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DIGITAL IMAGE CORRELATION IN EXPERIMENTAL MECHANICAL ANALYSIS KORELACIJA DIGITALNE SLIKE U ANALIZI EKSPERIMENTALNE MEHANIKE

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Keywords

- digital image correlation
- mechanical analysis
- Aramis software

Abstract

Digital image correlation (DIC) is a powerful non-contact technique for measuring surface displacement/strain fields. Some of the methods, focused on 2D analysis, are used for determining mechanical properties of specimens of simple geometric shape. More advanced 3D analysis can be used not only for specimens, but also for real objects of complex geometric shapes. Application of DIC technique in experimental mechanical analysis using software Aramis for 3D displacement/strain measurement is presented in this paper.

INTRODUCTION

Measuring systems for 3D deformation analyses provide the right tools for understanding of materials and components as they are independent from material, size and geometry. 3D analysis of surface deformations, e.g. vibrational spectroscopy, /1/, real time holographic technique /2/, can lead to better understanding of mechanical properties of materials, and complement other means of analysis. Measuring systems consider the real component geometry which would not be possible with traditional measuring devices such as strain gauges, displacement sensors, vibrometers, etc. More techniques and holographic interferometry (ESPI) /2, 3/ have been thoroughly described as well as the application engineering viewpoint, /4/. A system for 3D optical deformation measurement is presented, alongside with basic instructions for system settings, measurement procedures and result processing. Some of the application possibilities are also presented for different kinds of materials and real objects (components, parts, etc.).

DIGITAL IMAGE CORRELATION SYSTEM

Aramis is a non-contact and material independent measuring system providing, for static or dynamically loaded test objects, accurate: 3D surface coordinates, displacements and velocities, surface strain values (major and minor strain, thickness reduction) and strain rates. The system uses two

Ključne reči

- korelacija digitalne slike
- mehanička analiza
- Aramis softver

Izvod

Korelacija digitalne slike (DIC) je moćna beskontaktna tehnika za merenje polja pomeranja/deformacija na površinama. Neke metode, zasnovane na 2D analizi, se koriste za određivanje mehaničkih osobina epruveta jednostavnih geometrijskih oblika. Naprednija 3D analiza se može primeniti, ne samo na epruvete, već i na realne objekte složenog geometrijskog oblika. Upotreba tehnike DIC sa primenom softvera Aramis za 3D merenja pomeranja/deformacije je predstavljena u ovom radu.

digital cameras that provide a synchronized stereo view of the specimen or object, /5/. The system also includes the stand, providing stability of sensors, a power control and image recording unit, as well as the data processing system.

The system is applied in solving problems when analysing structural integrity, determining properties of materials, soft tissue behaviour, verifying numerical calculations, /6, 7/, etc. It is suitable for analysis of irregular object geometries made of various materials, such as metal, composite, gum, wood, organic materials, biomaterials, and for the analysis of hyperelastic materials, /6-9/. This software provides all results for static and dynamic tests even at high speeds for small to the large-sized components for strength assessment, vibration analysis, durability studies etc.

MEASUREMENT

Depending on the chosen measurement volume, calibration is performed by using the calibration panels or cross. This volume is chosen based on dimensions of measured object and all other dimensions are set based on it, in accordance to the tables in the instruction manual, /10/. If the measurement volume and the camera position are successfully aligned by the calibration, the measurement may commence. For correct calibration, the calibration deviation is 0.01 to 0.04 pixels. The preparation of the object to be measured starts with the placement of referral points – markers. The measurement includes creating a new project, setting the

recording speed and lighting around the object. After creating the measuring project in the software, images are recorded in various load stages of the object. After the evaluating area is defined and a start point is determined, the measuring project is computed. During computation, Aramis observes the deformation of the object through the images by means of various square or rectangular image details (facets). Aramis recognizes the surface structure of the measuring object in digital camera images and allocates coordinates to the image pixels.

