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Using Acoustic Emission Method When Carrying out Fatigue Tests of Pitch Arm of EH-101 Helicopter

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***Abstract.* In the process of fatigue testing it is important to register the arising of the fatigue damages at the earliest stage. This work shows the efficiency of using acoustic emission method on the example of conducting fatigue testing of pitch arm of EH 101 helicopter. There is given the description of a stand and methods of conducting fatigue testing of a pitch arm of EH 101 helicopter. The AE method was used for monitoring the arising and growth of a fatigue crack.**

***Key words*: acoustic emission, arising and growth of a fatigue crack, pitch arm**

INTRODUCTION

At the given moment one of priority directions of the development of modern aviation is the increasing of periods of safe operation of aircraft equipment. Carrying out on-ground static and fatigue strength tests of aircraft equipment and its components with the use of various kinds of non-destructive testing (NT) is a necessary condition both for the certification of new equipment and for the prolongation of operation time of airplanes and helicopters already in use. As it is known, fatigue cracks along with metal corrosion are the principal causes of the arising of multi-site damages and the development of catastrophic faults, which is the greatest danger in the process of the operation of aircraft structures [1]. Therefore in the process of fatigue testing it is important at the earliest stage to register the arising of the fatigue damages and to monitor the development of those by modern methods used for monitoring the state of the structure including methods of high-and-low-frequency eddy currents, radiographic methods, methods of ultrasonic waves of pigmented penetrating liquids. However, in most of these methods, it is rather complicated to automate the process of diagnosing. A very much promising method is a method of acoustic emission (AE). The AE method allows discovering structure faults and fatiguing damages at hard-to-access places with high reliability [2].

Using AE method, it is possible to discover with high reliability structure faults and fatigue damages at hard-to-access places of the structure and to monitor their development both during fatigue testing and the operation as well as classify the damages by danger degree. But in practice it is rather hard to use the AE method, for the energy level and principal characteristics of the useful signal significantly depend on properties of the material, and the process of the development of the fault is, as a rule, accompanied by noises close to the characteristics of the AE signals. This article examines the use of AE method for monitoring technical condition of the pitch arm of EH 101 helicopter when conducting fatigue testing.

TESTING METHODS AND THE USE OF EQUIPMENT

Fatigue testing was conducted according to a testing program submitted by the testing customer. On Fig. 1 there is presented a diagram of a stand for EH 101 helicopter pitch arm testing, indicating the direction of loading application for each hydraulic cylinder.

For loading application set by the testing program there are used four cylinders: HF - horizontal force, VF – vertical force, RF – pitch link force, CF – centrifugal force. Minimum and maximum loading value for each loading channel are presented in Table 1.

TABLE I
MINIMUM AND MAXIMUM LOADING VALUE FOR EACH LOADING CHANNEL

	Pmin, kN	Pmax, kN
HF	0,00	-44,14
VF	-29,43	39,24
RF	0,00	42,18
CF	0,00	462,00

The loading of the testing object was conducted cyclically. Each loading cycle had trapezium shape and consisted of four loading stages (See Fig.2). Stage 1 – loading preparation (t=1s, HF=0kN, VF=-29,43kN, RF=0kN, CF=0kN) Stage 2 – arrival at the set load (t=s). Stage 3– keeping the load (t=1s, HF=-44,14kN, VF=39,24kN, RF=42,18kN, CF=462kN). Stage 4 – unloading (t=1s). The total duration of one loading cycle is 4 s.

The testing of the pitch arm was conducted until discovering a fatigue crack by visual method. For this purpose there was conducted periodical visual inspection of the testing subject for a crack. The AE method was also used for monitoring the arising and growing of the fatigue crack there. In Fig.3 shows a diagram of the connections of AE equipment for pitch arm testing.

A piezoelectric transducer (4) was used as an AE (5) sensor. Signal from the AE transducer via the prime amplifier was brought to AF-15 (7) measurement complex. Further on AE formed pulses through a matching device serving for galvanic signal decoupling and AE pulse synchronization with loading parameters are brought to АЦП Lcard L-783 (9). A signal of dynamometer channel CF was used for the synchronization of AE pulses with the load applied.

