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OPTICAL FIXING FEATURES OF CRACK INITIATION MOMENT DURING BENDING FATIGUE

The article contains a method for fixing by camera the moment of fatigue crack initiation during specimen lateral bending cycle loading.

Key words: *fatigue; fatigue crack; nondestructive control method; Arduino.*

Introduction. The damage tolerance principle is used in the design of modern aircraft [1]. Such approach is based on the fact that defects are present both in new constructions and in those that are already in operation. Therefore, at the stage of an aircraft design, the possibility of damage and / or fracture of any element is expected, but without loss of structure bearing capabilities that can lead to catastrophic consequences. The focus is on crack initiation and propagation. Taking into account the methods for its state controls during operation and repairs each critical structure element has determined maximum size of flaw that can remain undetected that lead to a critical consequence. Therefore, the fatigue crack growth rate is one of the main indicators that determines the aircraft structure safe operation possibility for some operation period [2].

Study of crack propagation in laboratory makes possible to specify models that describe the fatigue crack growth in aircraft structures [3]. For this purpose, can be used both ordinary optical control devices and special non-destructive (X-ray, eddy current and ultrasonic detection, etc.) methods of defectoscopy.

Object. To develop a valid method for detection of fatigue crack initiation during bending cycle loading.

Results. For capturing the crack initiation specimen from the aircraft construction alloy D16T were used. To localize the area of fatigue crack initiation stress concentrator was made in the form of a lateral half-hole (fig.1).

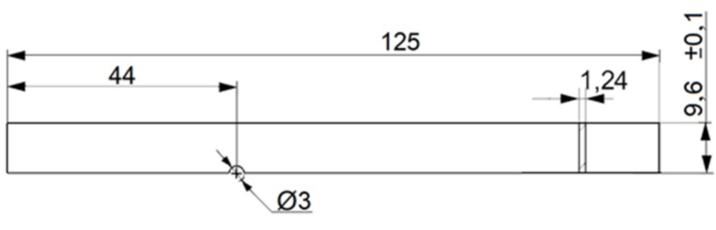


Fig.1. Geometry of specimen to research nucleation of fatigue cracks

The surface of the specimen was painted black by permanent marker, thus paint applied evenly and uniformly. The purpose was to highlight the place of flaw due to the contrast of painted black and silver aluminum alloy surface, which can be observed during crack propagation.

Fatigue bending tests during symmetrical load cycling were carried out at the facilities that had been developed in the laboratory Aircraft Design Department of National aviation university.

The specimens were captured by DSLR camera Canon EOS 550D, which was installed separately on a tripod to prevent the negative effects of vibration from the test facility.

To zoom in the specimen in image there were used macro extension tubes (fig.2) designed for macro photography. Considering that the minimum focal length of the lens is 28 mm, three macro extension tubes with a total length of 62 mm has made possible to increase the magnification ratio to 2.5: 1. It should be noted that the maximum scale of the camera lens is 3.8: 1. Thus an overall increase 9.5: 1 was obtained.

Fig. 2. Macro extension tubes

The main advantage of macro extension tubes that they do not have lenses in the design, which can lead to the image distortions. The significant disadvantage of usage is their effect on the relative aperture reduction during shooting, which reduces the aperture ratio of the lens. Therefore, it is necessary to highlight additionally the focusing point. For this were used LED CREE XM-L2 (2) (fig. 3) with maximum luminous flux that is equal to 800 lumens. During operation the LED heated up considerably, so for heat exchanging LED was installed on the radiator (3) with air blowing over it by blower (1).

The camera was initially configured to trigger every 4 seconds. However, the images processing showed the difficulty of analyzing the cracks initiation and propagation due to the different position of the specimen at the moment of photo-capturing and in most cases the specimen was in the position of the test surface under compression. To capture the crack in the best possible position of the specimen (the maximum bending of the specimen in the opposite to camera direction provides wide crack opening), the test facility was improved.

