EXPERIMENTAL BENCH TESTS FOR FATIGUE STRENGTH OF ELASTIC BEAM ELEMENTS OF HELICOPTER HINGELESS LIFTING AND STEERING ROTORS

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In the last two decades, in the light and middle weight helicopters ever increasing use is made of hingeless rotors with variously designed elastic elements. The basic types of these elements used at present in the bush constructions of up to date helicopters are the following: elastomeric bearings that work in compression under the action of centrifugal forces and provide a blade feathering at flapping, bending, and twisting; elastic beam-type elements that execute the same functions by using the distributed geometrical characteristics and characteristics of elastic element cross-section stiffness.

The basic requirement imposed on such an elastic element is to ensure fatigue strength but no less than that of other lifting rotor assemblies while executing al the functional characteristics.

In this paper a set of experimental research conducted in the laboratory dealing with strength of aviation technique at Tupolev Kazan State Technical University is examined. Research is aimed at the provision of fatigue strength of elastic beam-type element that is used in the lifting system of multifunctional helicopter ANSAT that has been developed at the joint-stock company "Kazan Helicopters".

The set of technical devices aimed at the test process automation, the test quality increase, the accuracy of designed load reproduction on the most important lifting system assemble is presented.

The elastic element under review represents a multilayer beam profiled with a special purpose along the length and composed from various modular composite materials by laying out and hot pressing method. The special selection of materials, personal cutting of every layer package, multidirected layered laying out as well as subsequent mechanical processing for geometrical form optimization makes it possible to provide an acceptable level of stresses (and structure lifetime) in the zones where large strains occur. On the plane a flap of the blade is attained due to shears in "soft layers of structures" and on the rotation plane – due to multichannel distribution of efforts. The construction "force" layers work in this case in loads that are close to the uniaxial loads.

A typical design diagram of temporary components distribution of curving moments on the plane along the elastic element is presented in fig. 1.

At present, there are no any purely design methods providing a proper lifetime for such critical elements. For this, use is usually made of the design experimental methods combined with the long-term test bench optimization of elements strength on the specimens and real assemblies.

For bench tests of elastic torsion-type element while creating of the ANSAT helicopter prototype the specialists of the OMEGA research center at Tupolev KSTU have developed the special-purpose test bench with hydraulic multichannel system of force excitation providing the unit loading such that is adapted maximally to flying conditions.

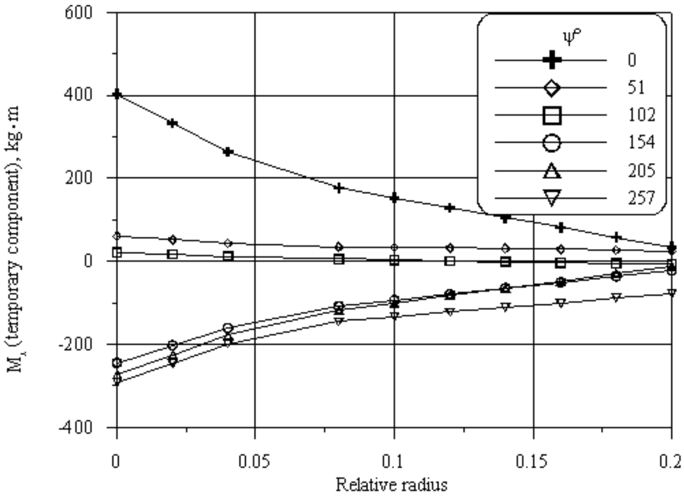

Fig. 1. Temporary components distribution of curving moments on the plane along the elastic element.

The fundamental scheme of fastening and loading of the bush elastic element specimen in the test bench is presented in fig. 2.

