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DIGITAL IMAGE CORRELATION IN MONITORING OF FATIGUE DAMAGE DEVELOPMENT IN P91 POWER ENGINEERING STEEL

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ABSTRACT

The paper aims to investigate the effectiveness of the Digital Image Correlation (DIC) technique during fatigue damage development monitoring in X10CrMoVNb9-1 (P91) power engineering steel. It was found, that DIC enables to monitor of the fatigue behaviour of steel specimens and accurately indicates the area of potential failure even within the initial stage of the fatigue damage development.

Keywords: fatigue development, damage, P91 steel, digital image correlation.

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 components measurements. Such methodology enables continuous recording of strain changes in a particular direction defined at the beginning of the mechanical test. Moreover, the extensometers can only monitor a displacement on the limited strain gauge, and more importantly, give only average values of it. This is a serious limitation of the technique, particularly in the case of fatigue investigations. Although the 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. Indication of the crack initiation location within the gauge length is practically impossible using conventional extensometers. Such a problem may be effectively solved by the application of the DIC full-field optical method.

RESULTS AND CONCLUSIONS

The fatigue tests were force controlled with zero mean level and a constant stress amplitude with a frequency of 20 Hz in the range of stress amplitude from ±400 MPa to ±640 MPa. The range of fatigue loads was established on the basis of the yield strength R0.2 determined from the uniaxial tensile test. The fatigue development was monitored by DIC Aramis 12M equipped with lenses of total focal length of 75mm and calibration settings appropriate to the measuring area equal to 170x156mm. The calibration was performed prior to testing using a certified GOM calibration plate. DIC technique captured a strain localization area after just one cycle (Figure 1a).

DIC technique captured a strain localization area after just one cycle (Figure 1a). The subsequent evolution of fatigue damage to 100 000 cycles enabled to clearly indicate the area of potential crack initiation (Figure 1b) and its development (Figures 1c-d) up to specimen fracture. The effectiveness of the DIC method was further confirmed by performing additional measurements for the stress amplitude equal to 600 MPa, 630 MPa and 640 MPa (Figures 1-3). For each measurement, the area of potential crack initiation was precisely captured after the initial number of fatigue cycles and specimens fractured exactly in this specified region. It should be mentioned, however, that the application of the highest values of stress amplitude required modifying the scale in order to clearly present the strain distribution.

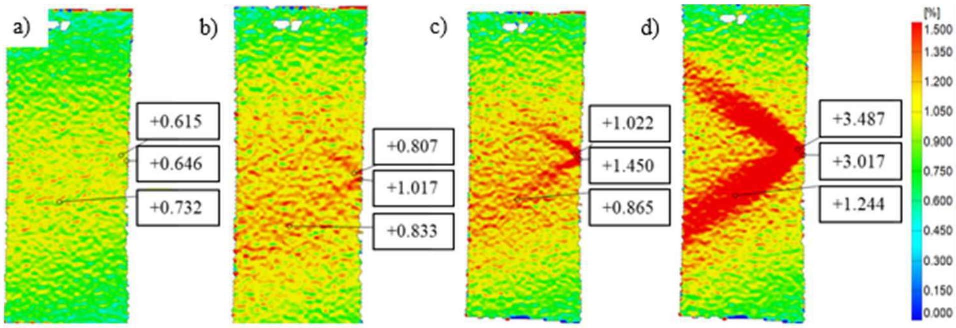

Fig. 1 – DIC measurements performed for the stress amplitude equal to 500 MPa with unified scale after : 1 cycle (a); 100 000 cycles (b); 250 000 cycles (c); 301 251 cycles (d).

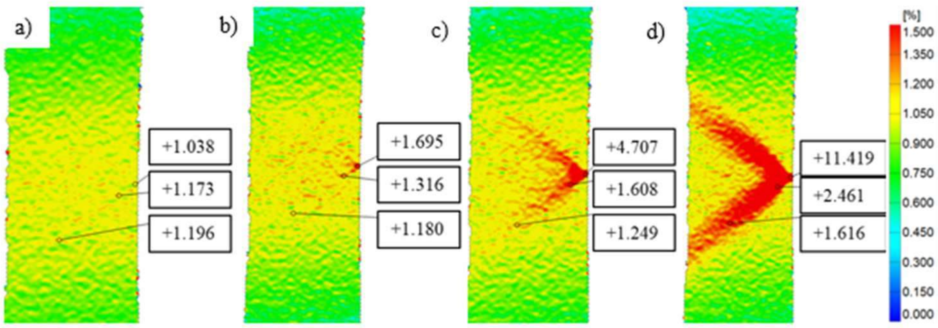

Fig. 2 – DIC measurements performed for the stress amplitude equal to 600 MPa with unified scale after: 50 cycle (a); 130 000 cycles (b); 138 000 cycles (c); 144 000 cycles (d).

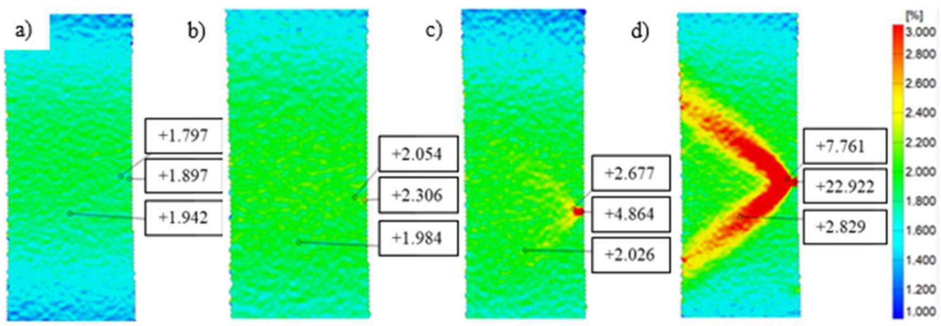

Fig. 3 – DIC measurements performed for the stress amplitude equal to 630 MPa with unified scale after: 50 cycle (a); 50 000 cycles (b); 95 000 cycles (c); 110 000 cycles (d).

REFERENCES

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