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X-RAY COMPUTER TOMOGRAPHY INVESTIGATION FOR POLYMER COMPOSITE MATERIAL UNDER THE STATIC LOAD

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Abstract

This paper shows the changes fixed by X-ray computer tomography in the polymer composite material structure under static tensile or compressive load. The study was conducted as during loading and just after it.

1 General Introduction

The specificity of a composite material consists of combining the technological process of formation of material and finished product . Therefore, the performance is complicated by the variety of schemes reinforcement and constructive implementation.

One option is to predict the behavior of materials laboratory study using high-precision methods for investigating the structure of the development of damage models using the specified loading conditions and structure of the material (stacking).

The practice of non-destructive testing of composite materials has shown that for the detection of defects found application in almost all NDT methods used in production, testing and equipment maintenance, especially in the control of materials with non-metallic matrix and the filler or combined. This optical, electrical, acoustic, radiation, magnetic, thermal, holographic and other control methods. The most widely spread of ultrasound and X-ray methods of control.

One of the most promising methods of X-ray inspection is radiation (X-ray), computed tomography (CT). CT advantages compared with conventional radiography are:

- No shadow overlays
- More precise measurement of geometric relations image;
- An order of magnitude higher sensitivity than conventional radiography.

Sensitivity control computer X-ray tomography (XRT) exceeds traditional technical means of radiation NDT by two orders.

The results of the study are presented in the form of digital arrays, intensity images or the digitized graphics. This graphs show the spatial structure of the linear attenuation coefficient (LAC) in the test section of the object control

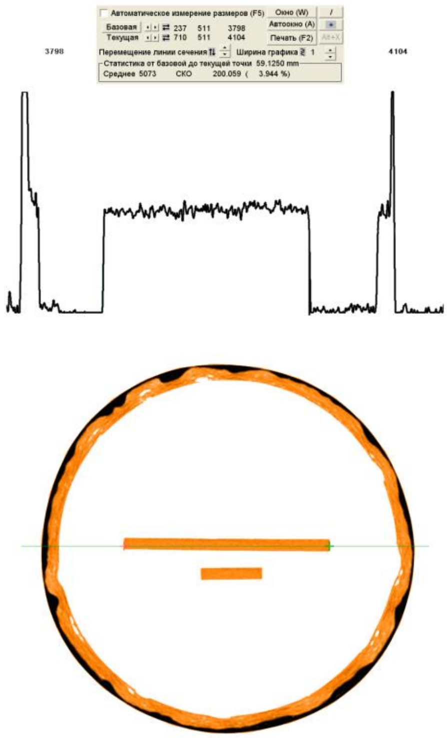

Fig.1. LAC distribution in the sample.

In MAI set computer X-ray tomograph VT-600XA (Fig. 2). It is intended for layered imaging and nondestructive inspection of internal structures of the wide spatial-class products, including: glued joints, and the assembly of multilayer structures, honeycomb structures, composite materials.

Fig.2. A general view the X-ray tomograph computing VT-600XA.

Determination of average values is carried out by 90% of the controlled section. This approach avoids the undesirable effects arising from the edges of the object. On the fig. 4 shows the area to determine the tomographic parameters.

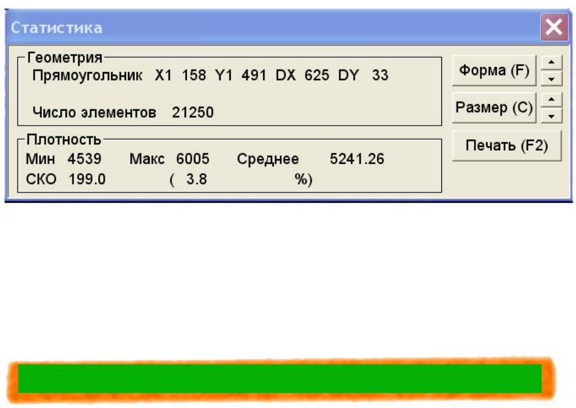

Fig.4. The study area.

2 The investigated characteristics

In this paper we consider only the secondary damage. They appear in the area of of technological presence of defects or in the process of external factors. Their causes can be a force loading, both static and dynamic; thermal, radiation, climate impacts and their possible combinations. We consider only the the force action, dynamic effects are considered in the work.