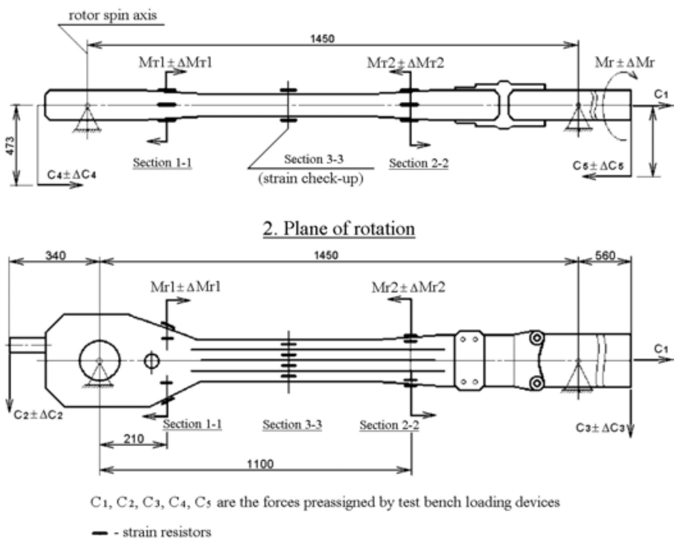

Fig. 2. Scheme of fixture and loading of a specimen of rotor hub elastic element on test bench (shown conditionally are only the torsion and blade adapter).

As it is shown on the scheme the loading of the specimen is done from the both ends that provides the conformity of the loading with the design values in two construction cross-sections at the minimum (section 1-1, section 2-2).

The test bench was loaded in accordance with the block diagram that uses the split axis programmed control of loading with the use of six independent channels.

Force influence on the load application point is executed by hydraulic force excitators that is why a set of technical devices for force excitation control considered as the subsystem of load control has been created. Measuring and design operations are also conducted with the help of a technical devices set singled out for the subsystem of acquisition, processing and representation of measuring data.

Loading control subsystem

The subsystem of load control is grounded on the basis of technical devices of Micro PC family and can be set in the immediate proximity to the test bench. The main task of the subsystem is the multichannel (N=1,…,n) generation of sinusoidal form signals $F_n=A_n\sin(2\pi f_n t+\varphi_n)$ for controlling force excitators with A_n amplitude, f_n frequency, φ_n phase separate regulation on the real temporal scale. Nominal values of these parameters are defined by a test program. While regulating the phase it is supposed to change the phase of all every single taken channel with respect to the first one within the range of 0-2π. The phase shear sets independence in the work of force excitators at periodical construction loading if it is demanded by the terms of a program. The subsystem is aimed at the generation of signals with the frequency of up to 50Hz in 12 channels. The functional subsystem scheme for load control is represented in fig. 3.

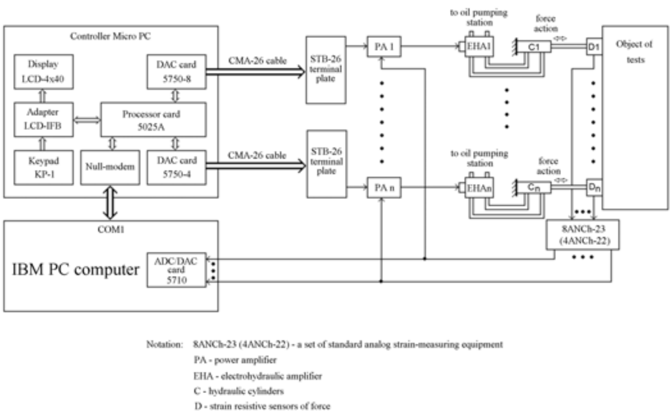

Fig. 3. Functional circuit of loading control subsystem.

At bench adjustment the regulation of parameters is executed in the real time and selected values are kept in memory for being reproduced at the bench halts and restarts.

Generated analogous loading control signals regulate the oil feeding from the oil pumping station in the hydrocylinder cavity providing recurrent and translational movement of hydrocylinder rods. Hydrocylinders create constant and temporary loads leading to the appearance of curving and rotating moments in the tested construction.

Subsystem of acquisition, processing and representation of measuring data

At fatigue strength tests periodical loads are applied to the construction in the frequency range starting from infralow ones up to 50Hz during a long period of time. The structural scheme of acquisition, processing and measuring data representation subsystem at fatigue strength tests of experimental helicopter ANSAT lifting screw bush is presented in fig. 4.

