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Comparison of ESPI and DIC Strain Contours Measurements under Three Loading Cases

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Abstract. This article describes strain and displacement contours comparison of Electronic Speckle Pattern Interferometry and Digital Image Correlation. Both methods were used in tension mode, shear mode and combination of these modes.

Introduction

Electronic Speckle Pattern Interferometry (ESPI) is widely used contactless method based on the principle of optical interferometry. For instance, Dantec Dynamics Q100 ESPI system allows to measure the displacement field, which can hold sensor, approximately 50x50 mm. During measurement it is necessary to proceed step by step and always keep the load value for as long as necessary. The principle of measurement is based on the lighting pattern from four different directions. The reflection of light is sensed by one central CCD camera [1]. In contrast Digital Image Correlation Method (DICM) is more progressive than ESPI, because it allows continuous scanning of surface without making load steps and less sensitivity to vibrations. The principle of DCIM is based on scanning pattern on the specimen by two cameras with external lighting. Differences in displacements obtained by an appropriate correlation algorithm for each evaluation points captured by both cameras are evaluated as the displacement field [2]. This field can be many times larger than the ESPI's field (considering Dantec Dynamics Q100 equipment) [3]. In case of composites more attention must be paid to find out suitable methods for deformation measurements and precise execution of the experiment [4].

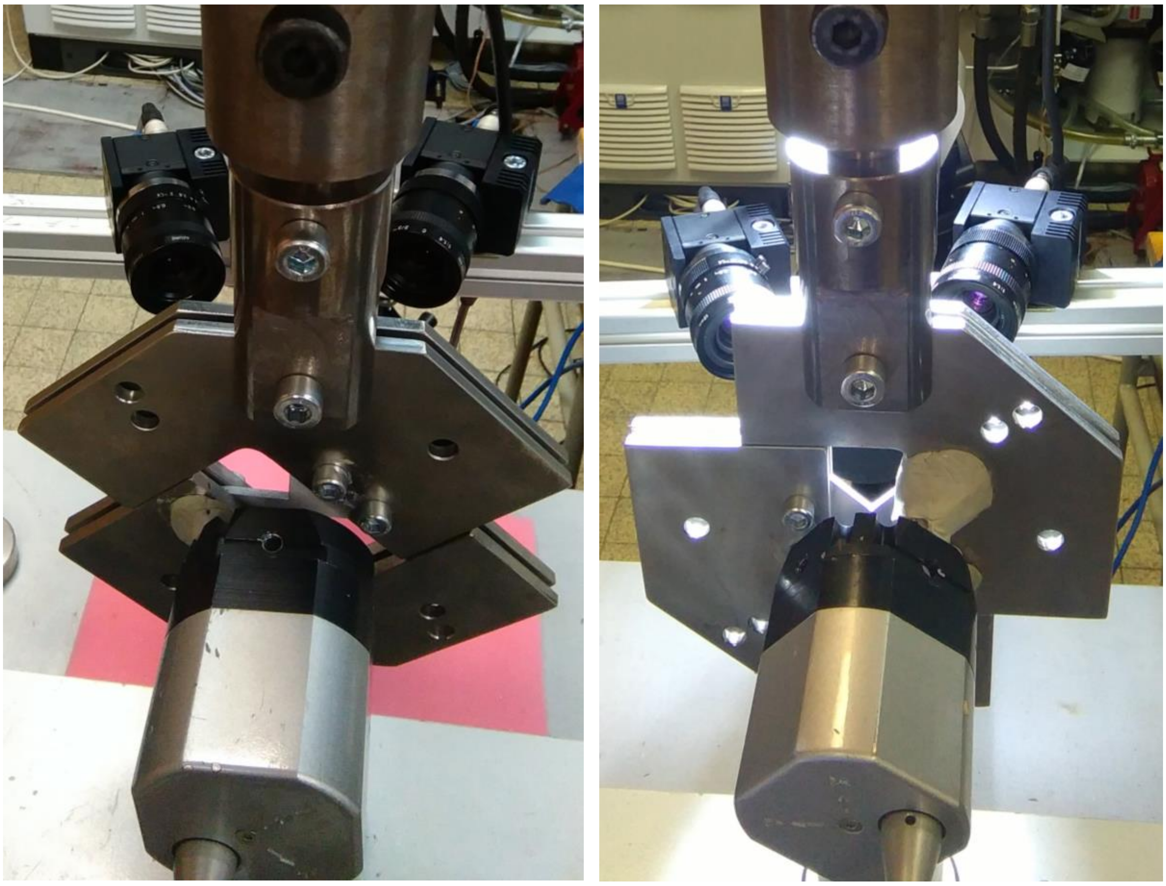
This article presents comparison of strain fields and displacement fields measured on the sheet specimen surface under shear, tension and combined loading by ESPI and DICM methods in the area of small strains.

