Conference Paper

The Mechanical Testing of Materials Using the Method of Digital Image Correlation

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Abstract

The mechanical testing of materials is regulated by standards, which established requirements for samples, test equipment, testing conditions and methods of processing the results. When performing tests, it is important to control the quality of the sample surface, its geometric dimensions and deviations from a predetermined shape. Not less important stage of the testing is to control the fixing of the test specimen in the test equipment and the need to render its stress-strain state in the process of loading.

Using the method of digital image correlation when conducting mechanical testing allows you to successfully control all phases of mechanical testing, from the quality of specimen production, testing equipment, to visualize the stress-strain state and its compliance with the adopted design scheme.

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1. INTRODUCTION

To correctly carry out mechanical tests in accordance with GOST 1497-84 tensile GOST 25.503-97 compression and GOST 14019-80 bending, respectively, it is necessary to prepare samples that meet the requirements of the above Standards [1-4].

The samples are requirements concerning the surface quality, the deviations in linear dimensions and shape. The roughness of the processed surfaces of samples should be no more than 1.25 microns for the surface of the working part of the specimen and not more than 20 μm for the lateral surfaces in the working part of the flat sample. When conducting compression tests, great attention is paid to alignment of the loading. The error of measurement of the height of the sample should be no more than 0.01 mm. the Samples should be proportional shape, it is also possible the use of proportional samples of other sizes. Tolerances for thickness of flat specimens with machined surfaces ± 0.1 mm.

The measurement error of the diameter and cross-sectional dimensions of the specimen prior to the test should not be more than 0.01 mm for dimensions up to 10 mm; 0.05 mm for dimensions above 10 mm.

The standards also detail the deviation of the shape of the working surface of the sample during its manufacture. The changing shape of the working surface of the sample occurs when it is fixed in the grips of the test equipment.

Mechanical testing of samples is carried out on universal or discontinuous machines. To obtain correct results, the machine must meet certain standards. One of the main requirements is the alignment and the flatness of the grips of the testing machine. They must be deployed about a vertical axis and to be in the same plane.

2. DESCRIPTION OF THE METHOD

The method of digital correlation of images based on the detection of the shape of the surface of the object by comparing pairs of digital images. Measurement is an optical system that records the speckle image, and then performs analysis on the basis of the tracking pattern distortion random dots of the speckle structure. The method of digital image correlation belongs to the class of noncontact optic methods, which allows to detect the displacement field and strains to visualize the shape of the sample surface and to calculate the elastic properties of the investigated materials [5].

Implementation of the method includes sample preparation, application of speckle-structures on its surface, the installation of optical surveillance system; guidance and focusing of the cameras on the surface of the object; calibrating the optical system; registration of the images of the sample during testing; a correlation of images; the viewing and processing of data; calculation of deformation fields in three mutually perpendicular directions for each point of the sample surface in the process of loading.

Speckle-pattern (spotted pattern) – a chaotic distribution of stains (speckles) at the surface, characterized by the intensity, density and size. The structure can be caused by artificial means, a projection on the surface or it may be a natural structure. In other words, the speckles must be distinguishable in contrast to the random black and white noise. On the surface of the sample is applied to a speckle structure with paint. The size of the speckle structure should be such that one speckle corresponds to multiple pixels on the sensor.

The next step is to perform calibration of the optical system to calculate variables associated with the internal parameters of the optical system of the measurement and registration of the images. The calibration plate is matched to the size of the working region of the sample, then it is placed into the vision field of the cameras so that the grid took the maximum field of vision and carry out the registration of images with different positions of the calibration plates.

The obtained calibration images are loaded in the software Vic-3D, further specified by the known parameters of the selected calibration records: the number of pixels in width and height, and the distance between points is step. Upon completion of the calibration check sample images and their subsequent processing (correlation). For the analysis required at least two images of the test sample, one of which is usually taken at zero load. The maximum correlation corresponds to the displacement of the surface and gives the length and direction of vector for each element of a subdomain. Thus, the constructed vector field of displacements of the sample (U, V and W indicate the displacement along the axes X, Y and Z respectively) are derived which give the deformation tensor (Exx, Eyy, and Exy) across the surface of the sample.

