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Health Monitoring of Aircraft Components and Assemblies through Non-Destructive Methods

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Abstract

At the present time vibration-based diagnostics methods are successfully being used to evaluate and predict the technical condition of onboard units and assemblies. They are the basis of health and usage monitoring systems installed on the helicopters. And these systems do not cover most of the details of helicopters and aircrafts. Therefore, it is necessary to develop new methods for covering all critical aviation units and assemblies which operate under complex structural load. These methods should be based on an objective evaluation of the technical state of structural materials which is used in the manufacture of products. It is important to get information on the controlled parameters of the structural material in the stage that corresponds to its predefective state. The development of these methods faces difficulties because of the fact that for measuring the parameters of the technical state of the structural material of aviation units and assemblies (structure, mechanical and structurally sensitive physical properties) requires to use special, as a rule, rather bulky equipment that can not be placed on board. Therefore, the authors propose an approach to select parameters that, on the one hand, have a very definite and unambiguous dependencies with the structure, mechanical and structurally sensitive physical properties of the structural material of aircraft assemblies and units. On the other hand, they can be monitored continuously during the aircraft operation.

Keywords (Tahoma 10 pt, bold): *health and usage monitoring systems,* vibration-based diagnostics, structural material.

One of the most important aspects of the development of aviation technology is the solution of economic issues which include reducing costs of development, production and maintenance. The principal methods that can reduce costs include complex diagnostics of technical condition and forecasting of the operability of aircraft parts, units and assemblies within the life cycle.

Forecasting the technical condition of units and assemblies at the stages of the life cycle helps to solve the following tasks:

- *development and design*: to assess the validity of technical solutions at the initial stages of design, thereby shortening the terms and costs for design, to forecast the performance capabilities and durability of the units and assemblies, to develop technical processes that ensure maximum reliability and durability of units and assemblies;
- *production*: to monitor and to correct timely production processes, thereby reducing decision-making time and saving stuff and energy resources, to create technical standards for suitable units and assemblies;
- *maintenance*: to diagnose timely the current technical condition of units and assemblies during operation, to predict their subsequent operability and to make a decision about the possibility of further operation.

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At the present time vibration-based diagnostics methods are successfully being used to evaluate and predict the technical condition of onboard units and assemblies. They are the basis of health and usage monitoring systems installed on the helicopters. And these systems do not cover most of the details of helicopters and aircrafts. Therefore, it is necessary to develop new methods for covering all critical aviation units and assemblies which operate under complex structural load. These methods should be based on an objective assessment of the technical state of structural materials which is used in the manufacture of products. In this case, the factors as the ability to resist external force, the influence of an aggressive environment, physico-mechanical and structural degradation of the material, the ability to self-repair throughout the life cycle of the product, etc., come to the forefront. The data on the quantitative and qualitative character of the monitored parameters and their variation over time at all stages of operation will make it possible to predict the operability of units and assemblies with a high degree of reliability. It is important to get information on the controlled parameters of the structural material in the stage that corresponds to its predefective state. The development of these methods faces difficulties because of the fact that for measuring the parameters of the technical state of the structural material of aviation units and assemblies (structure, mechanical and structurally sensitive physical properties) requires to use special, as a rule, rather bulky equipment that can not be placed on board. Therefore, the authors propose an approach based on the estimation and forecasting of the technical state through indirect parameters, which have the following distinctive features:

- parameters can be measured in-flight using compact measuring sensors;
- parameters are uniquely interconnected with the characteristics of the structural material (structure, mechanical and structurally sensitive physical properties) that determine its current and predicted state;
- a set of parameters is formed for each structural material.
- The approach includes the following main stages:
- the first stage is the studying of correlations between the characteristics of the structural material and its mechanical properties;
- the second stage is the determination of the structurally sensitive physical parameters that can be measured in-flight and they are uniquely related to the structural characteristics of the constructional material.

To illustrate the proposed approach there are presented some results on the evaluation and prediction of the technical state of aircraft parts made of TRIP-steel VNS-9SH. The X-ray diffractometry method was used to study of the structure of the material. The method has such advantages as:

- direct measurement, high accuracy of residual stress detection in comparison with electromagnetic, mechanical, optical, acoustic and other indirect methods,
- ability to get data on the phase composition of the material,
- ease of maintenance.

Structurally, the X-ray diffraction method can be implemented in a portable and radiation-safe way. It is necessary to emphasize that the X-ray diffraction method can serve as a technical standard for calibrating indirect methods.

The samples were subjected to cycling according to the scheme of zero-to-tension stress cycle with the maximum load of 4200 kgf and the frequency of 1 Hz. Then the phase composition of the samples was studied. The phase composition was determined using the ratio of the peak-to-background of the diffraction peaks {220} of austenite and {211} martensite. For control purposes, the percentages of the martensitic and austenite phases were also determined using the metallographic method.

These correlation dependences between the metallographically determined phase fractions and the parameters of the X-ray diffraction peaks indicate a reliable correlation of these parameters. This applies especially to the martensitic phase: the dependence between signal-to-noise ratio of the peak {211} and the metallographically determined percentage of martensite is practically linear.

Based on the experimental data it were constructed correlation dependences of the number of phases and mechanical properties (conditional yield strength and tensile strength) of VNS-9SH steel on the number of load cycles which became the basis for the forecast of the lifetime.