FATIGUE CRACK DETECTION BY SYSTEM OF STRUCTURAL HEALTH MONITORING

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This article is connected with 6FP Euro project AISHA. The basic purpose of the project is development of the structural health monitoring (SHM) system integrated into a structure. Progressive methods and means of the control over use of ultrasonic technology are developed. In thin-walled structures it uses properties of elastic Lamb waves. The final stage provides carrying out of full-scale fatigue tests on components of real aviation structures for demonstration of working capacity and efficiency of methods and means of the non-destructive testing. One of the objects of full-scale testing is the helicopter MI-8 tail beam.

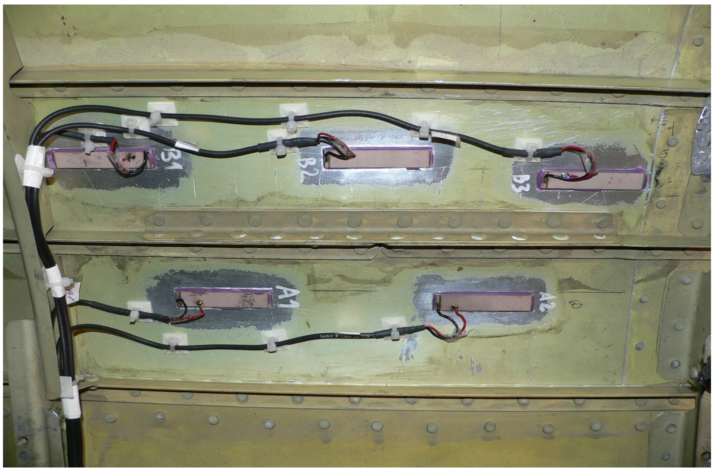


Figure 1. Transducers location on inner surface of skin

The local system of SHM was designed and mounted in a zone of selected hot spot for the fatigue cracks detecting and the establishing of "signal-damage" correlation. The piezoceramic transducer PIC 151, 0.5x10x50mm (PI Piezoceramic) was selected as a sensitive element of NDT system. The transducers were glued on inner surface of a skin by the epoxy paste. The fragment of structure with elements of SHM system can see in Figure 1. Lamb wave electronics LWDSS45 (a prototype of onboard electronic unit designed and produced by Cedrat Technology, France) with software of Catholic University Leuven (Belgium) was used as ultrasonic wave source. The oscilloscope PXI-5105 (National Instrument) and PC consists the data acquisition system.

Fatigue cracks growth from three cuts is shown in Figure 2. The stress intensity factor for this end of a crack was accepted as for isolated crack 2a in infinite sheet. It means in calculation the stress intensity factor was defined by formula $K_I = \sigma\sqrt{\pi a}$. The parameters of Paris' law ***C*** and ***m*** were defined for each of cracks using the result of crack propagation at dynamic cyclic loading.

$$\frac{da}{dN} = C(\Delta K_I)^m \qquad (1)$$

where ΔK_I is the range of the stress intensity factor in a cycle. Constants **C** were reduced to the same exponent **m=*3.5*** and the mean value was obtained. It is equal $4.63 \cdot 10^{-9}$ and relates with a unit of measure of a stress intensity factor in MPa· √m and the rate of the crack growth in mm/cycle. Using these parameters the cracks growth was predicted (the lines in Fig.3).

Earlier the crack resistance properties were investigated in special experiment on thin-walled samples of the same material at 12 Hz cyclic pulsing load (coefficient of cycle **r**=0). It was obtained the Paris' law constant **C**=$1.35 \cdot 10^{-08}$ at the same exponent **m**=3.5. Therefore there is possibility compare the crack resistance constants in these two tests. If accept the cyclic pulsing load could be at the full-scale test, the range of equivalent stress intensity factor only to 10.5% more than at real test at the cyclic pulsing load. This result shows the effect of compressed half-cycle of load to the rate of the crack growth. A impulse 5-cycle sine burst signal at 200 kHz used to excite the actuators at their resonance frequencies. Time extent of an impulse was 20 μcs, and the amplitude did not exceed 1.5 V . The Lamb waves excited by the actuators propagated along the plate and were received by the sensors. Ten piezoceramic transducers were used in local SHM system. Subsequently Each of them was used as an actuator but others nine as sensors. During fatigue experiment the essential change of conditions of signal propagation is connected with the growing of a crack. Therefore, the analyses of features of the response and detection the most essential of them which are caused by propagation of a crack is the key problem of processing of ultrasonic NDT results.

