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DETERMINATION OF ACTUAL CRACK POSITION USING DIGITAL IMAGE CORRELATION

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Summary: *This paper presents utilization of Digital Image Correlation and other image processing methods in determination of the actual position of the crack during the crack propagation in ductile material. This task is very important in fracture mechanics studies, especially in evaluation of full-field stress and strain in the vicinity of the crack. It encompasses detection of the crack faces, tracing of the crack tip and measuring the crack length.*

1. Introduction

For precise evaluation of the crack behavior in ductile materials it is necessary to observe full-field stress and strain in the crack tip vicinity. However measurement of the full-field stress and strain without knowledge of the accurate crack position may lead to wrong conclusions. Strain field calculated from displacement field supposes continuous material and due to this reason its measurement when crossing crack path gives incorrect values of strain and stress. For this reason a detection of crack faces is very important. With the knowledge of the shape and position of the crack during the crack growth it is also easy to evaluate the actual position of crack tip and then measure the crack length, see Figure 1. These parameters are also fundamental inputs in the case of determination of material fracture mechanics parameters.

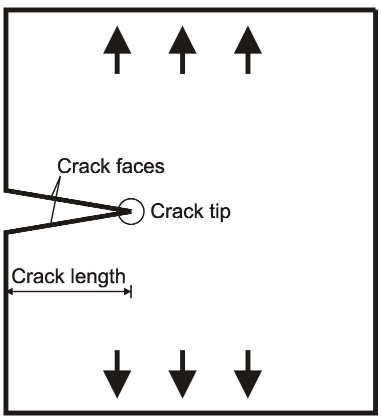

Fig. 1 Scheme of the crack in opening mode.

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2. Digital Image Correlation

Digital Image Correlation (DIC) is used for experimental mechanics studies, Russell & Sutton (1984). It is the non-contact technique (Optical or X-Ray) that provides full-field and high resolution measurement of displacements and strains within an object subjected to loading.

The technique utilizes a sequence of consecutive images that represents the progress of the object deformation. In this sequence DIC observes a movement of individual templates of some texture employing the correlation technique, Jandejsek & Vavřík (2007). The template is a cutout of the texture that contains a small but distinguishable part of the texture. The region containing a shifted template in the after-image of the sequence is scanned by the template of the original image to get a matrix of correlation coefficients (0 = no correlation, 1 = identity). A maximum value of this matrix gives the new position of the template and consequently the vector of displacement of the template. Sub-pixel accuracy is achieved by interpolating a neighborhood of this value by polynomial surface. For full-field strain measurement the regular grid of such templates is defined. This procedure is done for the entire image sequence so the time behavior of full-field displacements and strains is obtained.

In the case of X-Ray observation the texture is generated by distinct inner structure of material. In the following experiment the visible structure of grains distribution served as the necessary texture for DIC implementation.

3. Experiment - X Ray observation

As experimental data served the radiographic sequence of the crack propagation in the ductile Al-alloy flat specimen, Vavřík et al. (2007). The specimen with the pre-crack was loaded in tension by the portable loading device. The radiographic sequence of the crack propagation was obtained using a micro-focus X-Ray tube and X-Ray imager Medipix-2. The sequence of 120 radiograms (each radiogram has size 256 x 256 pixels) displays the crack growth until the failure, see Figure 2. In condition that an inner structure of material is conspicuous in radiograms, the full-field displacements and strain at the crack tip vicinity may be evaluated using Digital Image Correlation method discussed in chapter 2.

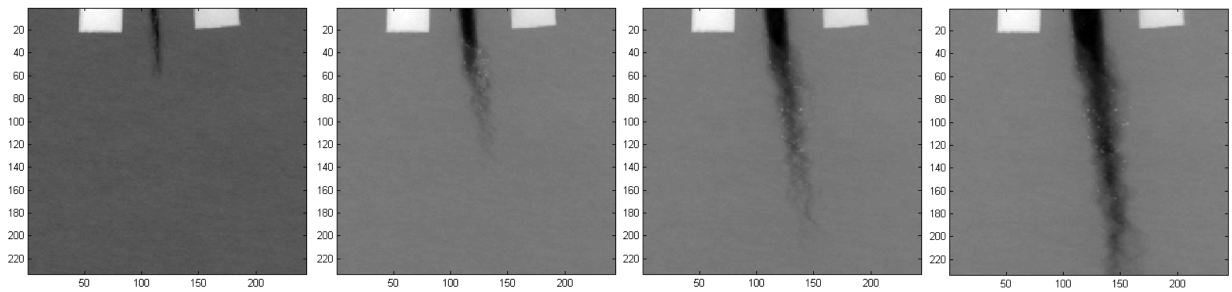

Fig. 2 Radiograms of crack propagation in ductile Al-alloy specimen.

4. Determination of actual crack position

In the case of the full-field strain measurement using DIC, there are two basic approaches in detection of the crack position. The first one is based on a significant change of correlation when the crack appears in the correlation template. Sudden change of the texture in such place leads to decrease of correlation coefficient, see Figure 3. There are a few problems in this approach witch have to be treated. The change of the texture has to be enough fast. Ideal case is when the significant change happens in the two successive images. Fluent change of the texture doesn't lead to distinct decrease of correlation coefficient and so the crack is not detected. Other problem is the size of the template. For fine tracing the template has to be big enough. However changes of texture due to crack may take place at smaller regions. This is solved using two concentric templates. The bigger one is used for tracing and the smaller one is used for observing texture changes.