RESULTS AND DISCUSSION

Different types of primitives can be formed inside each state (part of a plane, part of a circle, curved part) or inside the whole object to represent the results in diagrams. An example of a primitive (part of a plane), point-point distance,

and its application in result processing is given in Fig. 1 and in Fig. 2. Software Aramis automatically defines the referent coordinate system xyz . For every recorded point on the surface of the measuring object, Aramis assigns coordinates and tracks their movement in regards to the predefined coordinate system during the loading. The displacement field of the restored lower jaw with total denture, as shown in Fig. 1, is created by loading in the x direction, above the black line marked as section 0 in Fig. 2. Section 0 represents the intersection of a plane parallel to the $x-z$ plane and surface of the measured object. The section is used for displacement analysis of points of highest interest in the experiment. Lines 1 and 2, as shown in Fig.1, show the current distance between selected points during the loading.

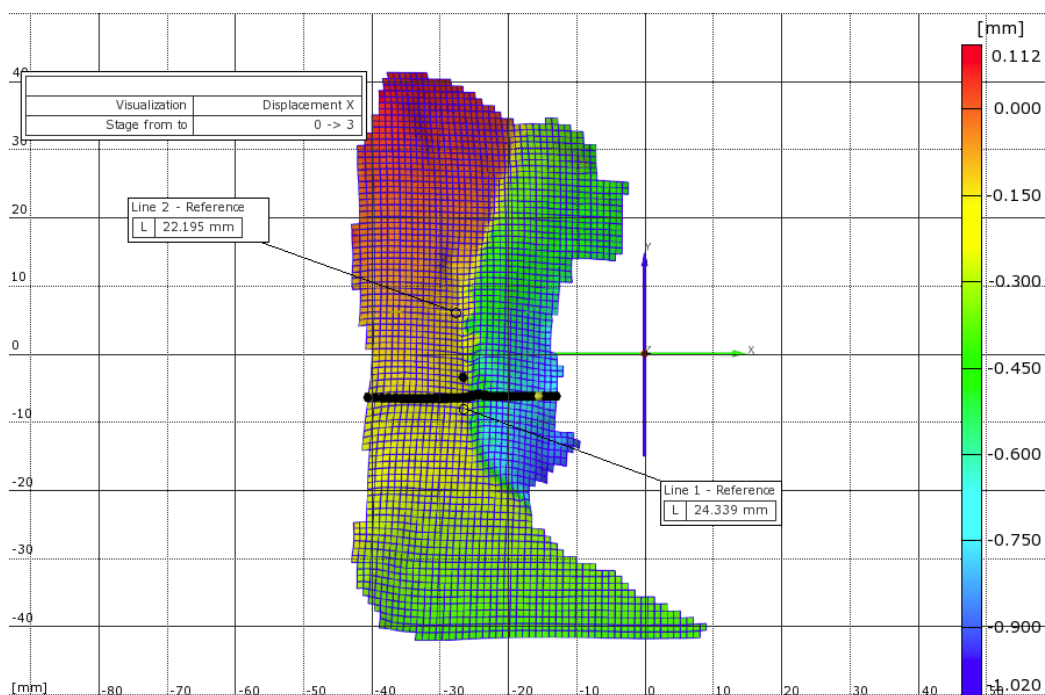


Figure 1. Displacement analysis of restored lower jaw with total denture.
Slika 1. Analiza pomeranja obnovljene donje vilice sa celokupnom protezom

