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Experimental Stress Analysis

Influence of spraying on the surface of investigated object to precision of digital image correlation

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Abstract: During deformation and displacement measurement by digital image correlation method must be on a surface of the object created random speckle pattern. Spraying of two colors of high contrast can create the pattern. Precision of correlation and measurement results depends on several parameters and quality of spraying is one of them. Paper describes influence of surface pattern quality to process of inverse reconstruction of space image of objects surface for the digital image correlation method.

Keywords: Digital, Image, Correlation, Speckle, Pattern, Quality

1. Introduction

Accurate measurements of displacements and stresses during deformation of material or machine part are priority task for designers and experimenters. Remarkable progress in the area of computer technologies suggests new possibilities that allow use unconventional measurement methods that fulfill the newest demands for accuracy and measurement conditions:

- no contact with measured object,
- enough space resolution that ensures measurement in arbitrary location of investigated area,
- ability to catch inhomogeneous field of deformations in whole area,
- ability of direct measurement that do not necessitate numerical nor analytical processing of results.

Logical answer to these conditions is optical methods. Digital image correlation method is one of them. Because it is an optical method, accuracy of measurement depends on several image parameters resulting from principle of method. One of the prerequisites is development of stochastic black and white

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speckle pattern on the surface of object. Its quality substantially influences to accuracy of correlation process and measurement results.

2. Principle of digital image correlation method

In case of classical image correlation are deformations of object determined by using of CCD camera. In process of digital image correlation are determined displacements and/or rotations and curvatures of small image elements, so-called facets. This procedure allows determining deformation of object in plane parallel with camera image plane.

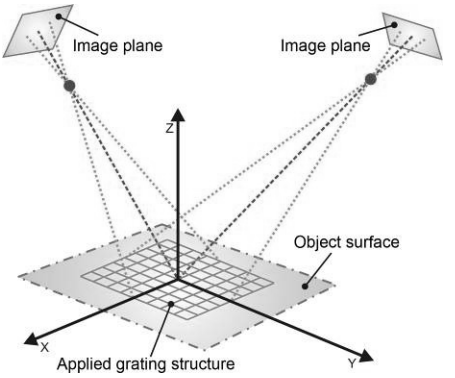

Fig. 1. Principle of 3D image correlation with two cameras [1].

In space deformation analysis is used stereoscopic arrangement of sensors [2]. If the object is investigated from two directions, then the position of every point of object is focused to certain pixel in image plane of individual camera (Fig. 1). Digitalized images from individual steps of measurement are compared with chosen reference step. Correlation algorithm provides this comparison facet by facet. In order to be able to correlate identical points of both cameras it is necessary to have contrast of surface points. This can be reached by spraying of black color on white base. Created patterns then represent material points on surface of investigated object. These are displaced and deformed under loading. Transformation of position of every point in images from both cameras into 3D coordinates is realized by parameters determined during process of cameras calibration. If they are known, the system determines absolute coordinates of every point of scanned surface and it is created its spatial contour and there are computed displacements and strains in every step [3].

3. Experimental assessment of spraying quality influence

Correlation mechanism in process of correlation investigate intensity of color of every point in image from both cameras and transforms identical positions of facets determined on the surface of object into 3D coordinates [3]. Accuracy of correlation depends on size of facets. Correlation error substantially increases if the size is smaller than 15px [4]. Minimal size of facets is limited by size and contrast of

pattern speckles. Every facet must contain characteristic part of pattern with sufficient sharpness [5]. Imperfections in surface pattern can influence correlation process into such extent that some facets will not correlate or they will correlate with errors (Fig.2). If are provided measurements with high demands on precision then it is important to create surface pattern of appropriate quality.

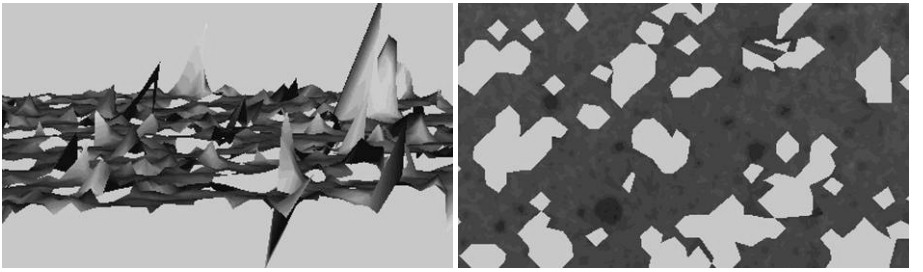

Fig. 2. Errors of contours of correlated surface of plane specimen.

In the process of experimental assessment of surface quality influence were compared four different stochastic patterns created on the surface of one plane specimen. The measurement was accomplished by correlation system Q-450 Dantec Dynamics (Fig.3). There were investigated the following quantities:

- percentual portion of uncorrelated areas,
- distance of contour from ideal plane surface,
- approximate inaccuracy of contour surface coordinates.

Fig. 3. Configuration of system Q-450 during measurement.