3. RESULTS

3.1. Check roughness

In the preparation of samples for testing of brittle materials, it is important to consider the value of roughness. The method of digital image correlation allows to determine the surface quality of test specimens. In Fig.1 presents the surface topography of a sample of graphite in three dimensions. The program allows you to build the roughness profile in a given direction and to estimate its magnitude.

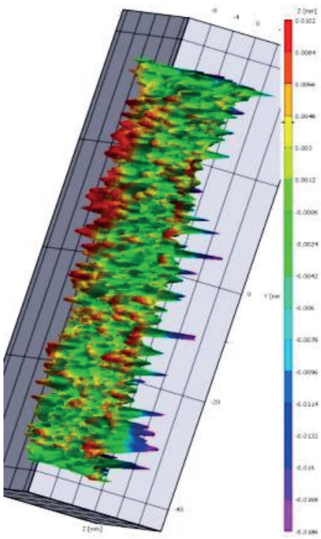

Figure 1: Three-dimensional model of the surface of graphite..

3.2. Registration forms and sizes

This method can be successfully applied to control the geometry and shape of specimens. In the manufacture of occurs curvature the shape of the sample. Below are two cases of variation from the norm. In Fig. 2 *a* represents the deflection of the specimen is 120 μm at a working field of 80 mm. In Fig. 2 *b* shows the sample, twist the "screw" with a deviation of 10 microns for the width of the sample at the edges of the work area in the sample plane. These deviations of shape of the surface as a result of tests will lead to a discrepancy between the actual stress-strain state analysis models.

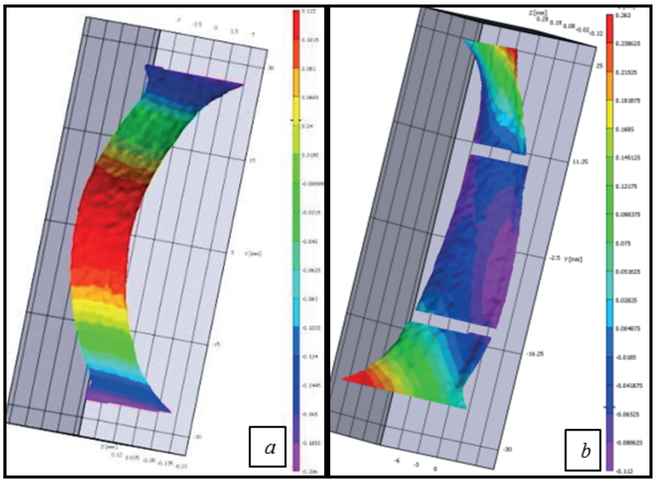

Figure 2: Three-dimensional models of specimens with manufacturing defects: *a* - curved working area; *b* - twisted "screw".

3.3. Inspection of the sample in the grips

The grips of the testing machine, the sample may be deformed due to the deflection of the mounts from the vertical axis. The method of digital image correlation allows to control the installation of the sample in grips of testing machine. In Fig. 3 shows the twisting of the specimen clamped in the grips of the testing machine, with the rotation in the vertical axis relative to each other (40 mm) and some inclination in the vertical plane.

3.4. The control grips of the testing machine

To control the position of the jaws of the gripper in space, they clamped a rigid steel plate having a size of 60x40x10 mm, the visible area was 40x40 mm. In result of the

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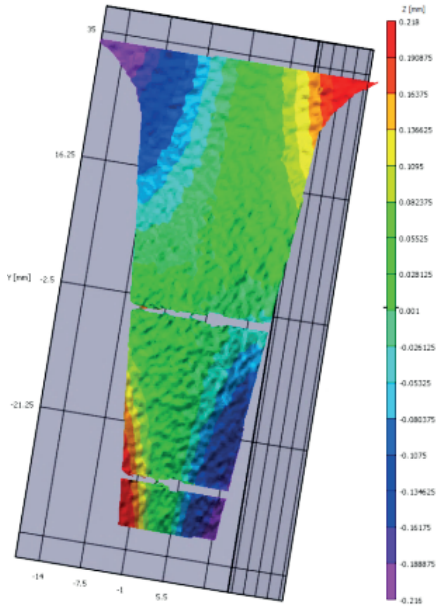

Figure 3: Twisting clamped by the grips of the sample.

registration surfaces of the plates by digital correlation of the received images of the plates showing the tilt and rotation of the grippers in the vertical plane (Fig. 4).

