRACKS IN AIRCRAFT STRUCTURAL COMPONENTS

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Key words: Aircraft structures, Fatigue cracks, Inspection policies, Detection

One of the most important problems in the fatigue analysis and design of aircraft structures is the prediction of the fatigue crack growth in service [1]. Available in-service inspection data for various types of aircraft indicate that the fatigue crack damage accumulation in service involves considerable statistical variability. The statistical nature of the fatigue crack growth is attributed to, among others, two most important factors: (i) the statistical nature of service loads and environments experienced by aircraft structures and (ii) the inherent fatigue crack growth variability of materials.

As aircraft structures begin to age (that is, as flight hours accumulate), existing subcritical cracks or new cracks can grow in some high-stress points of the structural components. The usual approach is to inspect the structures periodically at certain intervals. Thus, a catastrophic accident during flight can be avoided. The problem then arises of choosing a sequence of inspection times which avoids both too many inspections, which may be costly, and too few inspections, which may also be costly due to a crack in aircraft structure component not being detected for a long period.

In this paper, a simple approach is proposed. It allows one to find the inspection policies for detection of initial cracks in critical structural components of aircraft under the assumptions that the parameter values of the underlying distributions are known with certainty as well as when such is not the case. After each inspection before detection of an initial crack, we choose numbers τ and p and choose the next inspection point so that a crack (minimum observable crack size) is detected within a time τ (permitted for the initial crack to grow and reach the operational limit crack size) with probability p.

In other words, suppose an inspection is carried out at time t, and this shows that crack has not yet occurred. We now have to schedule the next inspection. Let *T* be the random time at which the crack may be occurred. Then we schedule the next inspection at time *x,* where *x* satisfies

$$\Pr\{T > x - \tau; T > t\} = p. \tag{1}$$

Equation (1) says that the next inspection is scheduled so that, with probability p, either the aircraft structural component is still working and free of crack or initial crack occurred less than τ time units prior to inspection, so that crack was undetected for a time τ at most.

With $x_0=0$, the inspection times x_1, x_2, ... can be calculated recursively. Various properties of these inspections are derived, and illustrations are given for some important special cases.

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THE DESIGN OF LOW SPEED WING SECTION FOR SAFETY AND PERFORMANCE

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Key words: wing section, design, calculation, experiment

The R. Eppler Airfoil Program System is used for the multipoint design of wing sections. The goal of the design is the low sensitiveness to leading edge contamination and low drag is. The XFOIL and MSES codes of M. Drela are used for the analysis. The examples of wing sections, calculated and measured results are presented.

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ESTIMATION OF PARAMETERS OF FATIGUE CURVE OF COMPOSITE MATERIAL

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Key words: strength, fatigue life, composite

Simple Markov's model of fatigue damage accumulation for fatigue lives of carbon composite specimens processing is discussed. In mathematical model fatigue damage accumulation is considered as brittle fracture of strands of unidirectional composite. Model based on the use of Markov chain theory allows to get S-type curve of internal stress growth and to calculate interrelation between static strength distribution parameters and parameters of fatigue curve. The maximum likelihood method of model parameter estimation on the base of fatigue curve information is offered. Numerical example is given. Unknown parameter has 6 components in general case so only approximate estimate is found, but calculated field of diversity of fatigue lives enough well cover the experimental data. It can be considered, as enough likelihood of offered model of fatigue damage accumulation.

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THE INVESTIGATION OF AEROBATIC PILOT'S FATIGUE

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Key words: Flight fatigue, Flight performance

Fatigue affects the mind as well as the body. It is well known that pilot's fatigue can reduce the performance by changing reaction time, reducing attention, diminishing memory and impairing perception time. A review of the literature shows a lack of consensus what it's a fatigue indeed, and how fatigue should be measured.

The aerobatic flight is specific flight, requiring extreme attention concentration, constant active spatial orientation as well as brawn.