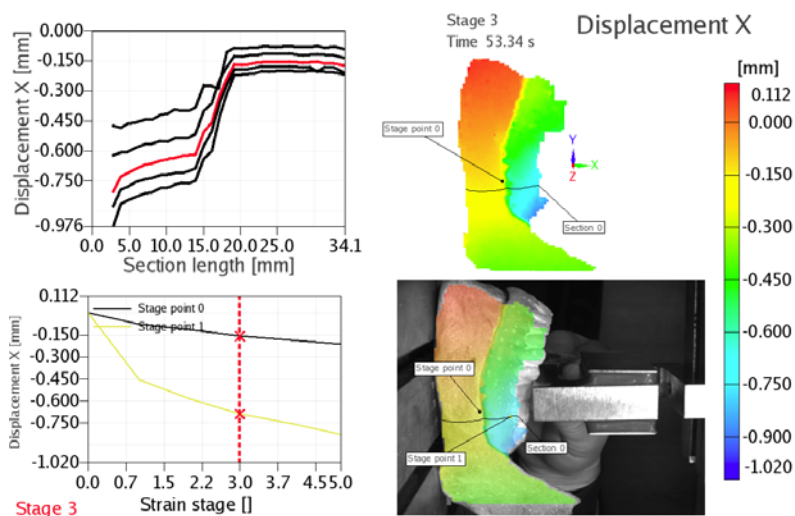


Figure 2. Example of an Aramis' report for displacement of restored lower jaw with total denture.
Slika 2. Primer Aramis izveštaja za pomeranje obnovljene donje vilice sa celokupnom protezom

In Fig. 1, the red colour in the displacement field represents movement in positive x direction, and the blue colour is the movement in the negative x direction. On the right part in Fig. 1, the scale for displacement is given in millimetres. In the upper left corner of the report in Fig. 2, the section diagram for displacement x is shown for different stages of loading, as described for Fig. 1. The red line in the Section diagram represents displacement values for section 0 and stage 3. Black lines in the Section diagram represent displacement values for section 0 and stages 1, 2, 4 and 5. The section diagram enables us to show biomaterial movement in relation with the tissue in contact. In the upper right corner of the report in Fig. 2, the displacement field is shown for loading stage 3, and colour values are shown on the scale on the right. The Multi-Stage-Point diagram shows displacements for two points through all load stages (lower left corner of the report in Fig. 2). The red colour in the Multi-Stage-Point diagram displays values for points 0 and 1, for loading stage 3. This kind of function can be used for analysing the behaviour at a critical point during loading. Camera images particularly make sense for an object with a distinct 3D structure as they can be rotated to an optimal position in 3D view, and therefore appear to be three dimensional in the report. Visualization of the displacement with an image of displacement overlay is shown in the lower right corner in Fig. 2. A photograph of a real object is displayed along with the image processed by the software. The images are overlapped, so the zones with the largest displacement can be easily spotted.

In Fig. 3, the report for the major strain field of the restored lower jaw with a total denture is shown. Section 0 (marked in black) represents an intersection of the plane

parallel to the y - z plane and the surface of the measured object, and sections 1 (yellow) and 2 (red) represent an intersection of the plane parallel to the y - z plane and surface of the measured object.

An example of volume shrinkage of dental composites before and after polymerization with UV lamp, by using the digital image correlation method is shown in Figs. 4 and 5, respectively. The dental composite is placed in the Teflon mould of circular cross-section (dark blue area in Fig. 5). After polymerization, there was volume shrinkage of the composite towards the light source. The highest values and distribution of Mises strain are shown on the circular primitive, marked as Section 2 (Fig. 5). Other functions are the same as in the above mentioned examples.

CONCLUSION

The 3D optical system is a promising tool, enabling qualitative and quantitative mapping of deformation fields in material and structural testing. Fast material development places huge challenges on existing technologies for measuring the full-field displacement and strain of materials and determining mechanical properties. Digital image correlation method is an useful experimental approach that helps to better understand full displacement/strain fields of loaded biomaterials and biomaterial structures. Accurate software calculations, data post-processing with a great number of options, and custom results presentation in reports, the possibilities of applying this method into current biomaterial studies are increased.