For every pattern were these quantities determined with respect to facet sizes (in range from 10 to 60 pixels). It was realized one measurement where was scanned whole surface of specimen. Every pattern was evaluated separately, but with same correlation parameters given in Tab.1. Software environment Istra4D of correlation system is able to determinate approximate inaccuracy of contour surface coordinates

and distances of its points from ideal plane. Matlab computed the magnitudes of quantities. On the base of analysis of contour mask was by Matlab also computed percentual portion of parts that do not correlate in dependency of facet sizes.

Table 1. Correlation parameters of system Q-450

Facet size:	10 – 60 pixel
Gray value interpolation:	Bicubic spline (normal)
Outlier tolerance:	Low
Correlation accuracy:	0,2 pixel
Correlation residuum:	30 (grey values)
3D Reconstruction residuum:	0,4 pixel

In Fig.4 are given patterns that were compared. Their quality can be characterized by size, contrast and clearness of speckles that determinate resulting brightness and sharpness of individual pattern. On the base of investigation of individual patterns and analysis of adjacent histograms (Fig.4) can be considered that the most contrast is on pattern number 2; a little smaller contrast is on pattern number 4, which average shade was the most clear.

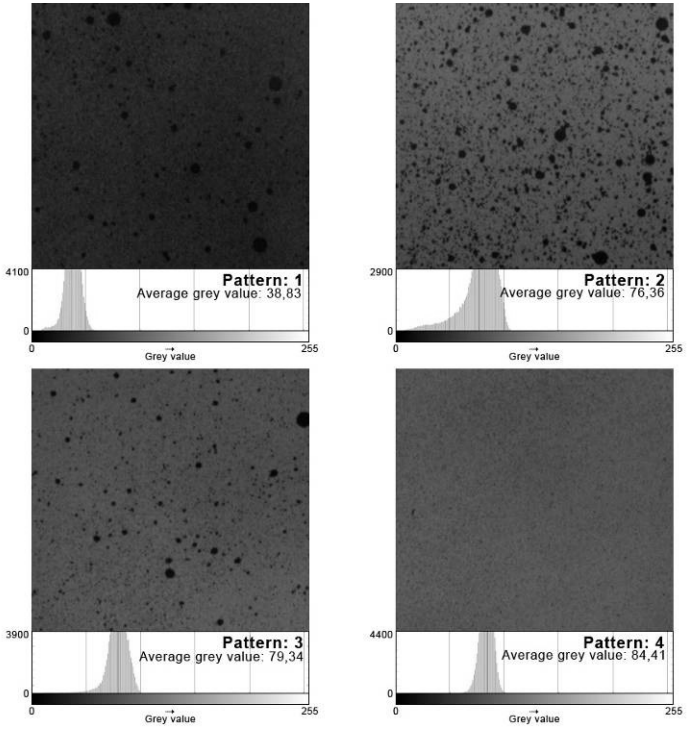

Fig. 4. Compared patterns and their histograms.

4. Assessment of experimental results

In the first step was quality of painting evaluated according to number of non-correlated regions of contour surface with respect to their whole number. From comparison of dependencies on facet sizes results that with increased facet size is the number of non-correlated areas dramatically decreased (Fig.6). The most portions of non-correlated areas were by using facets smaller than 16px. The worst results were with pattern number 4 where were not satisfactorily contrast and sharpness. In case of facet sizes 10px the algorithm correlates only on 8% of whole area of this pattern. On the base of investigation of non-correlated areas of individual patterns (see Fig.5) was possible to state that these areas had very small contrast and they did not catch characteristic patterns.

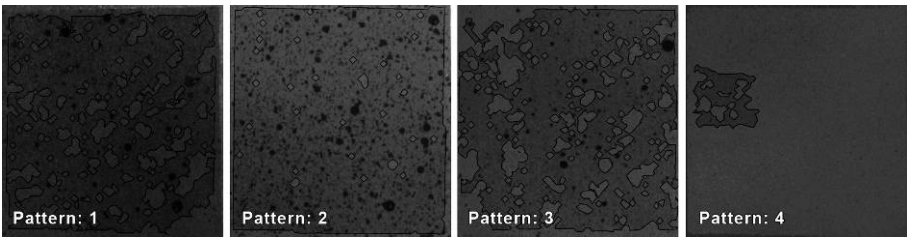

Fig. 5. Uncorrelated areas of individual patterns for facets of size 10px.

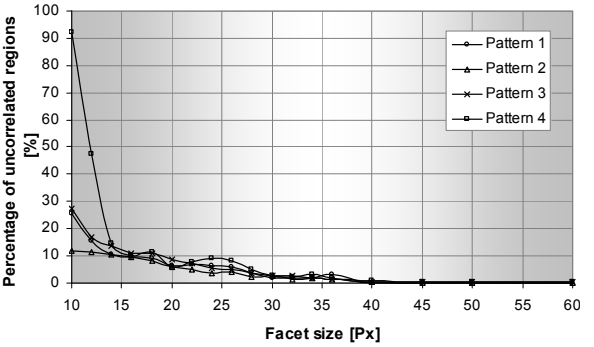

Fig. 6. Ratio of uncorrelated areas in dependency on facet sizes.