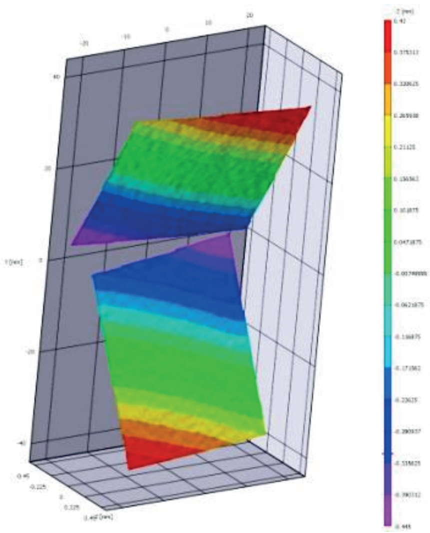

Figure 4: A three-dimensional image of the hard plates between the grips of the testing machine.

The slope of the seizures was caused by the deviation of the machine from a vertical plane, and the rotation offset relative to the vertical axis. In Fig. 5 shows the position of the plates after alignment of the lower grip. The upper grip of the testing machine is installed on a movable hinge, and the angle, and the rotation is automatically selected.

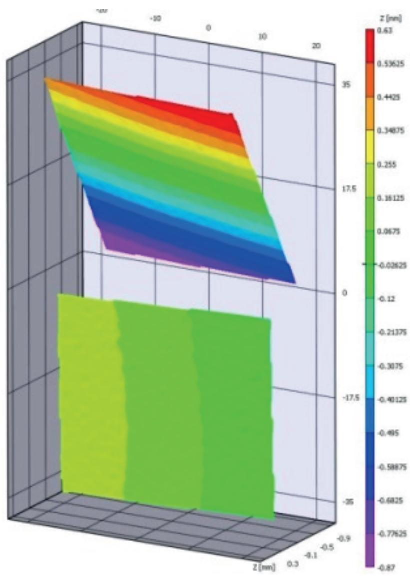

Figure 5: A three-dimensional image of rigid plates after alignment of the grippers.

3.5. The definition of young's modulus

The method of digital image correlation was used to check field displacements and calculate strains. The uniaxial tensile test was carried out on universal machine INSTRON 5982 samples from A 304 steel size: thickness 2 mm, width 25 mm and length of working area 65 mm.

The samples were mounted in the grips of the testing machine and loaded the initial load corresponding to the voltage equal to 5-10 % of the assumed limit of proportionality of the material. The loading samples were produced in equal steps up to the load corresponding to the voltage equal to 70-80 % of the assumed limit of proportionality.

Longitudinal strain was measured with an external extensometer mounted on the specimen (Fig. 6 *a*), and optical, located between the legs external extensometer (Fig. 6 *b*). To obtain the most accurate results, you should set up multiple extensometers.

The software VIC-3D has a wide range, and one useful tool is the inspect extensometer (optical extensometer). Is an optical extensometer that allows to obtain the values of deformations occurring on the surface of the specimen for further determination of mechanical properties of materials: young's modulus, Poisson's ratio.

At each stage of loading were computed voltage, and the determined values of longitudinal strain obtained with the external and optical extensometers, according to these data, we calculated the values of the young's modulus, which are presented in table 1.