The positional sensor switch (7), an optocoupler with interrupter configuration, was installed at the facility (fig. 3). It consists of infrared LED and a phototransistor that are located opposite to each other. Determination of the actuator position estimated by the light flux breaking during the passage of the interrupter between the source and sensor. A high-frequency optocoupler with 10 MHz frequencies transmitting signals was installed at the facility. A metal plate (6) is attached to the loading carriage (8) as a signal breaker. The signal is interrupted at the optocoupler during translational movement of the actuator with the carriage in the left extreme position.

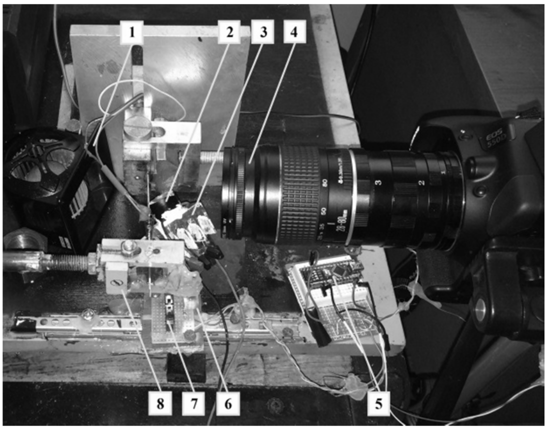


Fig. 3. General view of improved test facility: *1* – blower; *2* – LED; *3* – radiator; *4* – camera; *5* – microcontroller; *6* – interrupter; *7* – optocoupler; *8* – loading carriage

Then the signal from the phototransistor was transmitted to the Arduino - a board with an ATmega328 microcontroller (5). When the receiver detects incoming light from LED, the electric current flows and generated HIGH output signal, when the LED is blocked, the current will not pass through the phototransistor and in this case, will generate LOW output signal. These signals are further used in the program code that is downloaded to the ATmega328. The general scheme of optocouple and camera to the Arduino connecting is shown in fig. 4.

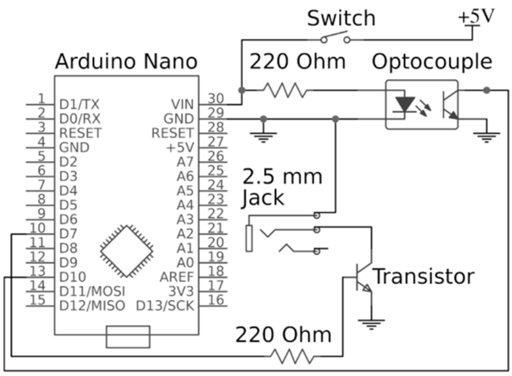


Fig. 4. Camera controller circuit diagrams

From the Arduino the signal goes to the transistor that transmit the signal to the camera without voltage transfer, and provides non-contact control. Program sent signal to the camera every two hundredth cycles (interrupts) on the optocoupler. Thus, photographs were obtained at the maximum deviation of the specimen with the maximum possible crack opening.

Image processing was carried out in three phases: selection and cropping of study area, stabilization of pictures, cracks detection. These processes were implemented in the Matlab software environment.

At the first stage, cropping of photographs is carried out in order to localize the study zone. Matlab program represents full-color images in the form of an array, each element of which corresponds to one pixel and is determined by a combination of red, green and blue color intensity [4]. The pictures were taken on an 18 MP camera with a picture resolution of 5184 × 3456 pixels. Thus, cropping has reduced the size of the matrix, thereby the efficiency of processing increased.

For crack detection it is important to fix study area of the specimen in one position. Due to the large vibrations of the test facility and the stationary placement of the camera on a tripod, angular and horizontal movements occur, which are compensated by stabilization applying. The algorithm of last provides pair wise frame comparison [5]. From both frames collecting points of interest, selecting likely correspondences between them and performed alignment. For processing time reduction, the full-color photos were presented as grayscale, since the color for the stabilization algorithm is not important.