In order to exclude influence of 3D reconstruction errors [4], it was investigated flat specimen. Deviations in back reconstruction of its shape were evaluated on the base of distances of surface points from ideal plane surface. In Fig.7 are, in dependency with facet sizes depicted average and maximal values of measured deviations

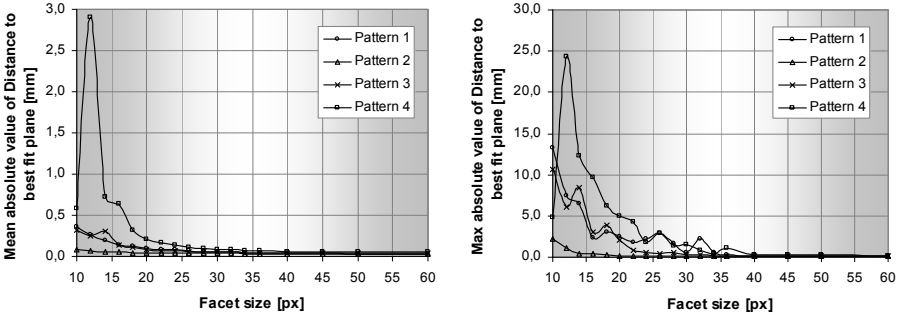

Fig. 7. Average and maximal surface deviation in relation to ideal plane in dependency on facet sizes.

From graphical charts result that shape imperfections of reconstructed surface of flat specimen decreased with increased size of facets. The best results were for painting number 2. The biggest errors of shape were again on pattern number 4. Patterns 1 and 3 had approximately comparable magnitudes of deviations (Fig.8).

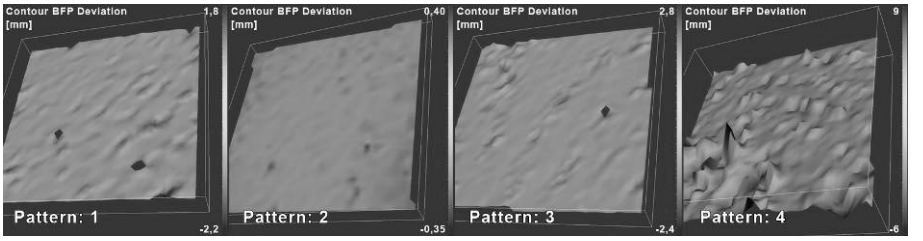

Fig. 8. Contour deviations of individual patterns with respect to ideal plane for facet size 16px.

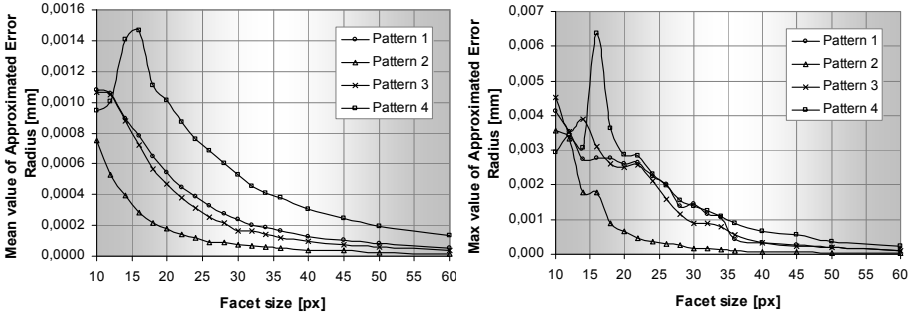

Fig. 9. Estimated uncertainty of points coordinates in dependency on facet sizes.

Even if the inaccuracy of coordinates of contour surface decreases with increased facet size, from the charts given in Fig.9 results that quality of pattern influence precision of results. Pattern number 4 reached in whole range the biggest

inaccuracies of coordinates. In contrast to this, the smallest inaccuracy was found out for pattern number 2.

5. Conclusions

In the paper was on the base of results of simple experiment described influence of quality of patterns on surface of investigated object on the process of reconstruction for digital image correlation method. For evaluation of parameters were not used any filters that could influence results in positive sense.

From the results of pattern quality analysis can be stated that pattern quality has significant influence to correlation process and consequently to accuracy of measurement results, especially for deformation analysis. From 4 various patterns were the best results gained with pattern number 2. In contrast to this pattern number 4 had the worst contrast and sharpness due to small black speckles. On the base of this can be stated that:

- every facet has to contain characteristic part of pattern,
- empty white areas or big black speckles caused significant contour errors,
- contrast of black speckles to white base has to be sufficient in order to have sharp image from sensing cameras.

During creation of pattern is necessary to consider also conditions and prerequisites of experiment, because resulting effect of spraying is influenced, beside of shape and size of sensing surface, also by light conditions, objectives, velocity of acquisition. Moreover, creation of pattern by spraying of black color on white base is to certain sense stochastic process and resulting quality depends on skillfulness of experimenter. Drawbacks of pattern can be corrected by change of correlation parameters.

Acknowledgement

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