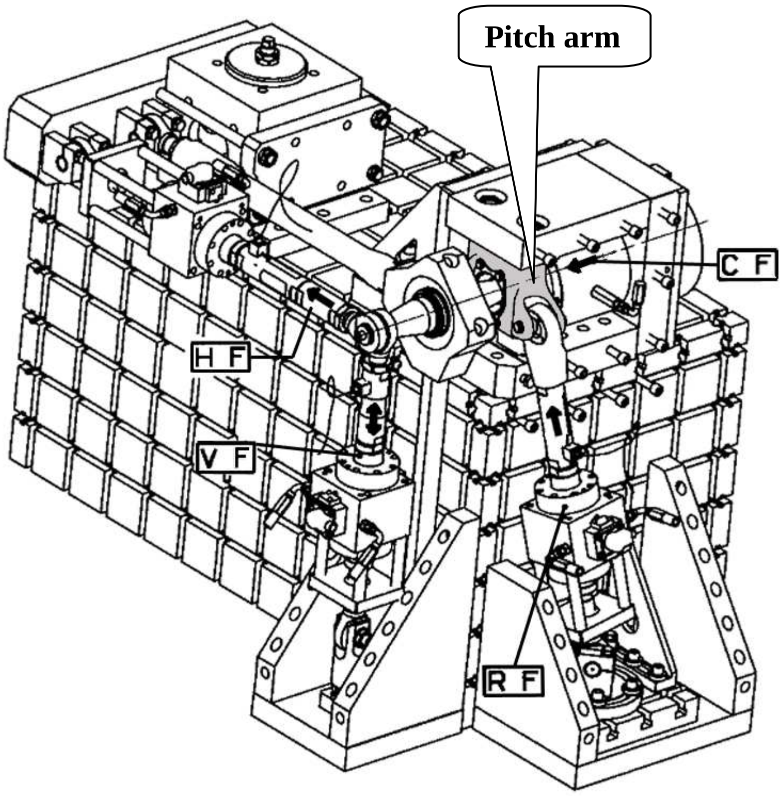

Fig.1. Diagram of a Stand for conducting fatigue testing of a pitch arm of EH-101 helicopter

