## AUTOMATIC CONTROL SYSTEMS

UDC 681.511.4 (045)

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# DEVELOPMENT OF AIRFRAME DESIGN ELEMENTS CONTROL TECHNIQUE UNDER OPERATIONAL CONDITIONS

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***Abstract****—The paper proposes to use a method of infrared pulse-echo inspection to control airframe design elements, made of polymeric composite materials under operators` conditions. The following is described: skeleton operation diagram of the given method, device structure and results of the preliminary researches confirming operation capacity of the method offered.*

**Index Terms—**Diagnostics; composite materials; infrared radiation; inspection.

## I. INTRODUCTION

Polymeric composite materials (PCM), fiberglass and carbon fiber reinforced plastic in particular, have wide application for reason of relative low price, the ease of fabrication and processing. So, for example, nowadays airframe design of some aircraft is made of fiberglass and fiber reinforced plastic more than for 80% [1], [2].

It is necessary to notice that with increase of specific part of PCM in airframe design (in particular in primary elements of structure) their effect on general structural strength increases. But together with undisputable advantages of PCM application there are significant disadvantages, in particular, shock vulnerability and insufficient humidity resistance. Except of that, formation and distribution processes of PCM cracks have the definite features, caused by composites structure. At the same time PCM are ones of the "youngest" structural materials, so their behavior under different operational conditions is not adequately investigated.

Thus, the defining of actual technical conditions of PCM structural element and forecasting of such a state change is a relevant objective.

## II. SOLUTION OF PROBLEM

The given objective is partially solved by international manufacturers of aviation materiel by the means of implementation diagnostic facilities and creation of specialized services at the premises of overhaul agencies.

There are two ways to perform PCM diagnostics. The first one presupposes creation of universal diagnostics methods and means of various PCM nondestructive testing (NDT). However it demands standardization of separate types of PCM, and this is not observed up to date. The second one presupposes creation of wide range of diagnostics facilities used for NDT of various composites.

Methods of acoustic, thermal and optical NDT are widely used to perform operational control of airframe structural elements, made of fiberglass. Despite wide application of the abovementioned methods all of them have advantages and disadvantages, complicating their usage in operation [3] – [8].

For example in order to perform ultrasonic inspection it is necessary to apply special gel on the surface of the control object. Except of that, inspection of relatively thin elements (thinner than 5mm) is complicated due to peculiarities of acoustic vibrations distribution in the solid medium. Also it is necessary to note that the duration rate of NDT performance is low.

Method of stereography shows the best resolving power while PCM defects localization under the conditions of thermal or baric loading of control object. That limits significantly the application of the given method under operators or field conditions.

From our point of view the optical methods of PCM elements NDT are developing insufficiently. At the same time it is necessary to note that infrared radiation is successfully used to test the state of fiberglass and glass fiber in related branches of engineering [3], [8].

However, if we are speaking about light aviation and operators, having Mini Park of light and ultra light aircraft there is no optimal solution to the problem of PCM state diagnostics by virtue of economic and technology factors.

The dominant position among all defects of airframe structural elements, made of PCM belongs to delaminating and separation (statistically up to 45% of all structural damages) [4], [5]. Also it is necessary to note the insufficient diagnozability of items, made of polymeric composite materials in the result of dispersion of their physical characteristics.

Due to set forth above, it is proposed to apply infrared pulse-echo inspection method in the process of fiberglass nondestructive testing.

This method belongs to the class of optic inspection. The principle of optic infrared radiation (IR) range interaction with materiel of monitored object is taken as a base.

Registration of spatiotemporal IR radiation amplitude distribution in the result of its interaction with the monitored object is used to receive inspection information [3], [6], [8]. It is obvious that the presence of mechanical defects (as surface so hidden ones), nonhomogenity of materials and also foreign inclusions influences on optical properties of monitored object. Transmitted radiation intensity, passed through the monitored object of study, which is used to infer about the defects of material, is and information-bearing parameter.

The peculiarity of the proposed method is the principle of IR radiation usage and the way of its supply to the monitored object.

The given method combines advantages of optic, acoustic and thermal methods, in particular:

– it is analogous with optic methods by the principle of IR radiation usage (the laws of optics are used in the process of IR radiation interaction with the monitored object);

– it is analogous with acoustic pulse-echo method by the principle of operation (the only difference is that the proposed method is based on usage of IR radiation, but not acoustic vibrations);

– usage of IR radiation as the monitoring tool gives the possibility to detect surface defects of material and also to monitor the hidden cavities (composite materials, which are not opaque to visible light, are optical transparent medium for infra-red emission).

