DIGITAL IMAGE CORRELATION TECHNIQUE IN SELECTED MECHANICAL TESTS

Adam Brodecki*, Tadeusz Szymczak*, Zbigniew Kowalewski, ***

* Centre for Mechanical Testing, Motor Transport Institute, ul. Jagiellońska 80, 03-301 Warsaw, Poland
** Department for Strength of Materials, Institute of Fundamental Technological Research, ul. Pawińskiego 5B, 02-106 Warsaw, Poland

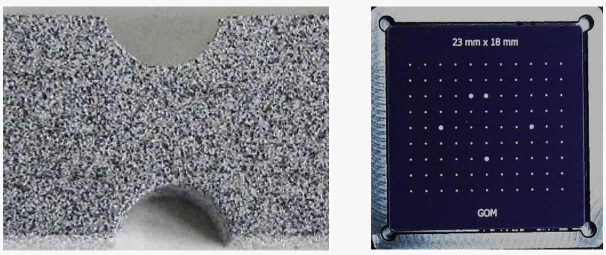
adam.brodecki@its.waw.pl; tadeusz.szymczak@its.waw.pl, zkowalew@ippt.pan.pl

Abstract: The paper shows how modern contactless Digital Image Correlation (DIC) method can be implemented for examination of material behaviour under various types of loading. DIC method was used to evaluate material straining under monotonic tension conducted by the use of flat specimens having artificial defects in the form of U and V notches. This technique was also examined during capturing of strain distribution in dynamic tests on Split Hopkinson Pressure Bar. On the basis of DIC results the strain maps at various stages of material deformation were elaborated in order to indicate characteristic features of a material behaviour. It enabled an analysis of damage zone evolution up to specimen fracture.

Key words: Digital Image Correlation, specimen, monotonic tension, Split Hopkinson Pressure Bar, strain maps

1. INTRODUCTION

Digital Image Correlation (DIC) is a contactless method used for examination of full filed strain maps in 2D or 3D coordinate systems. Mathematical description of the DIC technique is based on continuum mechanics of solid bodies (Fung, 1965; Novozhilov, 1861). Coordinates of displacement are directly used for Cauchy's equations, (Chu et al., 1985). For a digital approach to strain calculation facets having rectangular or square shapes are employed. Variations of their shapes and origin are carried out at any time and compared with the results for the reference stage (GOM, Szymczak et al., 2016). It is done basing on geometrical features of a special pattern represented by black dots arrangement on grey or white background. Usage of the DIC method requires two main stages: pattern preparing and calibration of the system. Typical example of prepared measurement zone and plate applied for the calibration process are illustrated in Fig. 1.



(a) (b)

Fig. 1. Measurement pattern (a) and calibration plate (b)

DIC method for 2D case requires application of single camera while in order to record 3D data more cameras are necessary. DIC technique can be used in many mechanical tests, e.g.: monotonic tension/compression, bending, fracture toughness and fatigue. It has to be emphasised that data capturing during tests under cyclic loading is only possible for selected periods, because number of measurement stages is limited. A special pattern can be used for capturing strain variations up to fracture either for monotonic or cyclic loading.

A comparison of the results obtained experimentally using tensometer technique and DIC system to those determined numerically (FEM) exhibits a good agreement indicating their complementary character in analyses to be carried out after a test, Fig. 2. Another advantage of DIC method is related to application of virtual extensometers to be used in calculation of strain components in selected directions. Such data can be directly compared with the results achieved by typical extensometer technique, and therefore, may serve as a validation of both strain measurements method. In this aspect a number of papers is still not sufficient, and further studies are required.

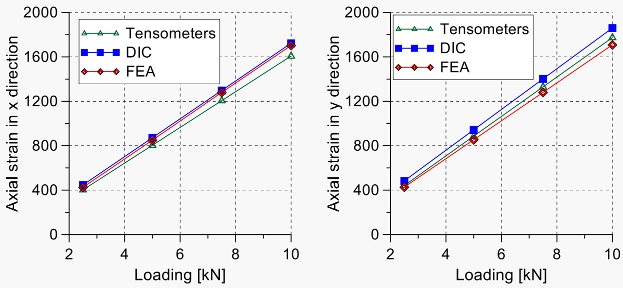


Fig. 2. Comparison of the results achieved by means of selected methods (Gower and Show, 2010)

Another important issue related to possible applications of DIC technique steaming from the dynamic testing needs in the area of strain distribution maps elaboration for materials subjected to very high strain rates.

The main aim of this paper is to show applicability of DIC method in selected mechanical tests for analyses of artificial defects and identification of damage evolution at very high strain rates.

2. RESULTS

Tests were performed using DIC system called 4M Aramis GOM, servohydraulic and electro-dynamic testing machines and Split Hopkinson Pressure Bar (SHPB). All experiments were carried out at room temperature using various types of specimens, e.g. flat unnotched/notched specimens in standard and mini scales.
The validation experiment was carried out in order to identify differences between variations in stress-strain curve captured by means of DIC and extensometer techniques, which were apllied simultaneously, Fig. 3. A very good agreement between both reults were achieved up to a neck appearance. Basing on the stress-strain curve a yield point and ultimate tensile strength can be calculated.