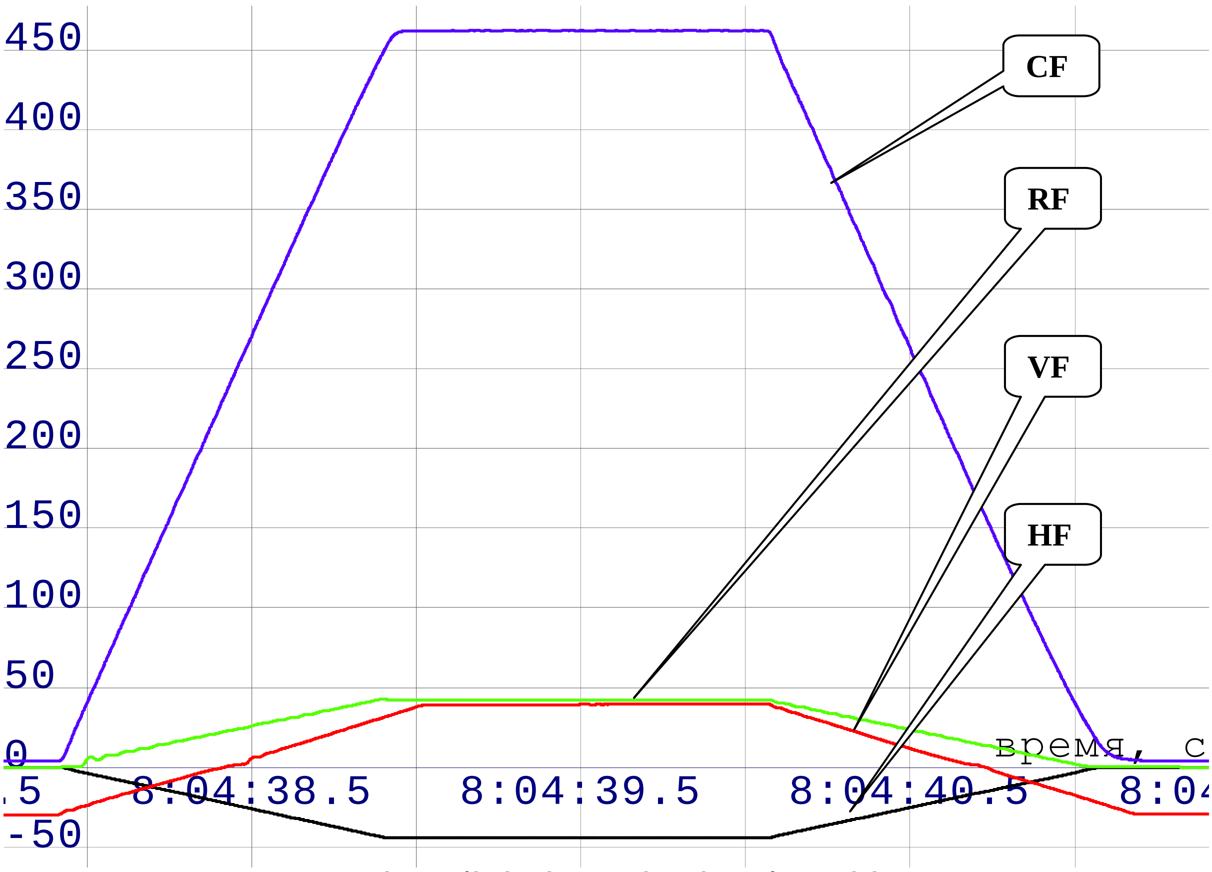

Fig.2. A Cyclogram of load application to the pitch arm of EH-101 helicopter

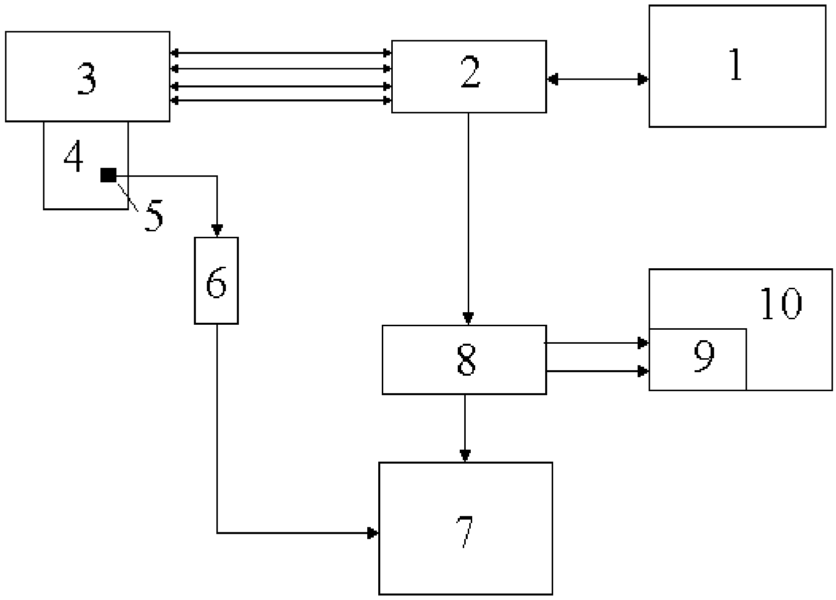

Fig.3. Measurement equipment connection diagram. 1 - Control system computer, 2 - Control system, 3 - hydraulic cylinders, 4 - pitch arm, 5 - AE Transducer, 6 - prime amplifier, 7 - АФ-15, 8 - matching device, 9 - АЦП Lcard L-783, 10 - AE registering computer.

TESTING RESULTS

Fatigue testing was stopped at 136137 cycle running after visual discovering of fatigue crack of 15 mm length (Fig.4).

Fig.4 Fatigue crack of 15 mm length after 136137 loading cycle.

The results of AE monitoring technical condition of the pitch arm are presented in the form of a graph of summary AE against cycle number (Fig.5). The presented graph may be divided into 7 sectors characterized by various speed of AE signal accumulation in the process of conducting the fatigue testing [3, 4, 5]. In Fig.6 there are presented fragments of synchronous record of AE signal intensity and the load applied, which is characteristic for each of the seven fragments.

Analysis of AE data obtained, results of fractographic research of the fracture as well as results obtained when conducting analogous research [6, 7], allow explaining the behaviour of the forming of AE signals in the following way.

Let us examine in more detail each of the sectors of the graph presented on Fig.4.