Figure 3 shows RMS correlation with a crack length and the number of cycles for some couple "actuator-sensor". For this couple the response to the fatigue crack growing is stable and allows detecting of crack length with acceptable accuracy.

Figure 3 shows that tight correlation function ***a(R)*** between the size of a crack ***a*** and some parameter of intensity ***R*** of response exists at right sensor/actuator location. Without others effects this parameter will change during dynamic loading that induces the fatigue crack propagation. So currant value of the crack length can be predicted, using the results of SHM

a(R(t)). Here ***t*** is current lifetime expressed in the cycles, the flight cycles, the hours of flight and others units of measure.

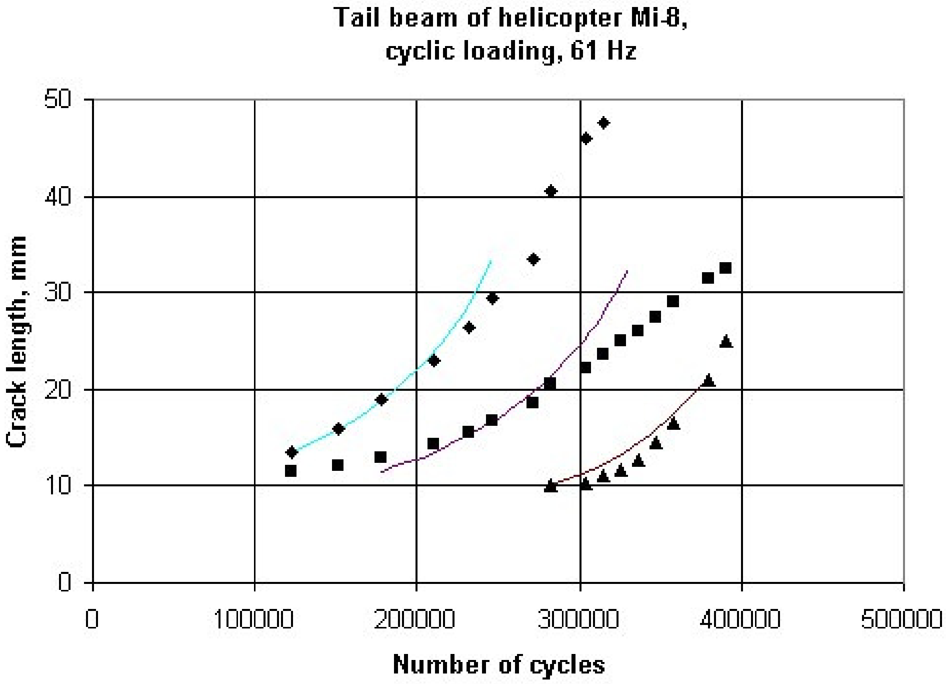
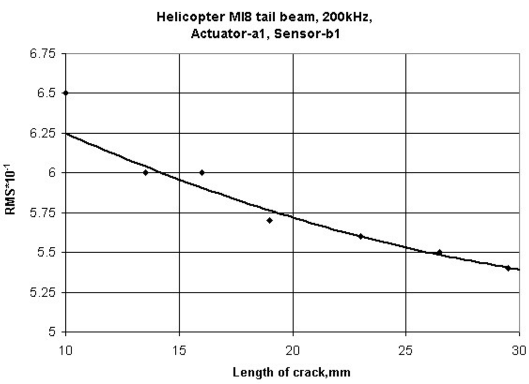
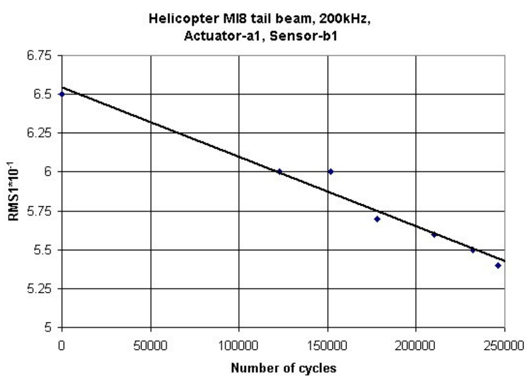


Figure 2. Fatigue cracks growth from three cuts. Points show experimental result, but the lines present the predicted result by Paris' law



a)



b)

Figure 4. A maximum of RMS correlation with a crack length (a) and the number of cycles (b) for some couple "actuator-sensor".

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