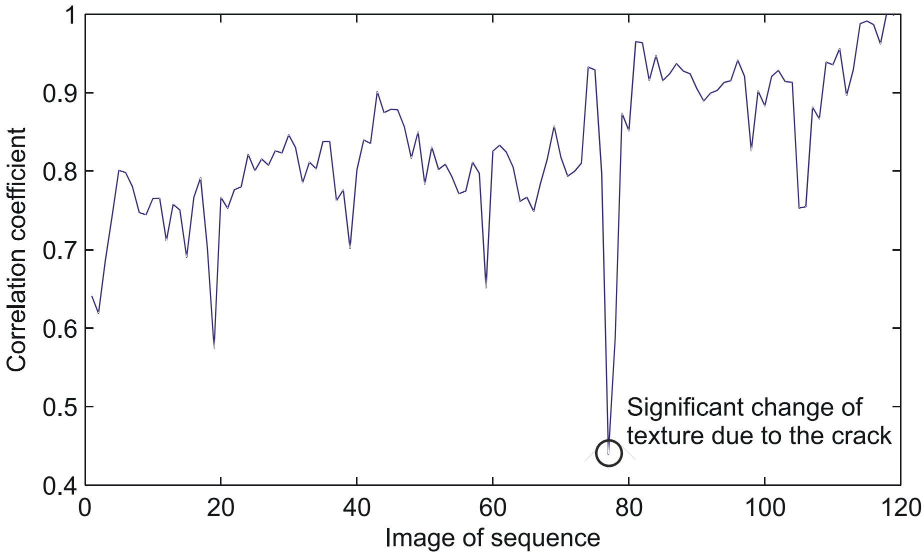

Fig. 3 Correlation coefficients of the template where the crack was appeared in the 77. frame of the sequence.

The second approach is based on the change of mean intensity of the template. In the radiogram the intensity of pixel defines a thickness of the material. Therefore, when the crack appears in the template, the mean intensity of the template rapidly decrease. However, it is not simple to define whether the crack is detected or if it is only the material reduction. Its well known that each given material has limited possible thickness reduction. This reduction depends on the strain-stress state. Therefore, the choice of the correct threshold value for a crack detection depends on the specific experimental data. Intensity of vacancy in the crack is assumed as zero or very low. Even here the two concentric templates were used. The bigger one traced the movement, the smaller one measured the mean value of intensity.

The following figure 4. shows the results of full-field measurement in the crack vicinity. The regular orthogonal grid of 20 x 20 templates (Each red cross is the center of the one template) was used for measurement. The size of the bigger template intended for displacement measurement was 37 x 37 pixels. The template intended for the crack detection had size of 9 x 9 pixels. The full-field displacements over the entire sequence were successfully evaluated. Zero values of strain and stress were assigned to the places where the crack was detected.

Measurement of the crack length and determination of the actual position of the crack tip are obvious from this detection.

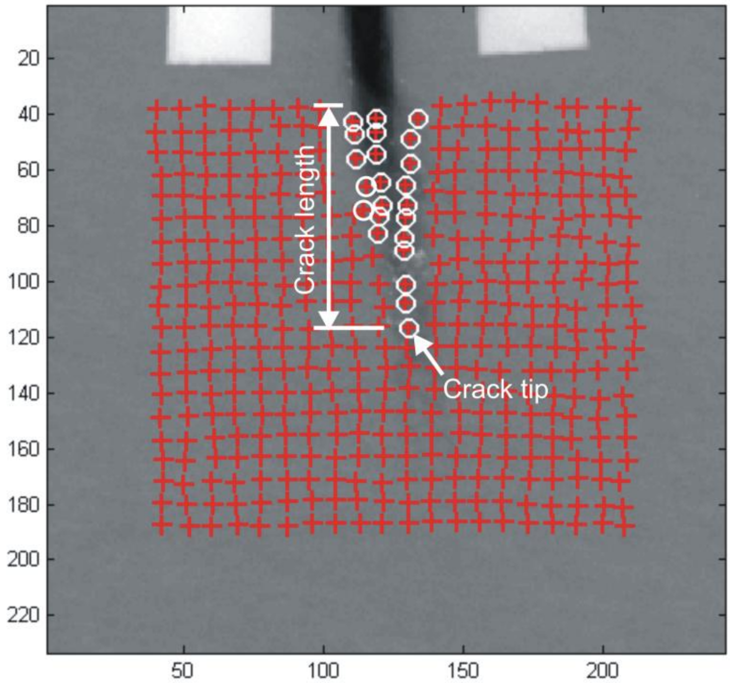

Fig. 4 Detection of the crack position in the measurement grid. Each point is the center of one template. Circled points are locations where the crack was detected.

5. Conclusions

The application of DIC in determination of the actual crack position was successfully carried out. This knowledge allows us to compute full-field strain and stress correctly. Moreover it allows us to measure the actual length of the crack.

4. Acknowledgement

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5. References

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