The aim of this research is to estimate quantitatively flight fatigue and to determine weight factors.

Methods: the subjective fatigue questionnaire, the Weston test were used for these purposes. Object of study is aerobatic pilots, have participated in the 13th European Aerobatic Championship, 2002, Lithuania. The investigation was performed during training flights before the competition. The 29 flight data were used for analysis.

Results: The fatigue during aerobatic flights have increase in 18 % though it has very small influence to the psychical fatigue. The factors affecting fatigue onset is: the time from wake-up and flight, the quality of last night sleep and the amount of alcohol used in last 24 hours.

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THE STATISTICAL CRITERION OF FATIGUE CRACK DETECTION BY INTENSITY OF AN ACOUSTIC EMISSION

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Key words: statistical criterion, fatigue, crack. acoustic emission

In connection with extremely high requirements to a reliability and availability of diagnostic of air structures it is necessary a construction of the justified criterion of marking decision using the statistical information on process AE. In the present paper using this basis the attempt of construction of evocative criterion and estimation of its effectiveness is made. There is a stochastic process consisting of two stationary segments.

On the first segment the average of process and standard deviation differ from same performances on the second segment. At some operating time t_1 there is a change of performances of process - passage from the first segment on second one. The measurements of process on each pitch are made, and on the first segment of its values equal $u_{11}, \ldots, u_{1s}$, and on second - v_{11}, v_{12}, …. Using this information it is required to define whether there has occurred passage of process from a first stage on second and probably more precisely to indicate number of a pitch s or operating time t_1, appropriate to the moment of passage. At construction of primary criterion of definition of the moment of passage t_1 from the first segment of process on second the method independent from parameter p - boundaries of a random variable was effectively used. This criterion was checked using experimental information about AE in fatigue tests.

Let $P(X>\tau)$ is the probability that X is more than some boundary , and it is required to define this boundary for some fixed probability p, i.e.

$$P(X>\tau) = p, \qquad P(X<\tau) = 1-p,$$

is equation for a solution of this problem.

In outcome the required solution notes by the way $\tau = c\eta_1 + \eta_2$, where

$$\eta_2 = \frac{1}{n}\sum_{i=1}^{n} z_i \qquad \eta_1 = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(z_i - \eta_2)^2} \qquad c = u_{p,n-1}\sqrt{\frac{n+1}{n-1}},$$

where $u_{p,n-1}$ - quantile of a level $1-p$ of a Student's distribution with $(n-1)$ degree of freedom.

The table 1. The information about intensity AE at the first stage

Number of observation	1	2	3	4	5	6	7	8	9	10
AE intensity	2,170	3,433	4,057	3,076	3,587	2,488	2,408	2,980	1,977	1,754
Estimation η_1	0,907	0,878	0,879	0,852	0,832	0,825	0,821	0,801	0,818	0,845
Estimation η_2	3,108	3,132	3,193	3,186	3,210	3,170	3,129	3,122	3,068	3,008
Estimation τ	6,060	5,939	5,963	5,834	5,766	5,680	5,604	5,517	5,498	5,501

INFLUENCE OF CORROSION ON THE REQUIRED NUMBER OF AN AIRFRAME INSPECTION

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Key words: Fatigue Crack Growth, Corrosion Medium, Failure Probability, Interval Between Inspections

The behavior of fuselage splice joints containing multi-site fatigue damage and corrosion is investigated. The objectives of this paper is to develop probabilistic analysis methodology that allows to calculate the probability of fatigue failure under specified interval between inspections and to make comparison of the cases when there is and there is not corrosion. As initial information the results of fatigue test of specimens of special type are used. By the use of this information parameters of the stochastic damage growth models were estimated. The probability of failure at the specified number of inspections at the fixed specified life was calculated by the use of Monte Carlo method and related formulas. It was shown that if the specified life is very large then relatively large probability of failure is nearly the same for both cases when there is and there is not corrosion. But if the specified life is relatively small then corrosion increases the probability of failure at the same number of inspection very significantly.