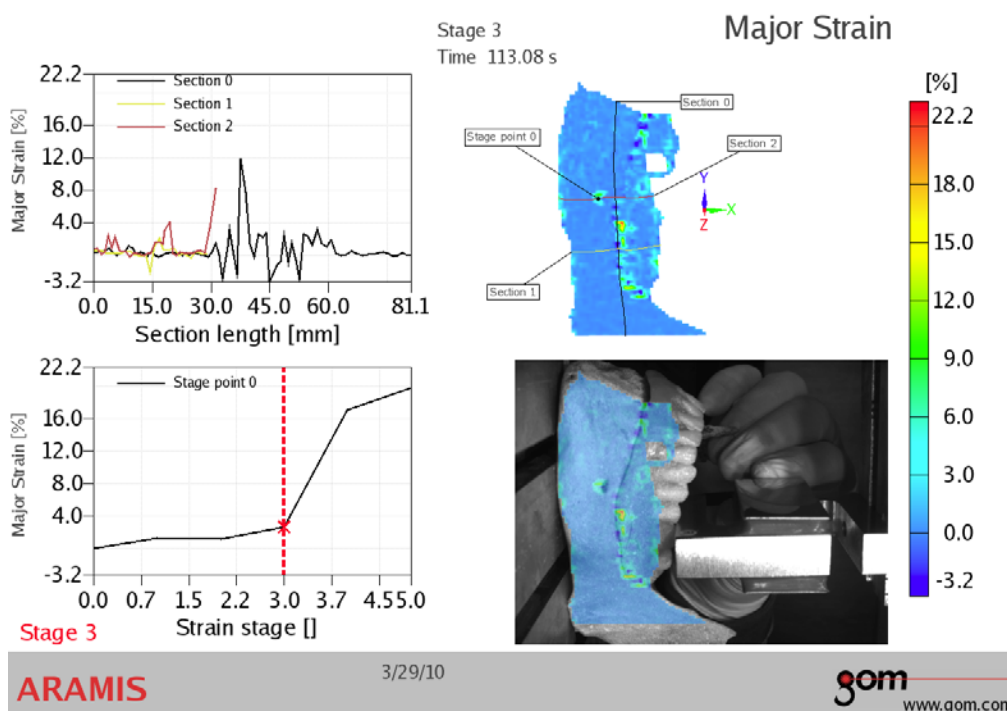


Figure 4. Example of an Aramis' report for major strain of restored lower jaw with total denture.
Slika 4. Primer Aramis' izveštaja za glavnu deformaciju obnovljene donje vilice sa celokupnom protezom

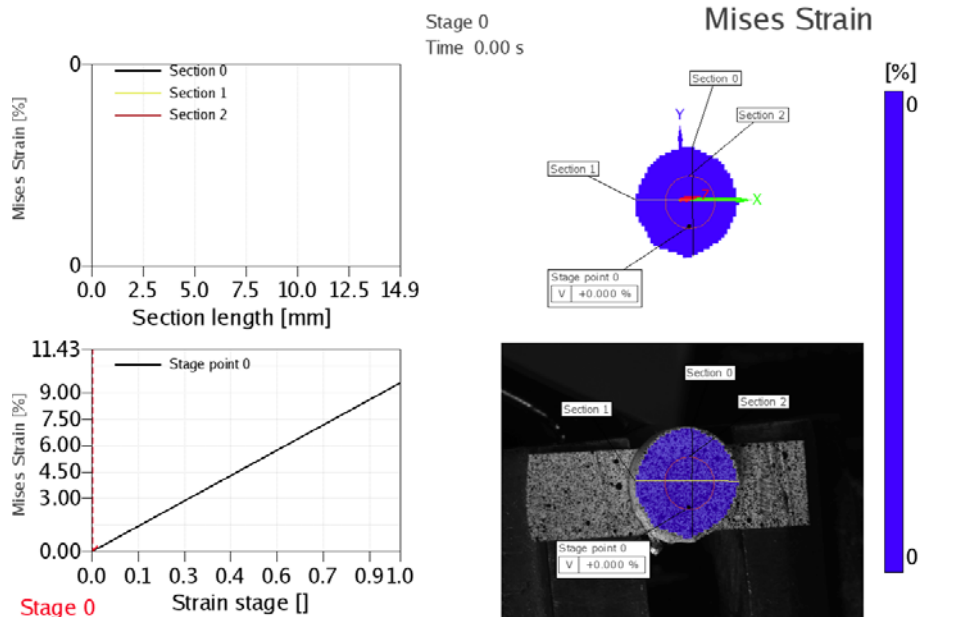


Figure 5. Example of 3D optical analysis of dental composite (undeformed stage).
Slika 5. Primer 3D optičke analize kompozitne proteze (u nedeformisanom stanju)