– pulse regime of IR radiation supply insures the high level of diagnostics system interference protection from background illumination (solar and/or artificial light) of monitored object.

Critical difference of the method proposed from thermographs and IR imagery [3], [6] lies in the supply regime of IR radiation and its subsequent registration. Thus, passive regime (receiving of IR radiation, produced by the monitored object), chronic irradiation of monitored object regime, or single-pulsing radiation regime (so called flash-thermographs) are applied in the above given methods. The principle of multiple passing of high frequency radiation impulses is used in the method proposed.

Consequently, it is necessary to compare IR radiation characteristics qualitatively and quantitatively after its interaction with damage-free or defective area of the design.

Regular changes of IR radiation optic characteristics changes in the result of interaction with dissipating medium are considered and the relationship of IR radiation intensity, passing through high dissipating optic medium (PCM is such a medium) and the presence of defects linear dimensions and class of delaminating and cracks are established in treatises [11]. However, the treatise considers the implementation of IR radiation “propagation” inspection method. This method makes only its applying for closed cavities monitoring difficult. The given disadvantage is made good if IR radiation “reflection” inspection method is used. In the given case one-sided access to the monitored object is insured, but the process of diagnostic signal mechanism becomes more complicated.

In our case, diagnostic system, applying IR radiation consists of the following elements (Fig. 1):

– master oscillator;
– pulse former;
– outlet power stage;
– infrared radiator;
– infrared detector;
– bandpass amplifier;
– peak detector;
– analogue-digital converter;
– microcontroller;
– indicator.

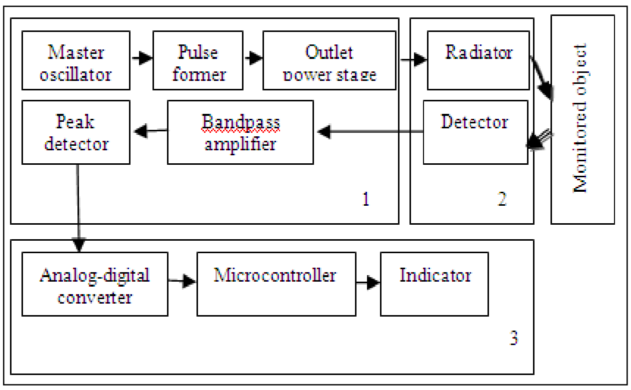


Fig. 1. Functional diagram of IR nondestructive testing instrument: 1 – analog line; 2 – probe head; 3 – digital line

Master oscillator controls the operation of infrared radiator, insuring supply of IR radiation impulses of the definite amplitude. Radiation impulse, produced by radiator, is supplied to the monitored object, where on the base of reflection, refraction and radiation absorption laws and it is subjected to the change, which is proportional to material structure characteristics.

There is closely-fitting screen between radiator and detector, used for registration of radiation, passing through the monitored object and reflected by its surface.

The radiation impulse, passed through the monitored object material is registered by infrared detector. Receiving of chronic and flash IR radiation impulses by the detector causes the necessity to differentiate impulse signal from the total received. In order to remove the chronic components of the signal (background illumination of the monitored object by the natural IR radiation sources) and low frequency components (background illumination of the monitored object by the artificial IR radiation sources) evolution of effective impulse signal with the help of band pass amplifier, adjusted for high frequency of the radiator, is used. By this way, only IR radiation impulses, produced by device radiator, are supplied for further processing.

High pulse-recurrence rate of radiation also insures high level of interference protection and compensates operator`s possible mistakes in the process of inspection.

Evolved impulse of radiation in converted into the voltage value, which is proportional to it, supplied to the analogue-digital converter and further processed with the help of microcontroller. Monitoring results are displayed in the convenient form (in the form of the graph or annunciate).

It is suggested that diagnostic information processing with the help of ECM may be insured.

Diagnostic parameter is not the absolute value of outlet signal but its change over the damage-free and defective areas of the monitored object.

Due to set forth above, experimental device of infrared pulse-echo inspection testing and laboratory bench to study the possibility to perform nondestructive testing of fiberglass by the given method were established (Fig. 2).