Testing initial period, sector 1 running from 0 up to 4700 cycles (Fig.5) is characterized by a little summary AE. In the synchronous record Fig.6.1 it is seen that AE pulses possess little intensity and frequency of the arising. The AE signals arise both when loading the testing object (stage 2) and when unloading that (stage 4) and are caused by acoustic noises due to the operation of the stand (backlashes and friction).

In the next section running 4700 up to 51300 (see Fig.5) the speed of building up of the summary AE increased in comparison with the first sector. On the synchronous record (Fig.6.2) it is seen that AE signal frequency has increased, AE signals arrive actually during all the time of achieving the set load (stage2) and when unloading the testing object (stage 4) and have the most intensity at the moment of their ending. At this section probably is going on the energy accumulation in various zones of the dislocation [8].

The third section of the graph, running from 51300 to 52125 (see Fig.5), is characterized by “wild” growth of summary AE. On all its length there was recorded the most speed of summary AE building up during all the “fatigue” testing. On the synchronous record (Fig.6.3) there is seen that AE pulses have great intensity and very high pulse frequency of the summary AE and come actually uninterruptedly during all four loading stages. The following investigation of the fracture conducted along the “fatigue crack” showed that the arising of the crack had taken place on the examined section from the opening of the bolt of the pitch arm fastening.