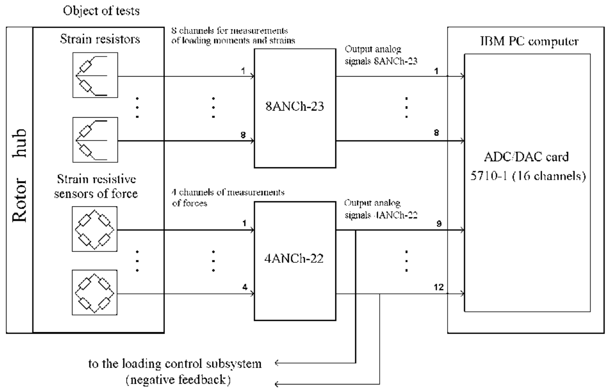

Fig. 4. Block diagram of the information computing complex for fatigue strength tests.

Testing of periodical signals is the main purpose of acquisition, processing and measuring data representation subsystem. The task of the subsystem software includes the definition of constant (static) component values and amplitude values for variable (dynamic) components of measuring parameters. For this signal values being measured at discrete moments are transformed with the help of analogous-digital converter and are sorted with the aim of maximum and minimum value definition. Calculation of maximum and minimum signal values provides acquisition of load period quantity calculation.

While archivizing parameter values on the computer hard disk there is no necessity to fix every signal minimum and maximum. Registration period duration depends on the frequency of a measuring process. The higher the process frequency the shorter is the registration period. For example, at process frequency f=16Hz it constitutes 1-2 seconds.

To define constant component values of measuring parameters during the registration period ($U_{c.m.}$ – constant mean) the following calculations are done:

$$U_{c.m.}=\frac{\sum_{i=1}^{n}U_{i\,\max}+\sum_{i=1}^{n}U_{i\,\min}}{2n}$$

where n – number of loading periods during a registration period, U_i – measuring parameter values. If calculated $U_{c.a.}$ are multiplied by corresponding coefficients obtained as a result of the experiment we get scaled values of constant component moments, strains in sections under control. To define average amplitude values of measuring parameter variable components ($U_{a.m.}$ – amplitude average) following calculations are done:

$$U_{a.m.}=\frac{\sum_{i=1}^{n}U_{i\,\max}-\sum_{i=1}^{n}U_{i\,\min}}{2n}$$

Calculated $U_{a.a.}$ multiplied by corresponding coefficients obtained as a result of the experiment will conform to amplitude values of moments, strains in cross-sections under control. During every registration period mean values of data are put down on a computer hard disk and make up an archives data basis on tests.

Strain distribution on elastic element obtained as a result of measurments done by the subsystem is shown in fig. 5.

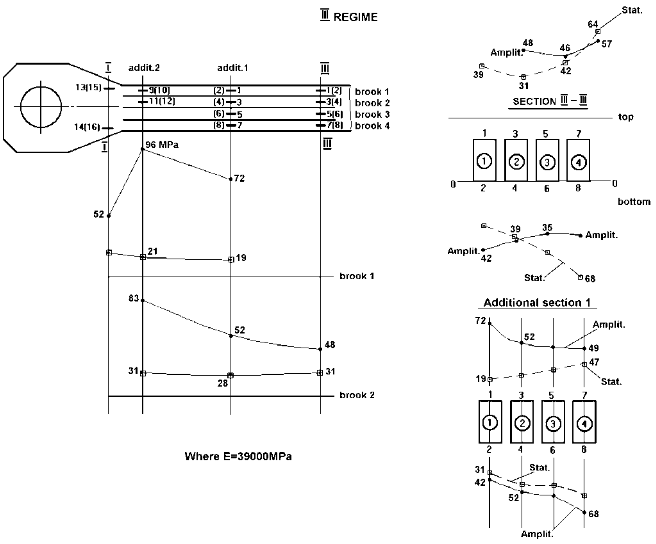

Fig. 5.

Conclusions

The use of up to date industrial computer systems, instrumental devices of loading, measurement, and control at testing for fatigue strength makes it possible to improve efficiency and qualitative potentialities of experimental methods for determining the fatigue strength of helicopter rotor assemblies. The basic advantages of these methods are:

– complete automation of inquiry and recording of parameters measured;
– flexibility of load regimes selection in frequencies, phases and amplitudes of forces and displacements;
– software and hardware compatibility with an IBM PC;
– high reliability at extreme situations;
– high speed of channel inquiry;
– high reliability and accuracy of measuring data processing (increase in characteristics of accuracy by a factor of 3–5);
– continuous check-up of test regime states on a display;
– large body of data recorded in the form to be convenient for further processing by using the complex algorithms;
– test data archiving.

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