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THE INVESTIGATION OF A POSSIBLE TRAJECTORY OF THE FATIGUE CRACK GROWTH IN STRUCTURE OF HELICOPTER MI-8

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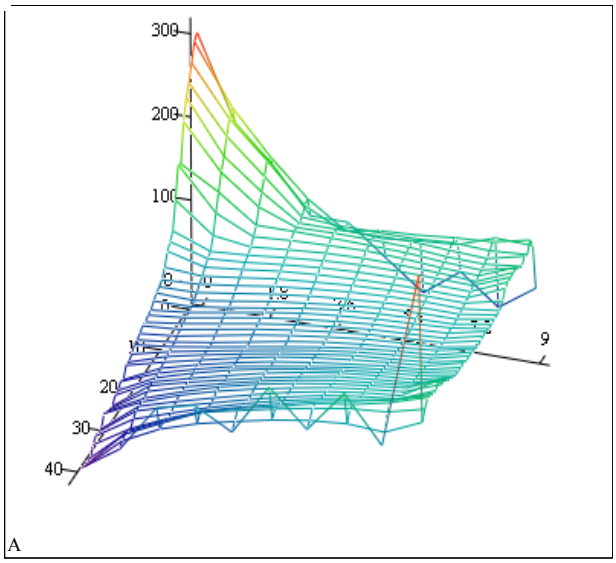
Key words: crack, trajectory**,** stress state

In the present paper there are considered the problems, bound with prediction of the regularities of cracks development and an estimation of residual strength of a structural unit at inhomogeneous stress state. The main attention is given to the analysis of an following problem: exact definition of a trajectory of crack propagation. The experimental outcomes of destruction are analysed at tests of a structure of the helicopter Mi-8. Using data about fatigue damages of a structure, which one are obtained on-stream or at alpha tests, the analysis of regularities of fatigue cracks development in tail and keel beams in a zone of their joint is carried out. In engineering process of the calculated scheme two main assumptions are adopted. On the one hand, the model should adequately mirror stress - strain state of a frame, and, with other, it should be enough simple for a numerical analysis operating a three-dimensional finite element method (FEM).



Effected there is analysis of regularities of development of fatigue cracks in the junction of the helicopter tail and keel beams obtained in trials and according to data of defectiveness of the construction in operational conditions. Given there is comparison of the trajectory of increase of the crack in conditions of sharply inhomogeneous flexible field. It is shown that the trajectory of the crack is close to the line of a maximum normal pressure on the surface. This result may be used to forecast development of the fatigue destruction in elements with a complex inhomogeneous character of the strained condition.

Considered there is problem of a rational designing of the carrying construction of the helicopter tail beam in the zone of junction of the tail and keel beams. Proposed there is an approach ensuring a required reliability and certainty of durability calculations in case of a crack developing in a sharply inhomogeneous field of flexible pressures. It is shown that on basis of a careful analysis of the strained deformed condition there may be achieved an essential effect of increase of the fatigue of resistance and endurance to cracks of the construction.

AIRCRAFT GAS TURBINE ENGINE'S TECHNICAL CONDITION IDENTIFICATION TECHNIQUE

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The new approach to identification of the aircraft gas turbine engines technical condition is considered at an fuzzy, limitation and uncertainty of the information. This approach is based on applicability of fuzzy logic and artificial neural networks (Soft computing).

Key words: fuzzy logic and neural networks, dynamics of correlation and regression coefficients, recursive least squares method.

Groundlessness of application probabilyty-statistic methods is shown, is especial at an early stage of the aviation gas turbine engine's (GTE) technical condition diagnosing when the volume of the information has property of the fuzzy, limitations, uncertainty and efficiency of application of new technology Soft computing at these diagnosing stages with using of the fuzzy logic and neural networks methods. Is made training with high accuracy of multiple linear and nonlinear models (the regression equations) received on the statistical fuzzy data basis.