Obviously, the nature of compromising the integrity of the structure and development (growth in service) of this damage affects the residual strength of the composite material. Residual strength of the damaged zone composite determine the rate of growth of secondary injuries and their area of distribution:

- In the direction of stacking of elementary layers;
- Inside the layer relative to the lines of orientation of the reinforcing fibers;
- Along the boundaries between the layers.

The study of secondary damage in the polymeric composite material by means of X-ray computer tomography may be carried out after loading the sample on the specific load and remove the sample from the test stand. This allows you to evaluate the residual changes in the material, similar to other NDT methods.

The following criteria correlation between the state of the structure of the sample material and reconstructed scan results:

1. The average value linear attenuation coefficient - quantifies the structural density in the i-sectional scanned after the j-th load (j = 0 - before loading), and decreases in direct proportion with increasing amounts of secondary damages on the unit cross section area;

2. Maximum and minimum value of the LAC - characterize the processes of growth of certain defects and the local structure of the seal material.

3. Standard deviation values LAC scanned section characterizes the amplitude of the absolute deviation from the LAC most probable value, increasing the absolute value of deviation confirm increase in the number of secondary damage to the unit area.

3 The design of the proposed stand

To assess changes in the force directly under the impact load in the Laboratory NDT MAI was designed and manufactured stand, allowing the force applied to the specimen uniaxial impact directly on the desktop X-ray tomograph. This solution is based on a large working area tomograph and opportunities to explore objects up to 300 kg.

A general view of the stand shown in Fig. 5. The device consists of three parts - the upper, middle and lower parts, which are made collapsible.

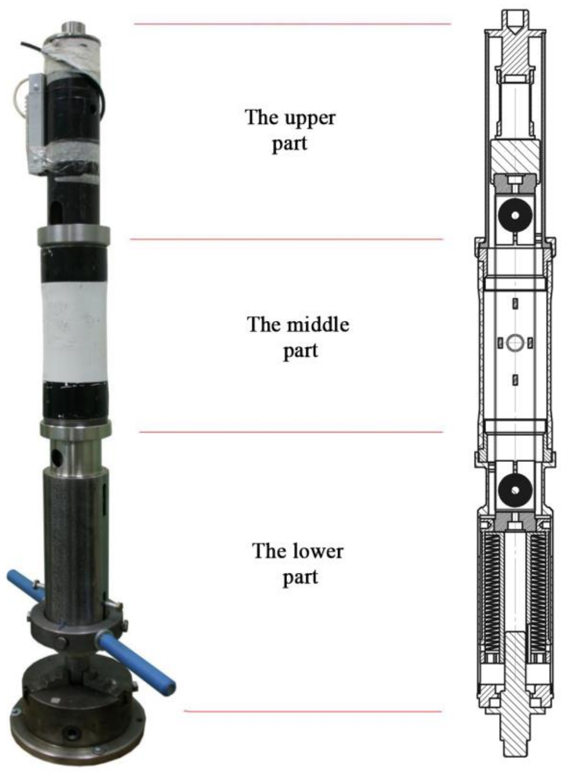

Fig.5. A general view the device.

The upper part - includes two hinge mechanisms, load control sensor (force sensor), the top of the cartridge mounting unit, and the sample data. The transmission unit is responsible for connecting the indicator current load and strain-gauge station (this equipment is presented in Figure 6). The indicator of the current load receives data from four strain gauges placed on the force sensor. The strain-gauge station receives data from deformations with strain gauges attached to the sample, from which information is read sequentially.

Fig.6. Load indicator and strain-gauge station.

The middle part made of composite material (carbon cloth), with two flanges with threaded parts. This reduced the number of artifacts in tomograms and reduce the need for radiation research. The flange has a shoulder for abutment of the composite glass by applying a tensile load to the specimen.

The lower portion includes the bottom of the sample holder mount block spring loading mechanism with a screw bearing retainer hexagonal desktop scanner, a power load transmission body, the handle for rotating the screw mechanism and a rotation angle control unit. Screw mechanism moves the cartridge down and creates a load on the sample. To reduce the load shifting and to ensure smooth increase of power impact load is transmitted through the unit disc springs. Dial located at the bottom to compensate for the possible departure of the sample position on the corner.