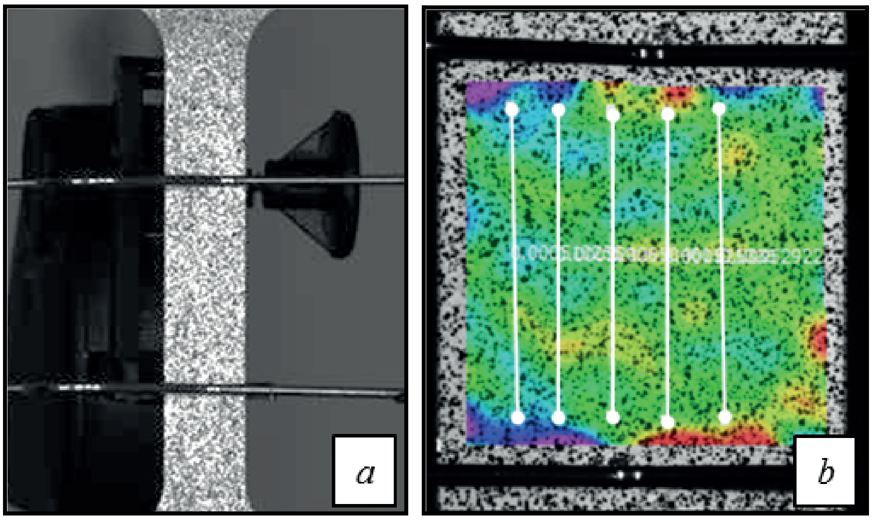

Figure 6: The measurement of deformations using: *a* - external extensometer, *b* - optical.

Table 1: The calculated values of the elastic constants of the material.

№	σ_y, MPa	ε_{yy}, Ext	$<\varepsilon_{yy}>$, Vic	E, MPa (Ext)	E, MPa (Vic)
1	247.81	1.11E-03	1.13E-03	2.06E+05	2.06E+05
2	267.05	1.21E-03	1.21E-03	2.01E+05	2.03E+05
3	284.74	1.30E-03	1.31E-03	2.09E+05	2.09E+05
4	301.23	1.38E-03	1.38E-03	2.06E+05	2.06E+05
5	317.60	1.46E-03	1.50E-03	2.08E+05	2.03E+05
The average value				2.05E+05	2.06E+05

3.6. The definition of Poisson's ratio

To determine the value of Poisson's ratio values were used for the longitudinal and transverse deformation obtained with optical extensometers. In Fig. 7 shows the arrangement of optical extensometers for measuring lateral deformations.

The calculated values of Poisson's ratio for each loading step is presented in table 2.

4. CONCLUSION

Application of the method digital image correlation when conducting mechanical tests allows to control the quality of the sample surface, the linear dimensions and geometric shape of the specimen, test equipment, stress-strain state of the sample material, determine the elastic constants of the material.

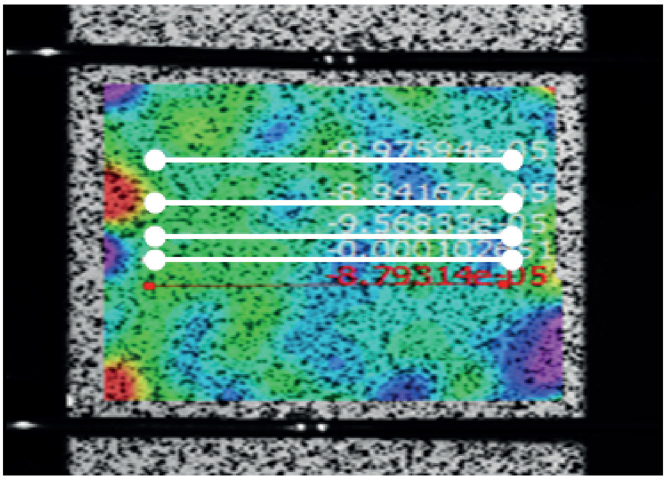

Figure 7: Transverse external extensometers.

Table 2: Values of longitudinal and transverse strains of the specimen and Poisson's ratios.

№	$\langle \varepsilon_{yy} \rangle$, Vic	$\langle \varepsilon_{xx} \rangle$ (Vic)	μ (Vic)
1	1.13E-03	-3.606E-04	3.10E-01
2	1.21E-03	-4.467E-04	3.21E-01
3	1.31E-03	-4.378E-04	3.07E-01
4	1.38E-03	-4.778E-04	3.10E-01
5	1.50E-03	-5.491E-04	3.07E-01
The average value			3.11E-01

ACKNOWLEDGMENT

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