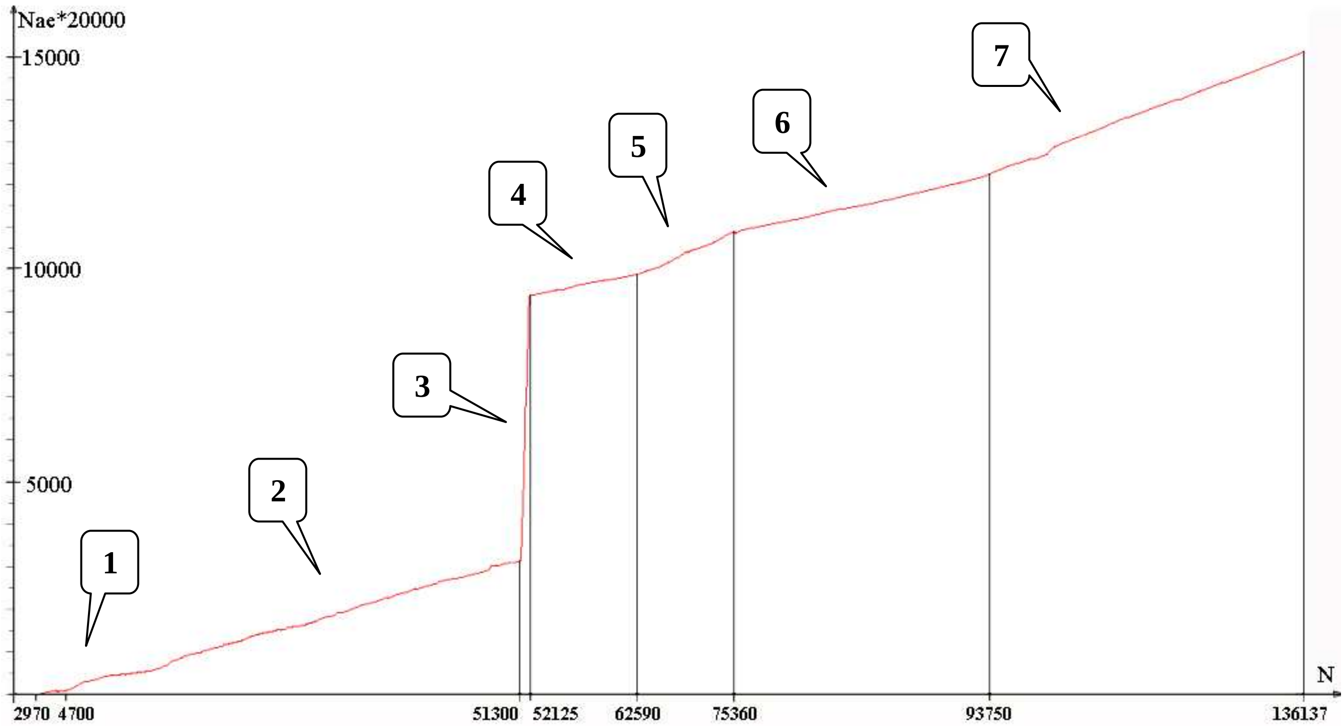

Fig.5. Summary AE against loading cycle number graph

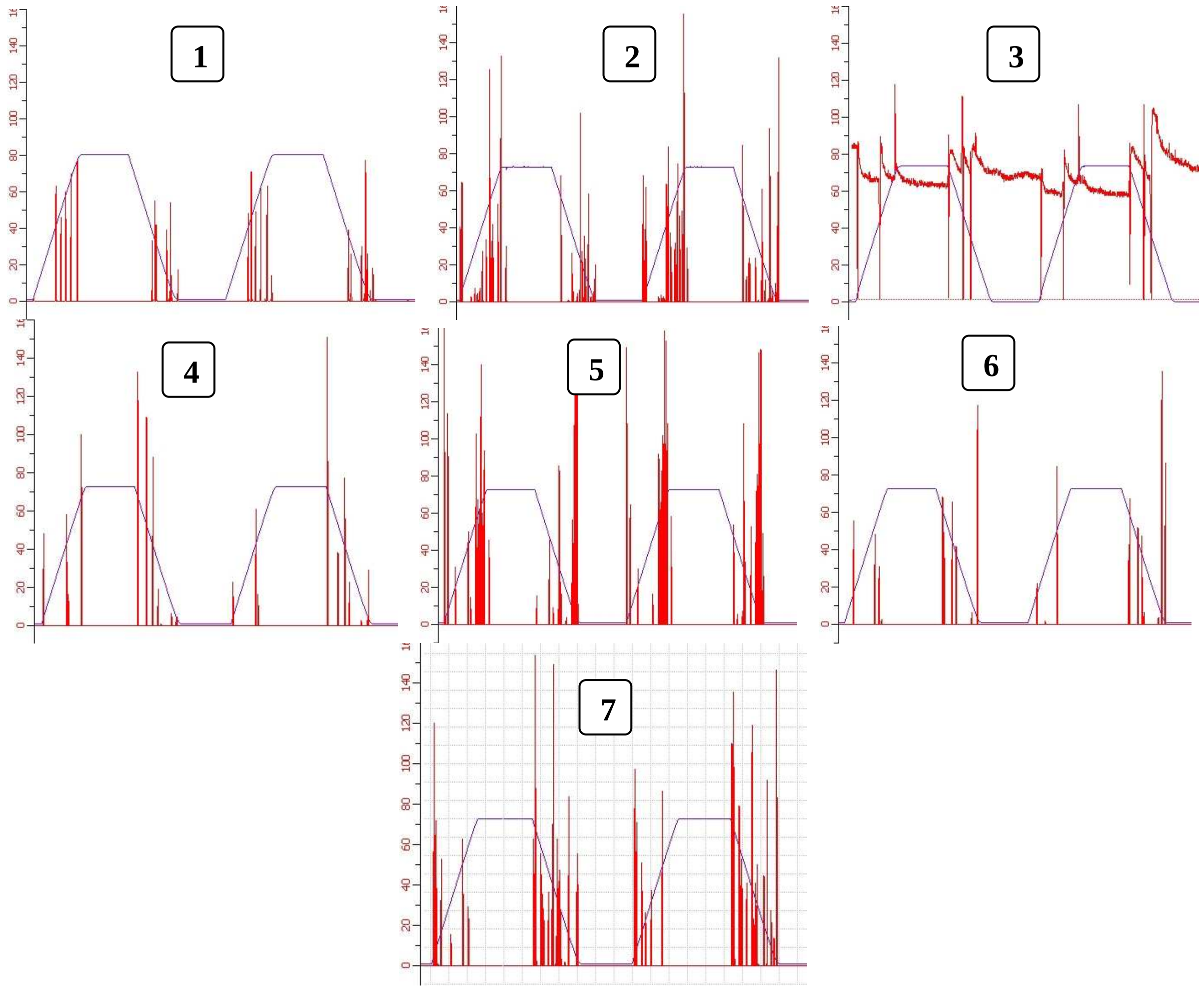

Fig.6. Fragments of synchronous record of AE signal intensity and of the loading applied by CF channel

After 52125 cycle running, the speed of the building up of summary AE lowered significantly, see section 4 from 52125 - 62590 cycle running (see Fig.5). Section 4 by the speed of the building up of the summary AE may be compared with the section 1. In the synchronous record (see Fig. 6.4) it is seen that AE signals have little frequency although their intensity then is rather high.