As part of this stand is planned to use to solve the following tasks:

- Identify the behavior of a heterogeneous structure by applying operational loads.
- Development of new methods of nondestructive testing of composite structures highly responsible.
- Building behavior of composite materials under the influence of different power factors.

- Testing performance (damage accumulation) of different types of heterogeneous materials.
- Investigation of the influence of various kinds of hubs on the growth defects in the material.

The special features of the proposed method include:

- Study the material state of the composite material products without removing the load.
- The research is conducted with an incremental loading on specially fabricated stand, which minimizes the effect of the surrounding elements of the analyzed structure.
- Applies a precision method for determining structural changes - Computer X-ray tomography
- Ability to create a uniaxial force action up to 10 tons.

3 The results of test study

Testing involves identifying the underlying state of the material. Certain tomographic parameters considered basic for a given sample (selected technology, styling and type of binder and filler). Next is the step-loading the selected load levels. At each step the lock state of the material and determine the values of the LAC and standard deviation are compared with baseline. This allows evaluate the changes occurring in the material (growth density anomalies associated with both the loosening of the material and its local seal). To track individual sites controlled by sealing the maximum LAC.

To determine the efficiency of the developed stand and validation of the proposed methodology were made flat samples Series UP-3 (with sample stacking 0 / ± 45/90). The study was conducted in 40 sections for debugging scan settings and repeatability sections. In the future, special patterns designed for research, meeting the conditions of fixing and scanning. General view of the samples shown in Fig. 7.

Fig.7. Samples for the preliminary study.

The study was conducted on four samples of the tensile load levels - 20%, 30%, 55%, 70% of the breaking load and then it is fully unloaded.

On the fig. 8-9 shows the results of measurements of the LAC and standard deviation in the 11th, 22nd and 33rd sections and the average value of these parameters. Obtained similar results of parameter changes in RMS and LAC data sections despite the large distance between the sections of the height of the sample (step sections was 30 mm), so further studies the amount of the controlled sections in the work area can be reduced.

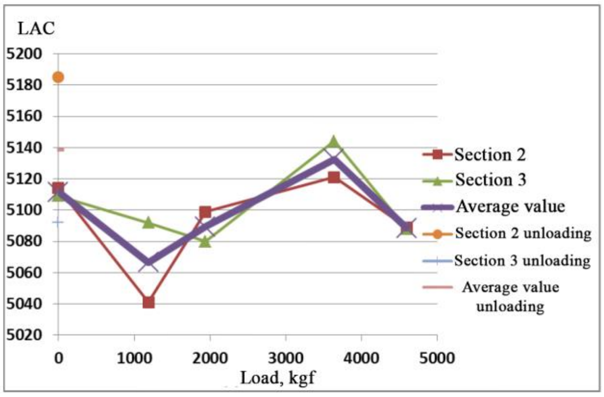

Fig.8. LAC load changes.

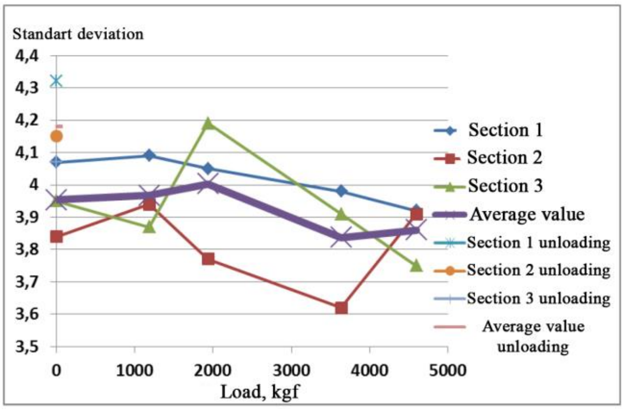

Fig.9. Standard deviation load changes.

Can draw the following conclusions:

- The use of ART in the assessment of the material behavior and structural elements of the polymer composite to obtain extensive information on the state structure of the material with high precision to obtain;
- Selected for the analysis parameters fully appreciate the processes occurring in the material under the influence of force factors.
- Designed stand creates a predetermined force and captures the deformation pattern on the sample, while conducting a CT scan.
- The use of "transparent" zone in the stand allowed to minimize artifacts in obtaining tomograms.
- The developed method monitors changes in structure of the material under load and after unloading. This significantly extends the capabilities of a preliminary study of heterogeneous material by computer X-ray tomography.

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