Experimental setup

Specimen was made of PP50GF composite material, which is a commonly used material in automobile industry. Glass fibers in specimen are oriented in angle 45° from longitudinal axis. All tests were realized on the universal testing machine Testometric 500-50CT at the VŠB –TU Ostrava. For DIC measurements the Mercury® RT equipment (2x2.3Mpx@40Hz) provided by Sobriety s.r.o. company was used [5]. For ESPI measurements Dantec Dynamics

Q100 equipment was used. Creation of optical contrast coating known as pattern was prepared on one specimen side for full field DIC measurements. The opposite side was sprayed by a white colour to prepare optically sensitive layer for ESPI method application. Both measurements were done on the same specimen in the same time, during test, so all measurements were performed simultaneously with DIC system and ESPI equipment.

In all measurements ESPI Q100 sensor was fixed to the testing jig. Therefore the coordinate system remained unchanged for all measurements. DIC equipment Mercury®RT was mounted on a tripod. For purposes of possible comparison of ESPI and DIC, the coordinate system for evaluation was always changed in postprocessing to be analogous to the ESPI coordinate system. Additionally, when the ESPI measurement was evaluated, the displacement offset was set to one selected point based on the DIC measurement. Otherwise, it would be impossible to make a quantitative comparison of the two methods, because ESPI sensor would be shifted with the test jig. All measurements were performed after preload of 100N.



a) b)

Fig. 1. Photographs of experimental setup: a) combined mode, b) shear mode

Results for tension mode

When the specimen was subjected to pure tension, load steps have been set to value 50N and subsequently decreased to the value of 30N. The measurement was performed up to a 300N load from zero state with established preload. Evaluation of the measurements of both methods is shown at Fig. 2. Displacement fields obtained by DIC (Fig.2a) and ESPI (Fig.2b) are comparable. Both methods also show strain concentration in the area close to notches (Fig.2c-d).