Signals with the most AE intensity appear basically in the first half of the stage of testing object unloading. Supposedly at this section there is arising a new stage – of low energy building up, and the growth of the crack has actually stopped.

After 62590- cycle running, section 5 62590 – 75360 cycles, there begins the second stage of the growth of the crack, which is corroborated by a significant speed of the building up of the summary AE. It is seen on the synchronous record (Fig. 6.5) that AE signals basically appear at the completion of stages 2 and 4. At these moments of time AE signals have the highest intensity and frequency. This process ends up at 75360 cycle running and is replaced by process of low building up of summary AE, section 6 75360 – 93750 cycles (See Fig.5). By summary AE building up speed it may be compared with section 1 and 4. It is seen on the synchronous record (Fig.6.6) that AE signals have low frequency and little intensity. AE signals having the greatest intensity in this sector arise at the completion of testing object unloading (stage 4).

On the next sector 93750 – 136137 cycles (see Fig.5) there begins the next period of the growth of the crack [9, 10], characterized by a significant speed of the building up of summary AE. In the synchronous record (see Fig. 6.7) it is seen that AE signals have high intensity and frequency along all the stage of the unloading (stage 4), although high intensity signals appear at the beginning of the stage 2 as well. A principal characteristic of this section – the crack grows up during each loading cycle, which is corroborated by the following fractographic analysis of the fracture.

CONCLUSIONS

When conducting fatigue testing, the AE method may be used for:

-the registration of the moment of the arising of a fatigue crack

- analysis of step by step development of the fatigue crack
- the monitoring of the growth of the fatigue crack.
- registration of the moment of a micro-crack having become a crack.

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REFERENCES LIST

1. **Stepanova L., Seryeznov A.** *Aircraft Structure Monitoring Using Acoustic Emission Technique*., Moskow, Mashinostroenie-Polyot,2008 p.180.
2. **Greshnikov V., Drobot Y.** *Acoustical emission*. Standard, 1976, p.272.
3. **Banov M., Konyaev E., Pavelko V.**. Principles of fatigue of structures in high-cycle fatigue on the basis of acoustic emission effect: *4th World Meeting of Acoustic Emission and icd International Conference on Acoustic Emission in Manufacturing*. - September, 1991. Boston, Massachusetts. pp. 110-120.
4. **Banov M., Vainberg V., Zuev A., Konyaev E., Pavelko V.**. *Method of the estimation of fatigue crack growth rate in sheet material,* USSR Author Certificate, No. 725020 [Russian].
5. **Banov M., Konyaev E., Pavelko V., Urbah A.**. *Method of the details inspection for microcracks detection,* USSR Author Certificate, No. 968735 [Russian].
6. **Banovs M., Doroshko S., Nasibullins A., Turko V.** „Undercarriage fatigue test control by acoustic emission method.”, *Ultragarsas. - №2(59),* 2006, pp.16.-18..
7. **Urbahs A., Banovs M., Doroshko S., Nasibullins A.** „Acoustic Emission Monitoring of Landing Gear Fatigue Testing”. *Proceedings of the 12th International conference. Transport means 2008*, 23-24 October 2008, Kaunas University of Technology, Lithuania, Kaunas 2008, -pp.33- 36..
8. **Shaniavski A.** *Tolerance Fatigue Failures of Aircraft Components. Synergetics in Engineering Applications.* Ufa: Publishing House of Scientific and Technical Literature “Monograph”, 2003, p. 803.
9. **Shaniavski A.** *Modeling of Fatigue Cracking of Metals. Synergetics for Aviation*. Ufa: Publishing House of Scientific and Technical Literature “Monograph”, 2007, p. 500.
10. **Kitagava H., Takahashi S.** *In Proc. Second Int. Conf. Mechanical Behaviour Materials.* – Boston, Massachusetts, 1976, pp. 627-631.

