Improvements in processing technique of digital image correlation data for optical measurement of mechanical properties of materials

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ABSTRACT. This contribution presents application of digital correlation method for optical measurement of displacements and techniques for improvement of data processing. The main point of the paper is a comparison of two different techniques of the data processing of the same experiment. First one is based on determination of the displacement field using the image of studied body surface at the beginning and at the end of load application, while the second evaluation technique relies on sequential evaluation and addition of the partial displacement fields derived from comparison of adjacent image pairs in the sequence. It is shown that the later approach is favorable from the point of view of the total error of the experimental results. This observation is especially true in the case of large deformations as explained in the final discussion of the paper. The scripts performing calculation were written in MATLAB providing a suitable development environment thanks its powerful image processing and data presentation functions.

Digital image correlation is effective method inside domain of image processing, it allow automatic pairing same spots on a scene, which they are recorded on least a two images. The basic pair of images is captured in the state before and after loading. An image correlation of same scene in a varies times is core of many varies optical method for measurement of the stress and the displacement. The main advantage of digital image correlation is reliability of measurement and simple programming code implementation. This makes it a very favorable method, also it is very often used in heart of many optics measurement based on computer data processing.

A basic principle of the correlation methods is statement that the biggest correlation between two random samples is when these signals are identical. The consequence of this is s possibility to find identical points on different images of the same body. The condition for successful measurement is have random signals, that means the recorded surface must have contrast layout with random, therefore non-repeating pattern. It can be either of natural origin (e.g. roughness or shadows of object) or artificially sprayed by contrast color, like is on Fig. 1.

The images are represented as huge intensity matrices recorded by sensor array of digital camera. The identification is based on matching the same patterns between the two images by digital image correlation. The true displacement can be deduced from the displacements in the image. In order to determine the whole displacement field, the image is divided into mesh of subsets and the displacement of every subset is calculated from the image pair. Size and number of subsets are chosen in relation to the size of random speckle pattern on the object's surface, size of object on the image and a resolution of recorded image. The size of subset is a trade of some contradictory requirements. With a larger subset certainty increase about unique position of subset, hence value of the correlation increase, but on the other hand having a smaller subset means that the object's surface.

is described in finer detail, thus array of the displacement and the array of strains are denser. This is preferable solution in the area where sharp gradients of stress are present.
The basic principle of DIC calculation is the matching the same subsets between the two images recorded before and after deformation. It is calculated the correlation coefficient for every possible place in define surroundings of reference subset. Best matching is place where is biggest correlation coefficient. This place is consider as the new location of the subset after deformation.

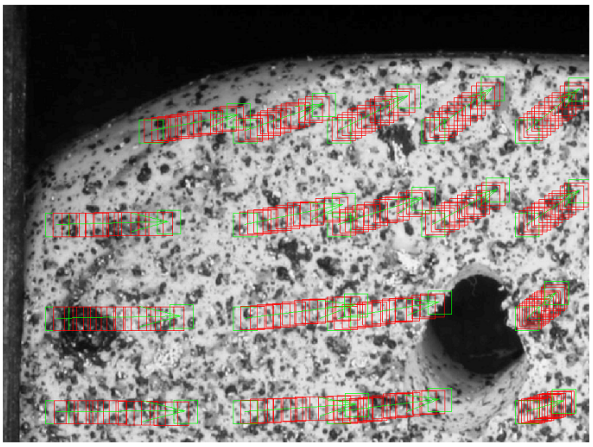

Figure 1: This figure show unsteady movement of the subsets in different region of the object. A red square shows a sequence of movement of the subsets during loading.

Described method operate only with integer displacements, but in some cases, especially in small displacement can be significant a non-integer pixel movement. In this case for improve the accuracy of DIC can be improved by subpixel approximation. Digital image correlation processing all images in series. A change between the two nearby image is representing partial deformation, where whole deformation is between first and last image in series. This work compare accuracy of the measurement in case correlation was occurred on sequence of images and when happened on images before deformation and after deformation. The works result show, that method based on sequence of images have significantly better accuracy in case of large deformation, although elementary view can suggest contrary, because addition errors of the correlation. Data was smoothed for random error suppression by open-source library gridfit.

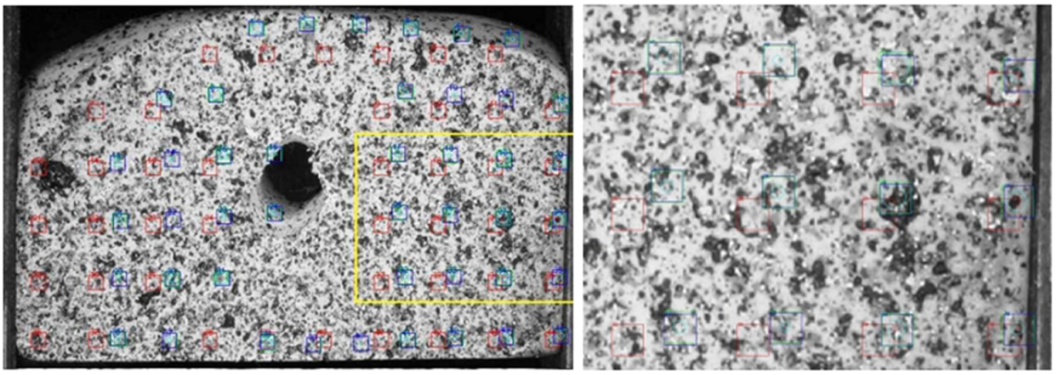

Figure 2: The image on the left shows the full-view of object. The image on the right is right-middle cutout from the full-image. The every subset have own number in the left-top corner for easier recognize. The red squares represent reference subsets (unload). The subsets after deformation are show for first-last method and sequence method. First-last are the green squares and blue squares are subsets found by sequence method. Turquoise circles were drawn in the center of green subsets for better representation of the difference location of both method. This circles show absolute distance between finding both method and distance was multiplied by five for better clearness. This images show advantages of sequence method again first-last method. The top-center area (above hole) clearly shows a supremacy of sequence method. There first-last method couldn't found any new location of the subsets, because a limit value of correlation coefficient for accept couldn't be achieved, but sequence method hadn't any problem found correct position with enough high correlation.

CONCLUSION

This article discusses improvement of the accuracy of a measurement through recording and processing a sequence of images. The proposed improvement is based on recording the experiment in the series of images and subsequently proccessing them instead of recording and proccessing only two images (unload and load).

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