For models choice is offered the application of the correlation analysis results. Dynamics of correlation coefficients changes is considered.

At the information sufficiency it is offered to use recurrent algorithm of aviation GTE technical condition identification (technology Hard computing is used) on measurements of input and output parameters of the multiple linear and nonlinear generalized models at presence of noise measured (the new recurcive least squares method (LSM)). The structure of the GTE condition monitoring system on base combined method shown in fig.1.

As application of the given technique the estimation of the new operating aviation engine D-30KU-154 technical condition was made.

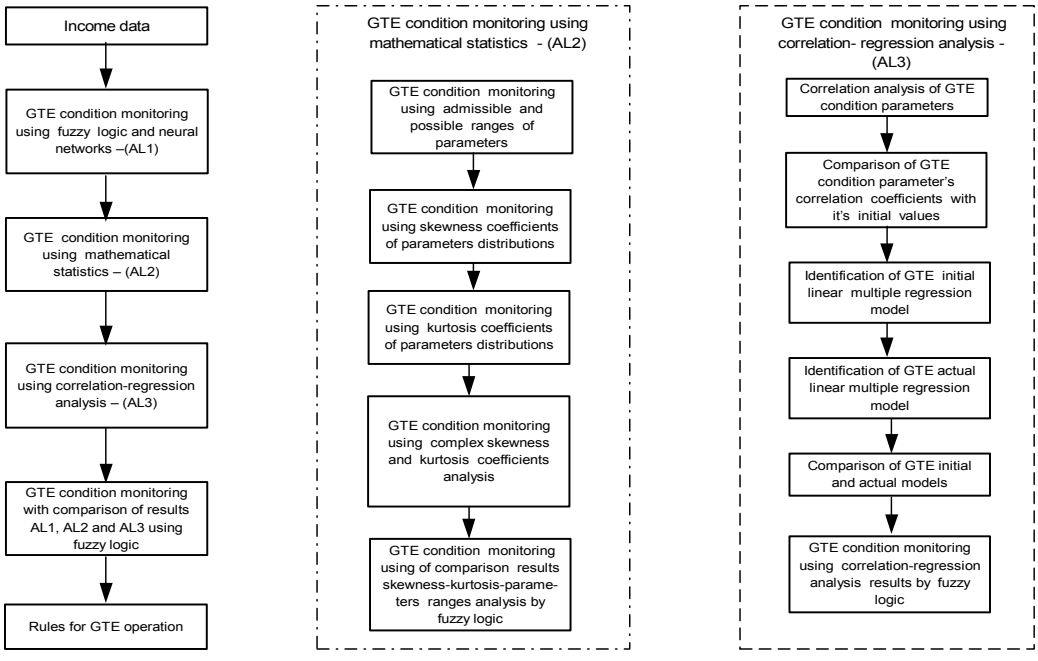

Fig. 1. Flow chart of aircraft gas turbine engine parametric diagnostic algorithm

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THE INFLUENCING OF SIZES ON FATIGUE DURABILITY OF SHEET DETAILS

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Key words: rod, crack, bending, compression, critical force

This paper completely is constrained with the indisputably established experimental facts about the influence of sizes on the fatigue characteristics of samples and structural elements. There is an attempt to construct a certain new model. The more adequate description of the special features of the fatigue fracture is this model basis. It is known that in structural steels and alloys the conception of fatigue fracture occurs in a comparatively thin surface layer that eventually leads to developing of complete destruction of a sample or a detail. In the absence of the surface shaping or other strengthened forms of treatment, the fatigue cracks are conceived from the surface. In this case, the greater gradient (in the absolute value) of the first principal stress in the particular point of surface calls the higher operating time to the origin of crack. The action of gradient is reduced to lowering in the result of effective stresses. In the proposed model it is assumed that the durability to the origin of fatigue crack in the environment of this point of surface is determined by stresses on a certain small depth ***b.*** In this case it is assumed that this parameter is a certain constant of material. The greater this constant, the more sensitive material to the non-uniformity of stresses in the surface layer appears.