Laboratory bench consists of chassis with carrier to fix the model, a motion base with Gog-belt type drive, actuated be step motor, a control system based on a microcontroller and a control panel. Infrared radiator, detector and screen are mounted on the motion base, forming a probe head point of the device.

Laboratory bench insures movement of the probe head along the model of study with the accuracy ± 0,1 mm, its secure fixation at any moment to perform testing and probe head returning to the initial point, taken for "0" of coordinates.

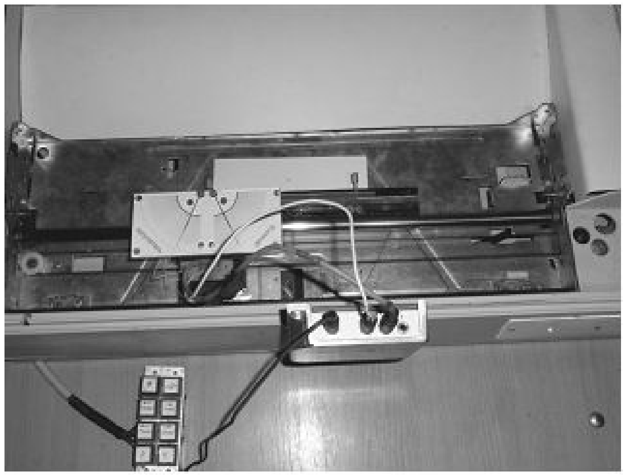

Fig. 2. Laboratory bench general view

The list of experimental works (as for the assessment of infrared medium signal intensity change in the result of passing through structural fiberglass models was hold to prove working capacity of the device. The following boundary conditions were assessed:

1. Change of diagnostic parameter if there is a defect of "delaminating" class in the model.

2. Change of diagnostic parameter depending on the paint coat over the monitored object surface.

While studying of fiberglass model, dimensions of which are 185×38×3 mm, with artificially embedded defect of "delimitation" class, dimensions of which are 50×38 mm for possibility to detect surface defects with the help of radiation intensity, passing through damage-free and defective area it has been found out that the change of diagnostic parameter is 27%. This value is out of background noise (Fig. 3.). Background noise equals not more than 5% of diagnostic signal.

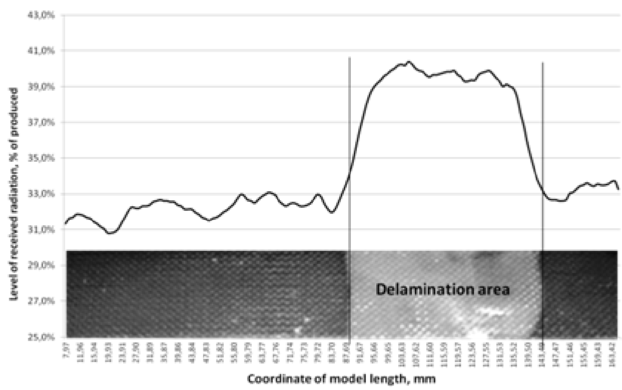


Fig. 3. Monitoring results represented by the graph

While measuring of diagnostic signal at painted model it is found out that the total decreasing of diagnostic parameter value is by 10% lower comparatively with unpainted model. The proportion of signal level is kept as in the damage-free area and defective area. This proves the possibility of testing over the painted surface.

## III. Conclusion

The principal possibility to apply the infrared pulse-echo inspection to control airframe elements, made of polymeric composite materials, is shown. The proposed device offers the possibility not only to detect the defect but also to determine the boundaries of defective area. The held background researches show that it is possible to apply the given method to detect PCM defects regardless of paint coat presence over the surface.

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Received September 19, 2016

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**О. Л. Пузирьов, В. О. Волкогон, О. М. Алексєєв, В. В. Ушаков. Розробка методу контролю елементів конструкції планеру повітряних суден в умовах експлуатації**

Запропоновано використовувати інфрачервоний ехо-імпульсний метод для контролю елементів конструкції планера, виготовленого з полімерних композитних матеріалів.

**Ключові слова:** діагностика; композиційні матеріали; інфрачервоне випромінювання; огляд.

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**А. Л. Пузырев, В. А. Волкогон, А. Н. Алексеев, В. В. Ушаков. Разработка метода контроля элементов конструкции планера воздушных судов в условиях эксплуатации**
Предложено использовать инфракрасный эхо-импульсный метод для контроля элементов конструкции планера, изготовленного из полимерных композицитных материалов.
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