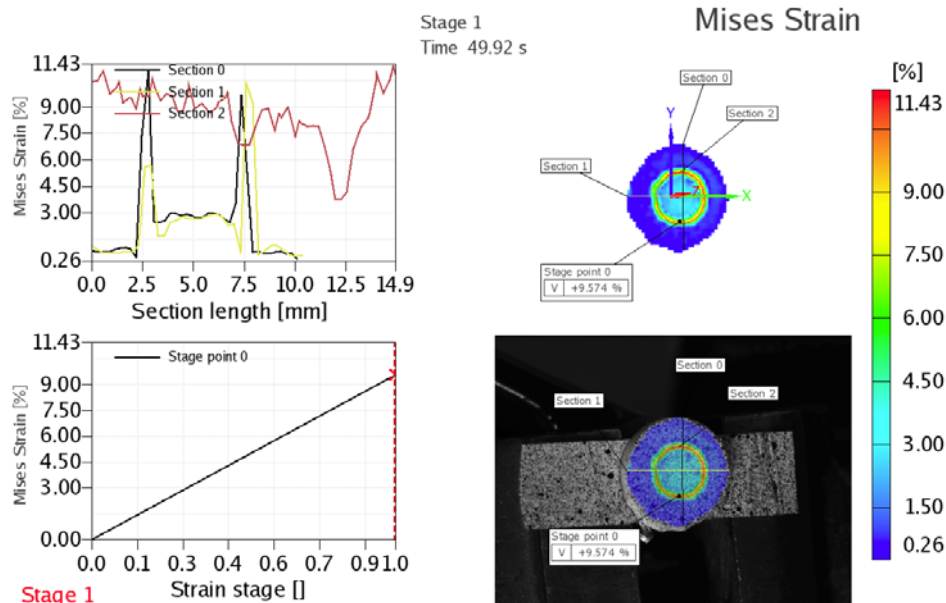


Figure 6. Example of 3D optical analysis of dental composite after polymerization.
Slika 6. Primer 3D optičke analize kompozitne proteze posle polimerizacije

REFERENCES

- Paluszkiwicz, C., Kwiatek, W.M., Długoń, E., Weselucha-Birczyńska, A., Piccinini, M., *Surface study of selected biomaterials using vibrational spectroscopy*, Acta Phys. Pol. A, Vol. 115 (2) pp.533-536, 2009.
- Pantelić, D., Blažić, L., Savić-Ševoć, S., Murić, B., Vasiljević, D., Panić, B., Belić, I., *Holographic measurement of dental tissue contraction and stress, due to post-polymerization reaction*, Acta Phys. Pol. A Vol. 112, pp.1157-1160, 2007.
- Cloud, G., *Optical Methods of Engineering Analysis*, Cambridge University Press, Cambridge 1995.
- Tyson, J., *Non-Contact Full-field Strain Measurement with 3D ESPI*, Sensors, Vol. 17 No. 5, pp.62-70, 2000.
- GOM - Gesellschaft für Optische Messtechnik mbH, <http://www.gom.com>
- Bummo, A., Jung, K., *Measurement and characterization of soft tissue behaviour with surface deformation and force response under large deformation*, Med. Image Anal., Vol. 14, pp.138-148, 2010.
- Gilat, A., Schmidt, T., Tyson, J., *Full field strain measurement during a tensile split Hopkinson bar experiment*, J. Phys. IV France, Vol. 134, 687-692, 2006.
- Hogström, P., Ringsberg, J.W., Johnson, E., *An experimental and numerical study of the effects of length scale and strain state on the necking and fracture behaviours in sheet metals*, Int. J. Impact Eng. Vol. 36, 1194-1203, 2009.
- Li, J., Fok, A., Satterthwaite, J.D., Watts, D.C., *Measurement of the fullfield polymerization shrinkage and depth of cure of dental composites using digital image correlation*, Dental Materials, Vol.25(5), 582-588, 2009.
- <https://support.gom.com>