A crack detection was performed by subtracting a photograph (data array) with a crack from a photograph (data array) without it. After that the resulting data array is again presented as grayscale in the range from 0 (black) to 1 (white) [6]. The results are shown in the photographs (fig. 5-7) where (a) not processed photos, (b) processed using the described above method.

a *b*

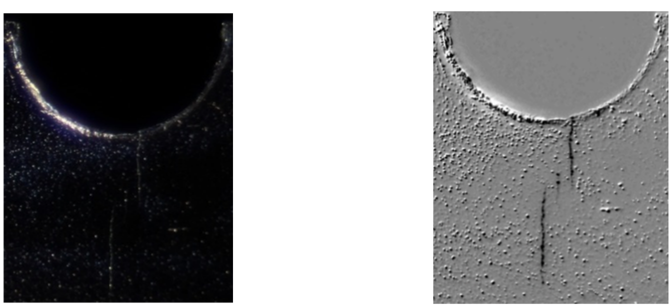
Fig. 5. Specimen before testing

a *b*

Fig. 6. Minimum recognized crack length 0.12 mm

a *b*

Fig. 7. Crack length 0.4 mm



a *b*

Fig. 8. Crack propagation

Figure 5 shows a photograph of the specimen before testing, which indicates the absence of cracks. Minimum recognized crack length was 0.12 mm (Fig. 6). This method allowed to reliably detect a crack length equal a_{min}=0,4 mm (Fig. 7).

Conclusions. Based on the proposed method of capturing and image processing it is possible to reliably detect the crack initiation length 0.4 mm during bending cycle test using non special research devices.

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ОСОБЛИВОСТІ ВИЗНАЧЕННЯ МОМЕНТУ УТВОРЕННЯ ВТОМНОЇ ТРІЩИНІ ПРИ ЗГИНІ ОПТИЧНИМИ ЗАСОБАМИ ФІКСАЦІЇ

Одним із важливими напрямом вивчення процесу втоми авіаційних конструкцій є дослідження зародження тріщини. В першу чергу це обумовлено тим, що сучасні авіаційні конструкції створюються за принципом допустимого пошкодження, який передбачає можливість експлуатації повітряного судна з наявним пошкодженням при умові, що таке пошкодження в інтервалах між плановими роботам з технічного обслуговування не розвинеться до критичного значення. Зараз існує багато різноманітних методів контролю втомних тріщин: акустичний, магнітний, електромагнітний, радіаційний, оптичний та ін. Кожний метод має свої переваги та недоліки. Для дослідження моменту утворення втомної тріщині в статті було запропоновано методику оптичної фіксації з використанням цифрової фотоапаратури. Для вирішення проблеми збільшення прояву втомної тріщини на поверхні зразку було запропоновано використання чорнильного перманентного покриття та використання цифрової обробки отриманих зображень за відповідним алгоритмом. В результаті втомних досліджень для підвищення ефективності фотофіксації тріщини пропонується використовувати мікроконтролер Arduino, який дозволяє синхронізувати положення зразка у найбільш відхиленому положенні, що відповідає максимальному розкриттю тріщини із роботою затвору об’єктива фотоапарату. Інша суттєва проблема, яку вирішували при використанні фотофіксації була вібрація стенду із значними коливаннями за амплітудою при заданому збільшені об’єктиву камери. Для забезпечення стабілізація фотографій було застосовано алгоритм у середовищі Matlab, який здійснював вирівнювання фотозображень по відповідним характерним точкам на поверхні зразка.

Запропонована авторами методика оптичної фотофіксації зародження втомної тріщини є ефективним способом вирішення поставленої задачі із застосуванням непрофесійного та недорогого обладнання.

Ключові слова: втома; втомна тріщини; неруйнівні методи контролю; Arduino.