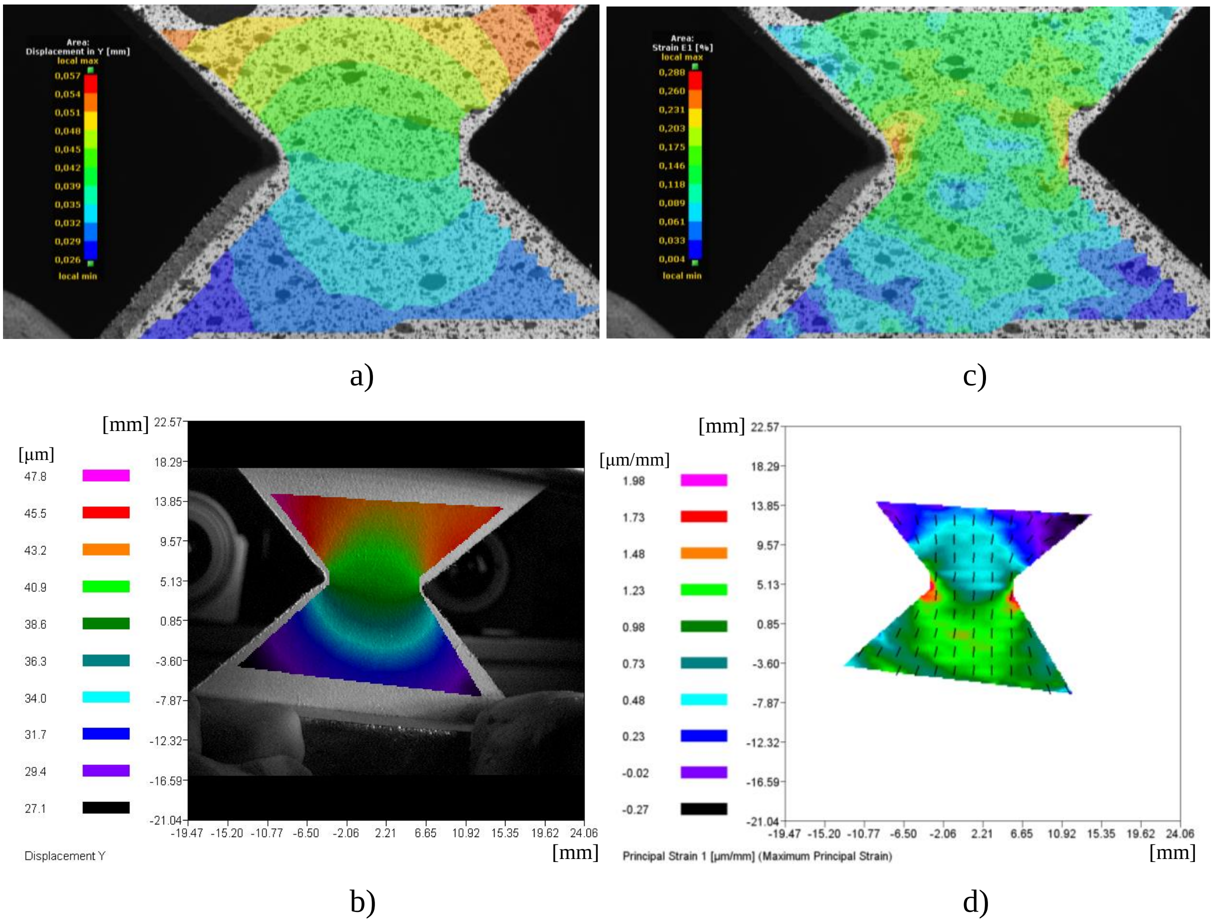


Fig. 2. a) Displacement UY contours - DIC, b) Displacement UY contours - ESPI, c) first principal strain contours - DIC, d) first principal strain contours - ESPI

Results for shear mode

For the case of shear mode, load steps have been set to value 10 N. The measurement was performed up to a 155N load from zero state with established preload. An example of evaluation of the measurements by both methods is shown at Fig. 3 and Fig. 4.

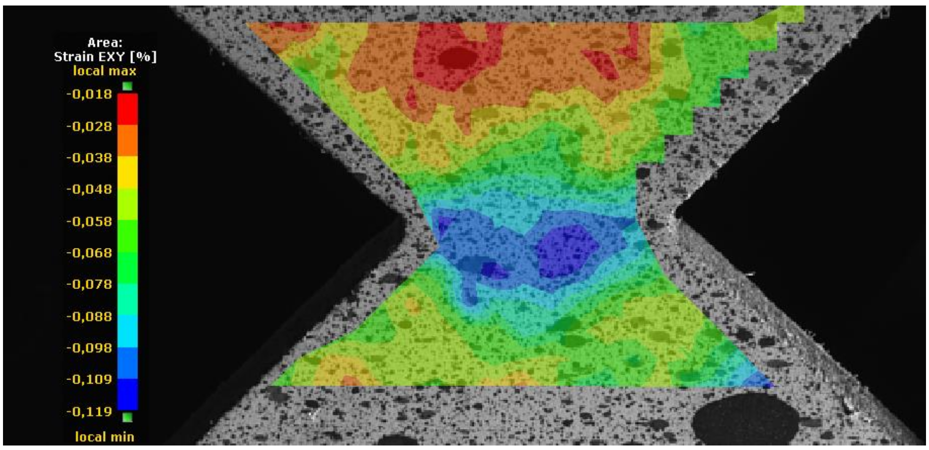


Fig. 3. Shear strain contours - DIC

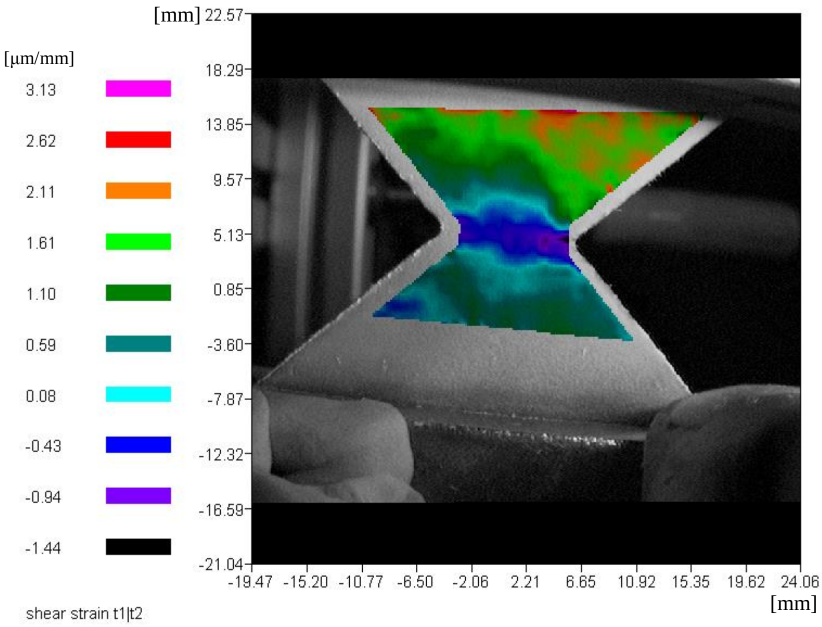


Fig. 4. Engineering shear strain contours - ESPI

It should be mentioned, that the ESPI equipment is configured to display the value of engineering shear strain, whereas the DIC equipment shows values half as ESPI, because the shear strain value is computed as a component of the strain tensor not as the engineering shear strain.

