SUITABILITY OF DIGITAL IMAGE CORRELATION FOR FATIGUE DAMAGE DEVELOPMENT MONITORING IN X10CRMOVNB9-1 POWER ENGINEERING STEEL

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1. Introduction

Material behaviour under various loading types could be successfully determined by using different measurement techniques. The most conventional method includes extensometer recordings during both, static and fatigue tests for subsequent strain component measurements. Such methodology enables continuous recording of strain changes in a particular direction defined at the beginning of mechanical test. Moreover, the extensometers can only monitor a displacement on the limited strain gauge, and more importantly, give only an average values of it. This is a serious limitation of the technique, particularly in the case of fatigue investigations. Although fatigue phenomenon has been investigated by many research centres for more than two ages, there are still a lot of difficulties in the prediction of crack initiation under cyclic loading, especially under multiaxial stress conditions. It is well known that the process of fatigue damage development and structural degradation is of local nature, and as a consequence, an application of the above-mentioned conventional extensometers for strain measurements cannot reflect strain distribution along the gauge length of the specimen tested and the indication of the crack initiation location within the gauge length is practically impossible using the conventional extensometers. Such a problem may be effectively solved by the application of DIC full-field optical method. DIC is a stereoscopic technique in which two CCD cameras, light sources and computational software are used. A mathematical theory of DIC was presented by Chu et al. [1]. In this method, a specimen needs to be covered with a special pattern (black dots on a bright background) [1, 2]. Such pattern defines the x and z coordinates which are further used to run the test under strain control. The origins of rectangular- or square-shaped pattern are directly applied to calculate the displacement/strain. The results obtained are presented in the form of full-field strain distribution maps [2]. The DIC method is mainly used for static measurements in which tensile and compressive behaviour [3], fracture toughness [4] and the geometrical imperfection effects on mechanical response [2] are investigated in detail.

2. Results and discussion

To assess an applicability of the DIC methodology, fatigue tests were performed up to the specimen fracture under stress amplitude equal to 500 MPa. As it is shown in Fig. 1a, DIC technique enabled an identification of the strain accumulation area, being a potential location of possible damage initiation, after just a single cycle (Fig. 1a). A subsequent fatigue process up to 100 000 cycles enabled to clearly indicate an area of the potential crack initiation (Fig. 1b). Further loading cycles evidenced its development (Fig. 1c, d) up to the specimen fracture. The effectiveness of DIC method was confirmed by additional tests carried out for the stress amplitude equal to 600 MPa, 630 MPa and 640 MPa. For each experiment, the area of potential crack initiation was precisely determined after selected initial number of fatigue cycles. As the final results of each of these tests shown, the specimens fractured exactly in the initially specified regions. It should be mentioned, however, that in order to clearly present a strain distribution the highest values of stress amplitude were required which enabled the strain scale unification.

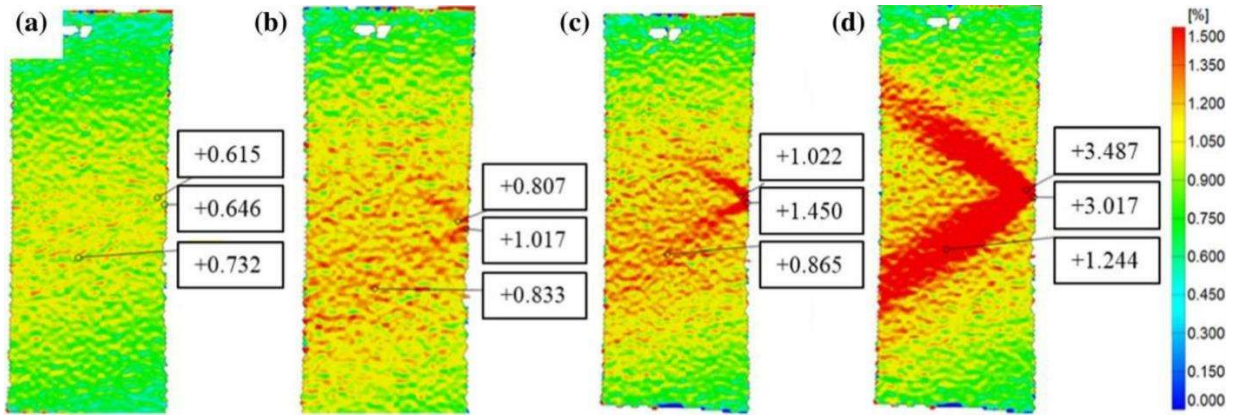

Fig. 1. DIC strain maps determined for the stress amplitude equal to 500 MPa with the unified scale after: 1 cycle (a); 100 000 cycles (b); 250 000 cycles (c); 301 251 cycles (d) [5]

3. Conclusions

In this research, steel specimens subjected to fatigue loadings in the range of stress amplitude from ± 400 to ± 640 MPa were monitored by DIC optical technique. A quality of the technique was assessed in terms of its effectiveness during fatigue damage development monitoring of P91 power engineering steel. It was found, that DIC enables an effective monitoring of the fatigue behaviour and accurate indication of an area of the potential failure at early stage of fatigue damage development.

Key Words: Fatigue development · Damage · P91 steel · Digital image correlation (DIC)

4. References

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