The procedure of the determination of the function of the distribution of fatigue longevity to the zone of detail is reduced to the following:

1. The analysis of the stress-strained state is conducted and define the boundaries themselves of zone with stress level, close to the maximum. The values of maximum stress and relative stress within the limits of this zone are determined.

2. The functional connections between the average values of fatigue durability in the elementary zones of the surface layer of detail are determined. In this case, actual stress, which determines destruction in this elementary section, is determined for the point of surface layer at the depth ***b*** by the formula

$$\sigma_i = \sigma_{i\,max}\left(1 + G_i \cdot b\right),$$

where σ_{imax} and G_i – the maximum value of the first principal stress and its relative gradient in the direction of internal normal to the surface in the elementary zone ***i***.

This fact is a basic difference in the system of the assumptions of the proposed model in comparison with the known theories.

3. Using a "weak chain" hypothesis it is determined the law of distribution $F(N,\sigma)$ fatigue durability N to the origin of main crack in a certain critical zone of detail on the assigned level of nominal load.

It is carried out a comparison the results of the tests of average logarithm and standard deviation of fatigue durability with a result of calculations on the basis of the proposed theory.

CROSS-PLY BENDING AND STABILITY OF THE COMPRESSED ROD WITH CRACK

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Key words: rod, crack, bending, compression, critical force

The peculiarity of a problem is that the increment of rod compliance under the crack influence is a function of deflection. Because of this in order to define the critical force for the compressed rod when crack presence at one of the sections it is convenient to consider the task of a rod cross-ply bending. An equation for determination of compliance of equivalent hinge simulating the effect of crack influence is added to the equation of this task.

In the basis of the concept there is the principle of the reciprocity works (Maxwell's theorem), It allows to define a compliance of an equivalent elastic hinge which influence on integral deformation of a rod coincides accurately with influence of a crack.

$$\delta_j = \frac{2}{Q_j^2}\int_S \left[\frac{\left(1-\nu^2\right)}{E}\left(K_I^2 + K_{II}^2\right) + \frac{1+\nu}{E}K_{III}^2\right] dS ,$$

where δ_j is the compliance increment (additional generalized displacement) caused by crack influence at an action of the generalized force $\overline{Q}_j = 1$; K_I, K_{II}, K_{III} are stress intensity factors caused by an action of the generalized force Q_j; E is Jung's module and ν is Poisson's ratio; S is area of crack surface.

It is obvious, that critical force F^* at the fixed parameters of a problem is determined by the size of a crack and the compliance of an equivalent hinge appropriate to it.

The rod deflection in cross-section with crack v_0 isn't known. It is defined the expression of this deflection v_0 as a function of axial compressing force F, normal disturbing force P and the compliance of a hinge δ.

$$\overline{v}_0 = \overline{P}\,\overline{L}_1(1-\overline{L}_1)\left[\frac{\dfrac{1}{kL(1-\overline{L}_1)\overline{L}_1}}{\dfrac{1}{tg\left(kL\overline{L}_1\right)} + \dfrac{1}{tg\left(kL(1-\overline{L}_1)\right)} - \overline{\delta}\,kL} - 1\right],$$

where $\overline{v}_0 = v_0/L$, $\overline{P} = P/F$, $\overline{\delta} = \delta/\delta_0$ and $\delta_0 = L/EI$ is the bending compliance of rod when there isn't a crack.

The buckling-bending task and definition of critical force can be solved by the successive approximation method. The algorithm of the solution is made.

It is shown that there are upper and lowerlimits of critical force. The results of experiment satisfactorily conform to theoretical conclusions.