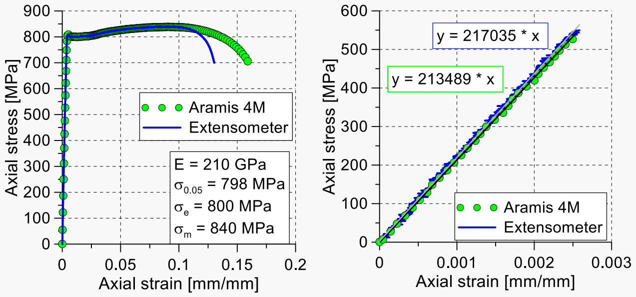


Fig. 3. Tensile characteristics determined by the use of DIC and extensometer; material: the S700 steel

The results in the form of isolines representing the same strain level for material subjected to tension conducted on un-notched and notched flat specimens enable identification of damage zones up to specimen fracture, Fig. 4 They can be used for modelling of material behaviour. Major strain values and their directions can be also determined thanks to DIC application (Szymczak et al. 2016).

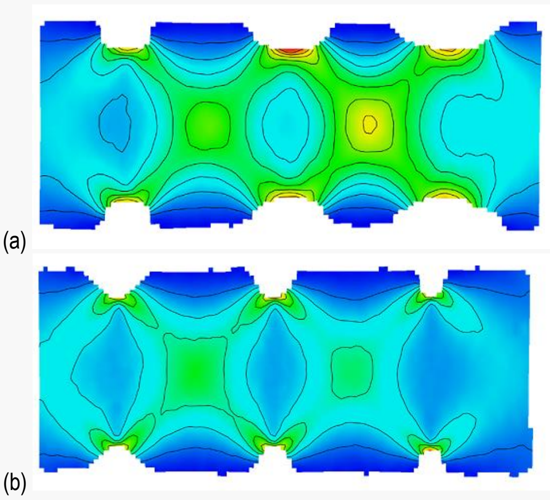


Fig. 4. HMH strain maps for specimens with artificial defects in the form of: (a) U and (b) V notches, material: the 40H steel

Analysis of strain distribution during dynamic characterization of materials by means of SHPB is another example of DIC application. In this case one can distinguish two stages of experimental procedure, i.e.: analysis of pattern by CCD HR cameras; (b) implementation of these results to DIC system for strain calculation (Moćko et al., 2015). As it is presented in Fig. 5, material deformation can be also recorded up to specimen fracture. The results of such programmes exhibit suitability of DIC to capture strain distribution even for very small specimens commonly used in SHPB technique.

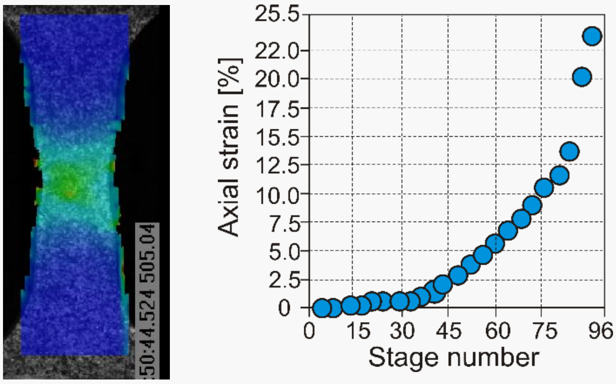


Fig. 5. The results of SHPB test: (a) HMH strain distribution; (b) axial strain versus stage number; material: dual phase steel

Besides of the great advantages the experimental programmes executed using the 4M Aramis enabled identification of its main disadvantages. Among of them one can indicate: limited number of stages for strain analysis; too strong sensitivity of the system into light reflections; strain measurements are only possible up to specimen fracture excluding a moment of decohesion.

3. SUMMARY

It is shown that DIC method can be recommended not only for determination of the full-field strain maps but also for capturing stress-strain curves and calculations of selected mechanical parameters. Moreover, the method can be also successfully used for detection of strain distributions at various tests and specimens.

REFERENCES

1. **Chu T.C., Ranson W.F., Sutton M.A, Peters W.H.** (1985), Application of digital-image-correlation techniques to experimental mechanics, *Experimental Mechanics*, 25(3), 232-244.
2. **Fung Y.C**. (1965), *Foundations of solid mechanics*, Prentice Hall Inc., Englewood Cliffs, NJ.
3. **Gower M.R., Shaw R.M.** (2010), Towards a planar cruciform specimen for biaxial characterization of polymer matrix composites, *Applied Mechanics and Materials*, 24-25, 115-120.
4. **Moćko W; Kruszka L; Brodecki A**. (2015), Strain localization during tensile Hopkinson bar testing of commercially pure titanium and Ti6Al4V titanium alloy. In: *EPJ Web of Conferences*. EDP Sciences.
5. **Novozhilov V.V.** (1861), *Theory of elasticity*, U.S. Department of Commerce Translation.
6. **Szymczak T., Grzywna P., Kowalewski Z.L.** (2013), Modern methods for determination of mechanical properties of engineering materials, *Road Transport*, 1, 79-104 (in Polish).
7. **Szymczak T., Kowalewski Z., Brodecki A.** (2016), Digital image correlation method for investigation of materials and engineering structures, *Technical Supervision*, 4, 22-31 (in Polish).
8. **www.gom.com**