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Aleksejs Nasibullins. Akustiskās emisijas metodes pielietojums helikoptera EH-101 propellera soļa vadības roksviras noguruma pārbaudēs
Nogurumu izmēģinājumu procesā ir svarīgi iespējami agrāk reģistrēt nogurumu bojājumu rašanos un turpmāk kontrolēt to attīstību. Akustiskās emisijas metode ļauj ar lielu ticamību atklāt struktūru defektus un nogurumu bojājumus grūti pieejamos konstrukcijas iecirkņos, kā arī kontrolēt to attīstību gan nogurumu izmēģinājumos, gan ekspluatācijā. Izmantojot akustiskās emisijas metodi, ir iespējams atklāt defektus agrā to rašanās stadijā, kā arī klasificēt bojājuma bīstamības pakāpi.
Šajā darbā ir parādīta akustiskās emisijas metodes izmantošanas efektivitāte, izmantojot noguruma pārbaudēs EH-101 propellera soļa vadības roksviras piemēru. Ir dotas stenda un EH-101 propellera soļa vadības roksviras veiktais noguruma pārbaužu metodikas apraksts ar pieliekamo slodžu maksimālo nozīmju norādījumu un to virzieniem.
Plaisas rašanās un attīstības kontroli veica gan vizuālā veidā, gan pēc AE metodes. Kontrolei ar piedāvājamo metodi uz propellera soļa vadības roksviras tika uzstādīts pjezoelektrisks devējs, ar kura palīdzību konstrukcijas slogojuma gaitā tika reģistrēti AE signāli. Izmēģinājumu gaitā sinhroni tika reģistrētas akustiskās emisijas signāla līmeņa un noslodzes vērtības, kā arī tika noteikts AE signāla stāvoklis katrā noslodzes ciklā.
Pārbaužu rezultāti tika attēloti atkarības grafikā, kur uzrādītas summārās akustiskās emisijas izmaiņas $N_{AЭ}$ no noslodzes ciklu skaita un uzrādītas cikliskās slodzes un akustiskās emisijas intensitātes maiņas sinhroni ieraksti. Ir veikta saņemto akustiskās emisijas metodes datu salīdzināšana ar fraktogrāfiskās lūzuma analīzes rezultātiem. Veiktie pētījumi parādīja - AE metode palīdz fiksēt noguruma mikroplaisu rašanās brīdi, kā arī to var izmantot noguruma plaisu bīstamas attīstības noteikšanai. Veiktie pētījumi ļauj iekļaut AE metodi atbildīgu konstrukciju stenda izmēģinājumu tehnoloģijā.

Алексей Насибуллин. Использование метода акустической эмиссии при проведении усталостных испытаний рычага управления шагом винта вертолета ЕН-101

В процессе усталостных испытаний важно на самом раннем этапе зарегистрировать возникновение усталостных повреждений и в дальнейшем контролировать их развитие. Метод АЭ позволяет с большой достоверностью обнаруживать структурные дефекты и усталостные повреждения на труднодоступных участках конструкции и следить за их развитием как при усталостных испытаниях, так и в эксплуатации. Используя метод АЭ можно обнаружить дефекты на ранней стадии развития.

В данной работе показана эффективность использования метода акустической эмиссии на примере проведении усталостных испытаний рычага управления шагом винта вертолета ЕН-101. Дано описание стенда и методики проведения усталостных испытаний рычага управления шагом винта вертолета ЕН-101.

Контроль возникновения и развития усталостной трещины осуществляли как визуальным способом, так и методом АЭ. Для контроля методом АЭ на рычаг управления шагом винта был установлен пьезоэлектрический датчик, с помощью которого в ходе нагружения конструкции регистрировались сигналы АЭ. В ходе испытаний синхронно регистрировали значения уровня сигнала акустической эмиссии и нагрузки, а также определяли положение сигнала АЭ в каждом цикле нагружения.

Результаты испытаний представлены в виде графика зависимости суммарной АЭ от числа циклов нагружения и фрагментов синхронной записи интенсивности сигналов АЭ и прикладываемой нагрузки. Проведено сопоставление данных полученных методом АЭ с результатами фрактографического анализа излома. Проведенные исследования показали, что метод АЭ может фиксировать момент зарождения усталостной трещины, а также может использоваться для определения степени опасности усталостных трещин по их развитию. Проведенные исследования позволяют включить метод АЭ в технологию стендовых испытаний ответственных силовых конструкций.