Results for combined mode

When the testing jig is used in such a way, that specimen's axis is situated in 45º angle to loading force direction, the stress state corresponds to the combination of tension and shear mode. In this case, load steps have been set to value 40 N and subsequently decreased to the value of 30N. The measurement was performed up to a 370 N load from zero state with established preload. Comparison of results gained by both measurement methods is possible in Fig. 4 and Fig. 5.

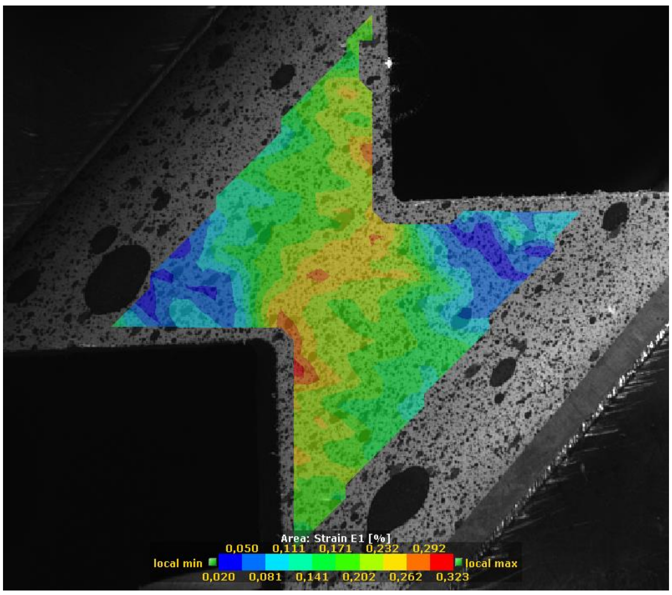


Fig. 4. First principal strain contours - DIC

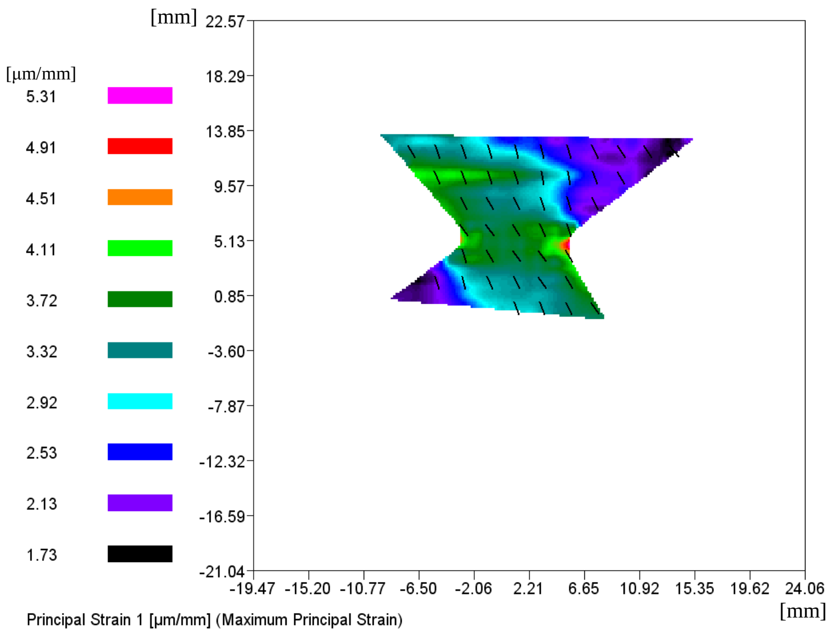


Fig. 5. First principal strain contours - ESPI

Conclusion

Two progressive methods of experimental stress analysis (Electronic Speckle Pattern Interferometry and Digital Image Correlation Method) were evaluated in this study. The measured results are qualitatively comparable for all three loading modes.

There are presented comparison of measurements results (displacement contours, first principal strain contours, shear strain contours) for tension, shear and combined measurements. From the comparison follows, that both methods are suitable for measurement of very small displacements and strain values. The ESPI method is more accurate for the case of small strain analysis [3]. The disadvantage of Q100 equipment in necessity of load increase interruption is not so important in investigated case.

The measured data will be used to calibrate a material model in a finite element software to describe properly the stress-strain behavior of investigated composite material in a 3D finite element simulations.

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