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Digital Image Correlation as an effective tool for fatigue damage monitoring

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Abstract. The paper aims to investigate an effectiveness of 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 the fatigue behaviour of steel specimens and accurately indicate the area of potential failure even within initial stage of the fatigue damage development.

Key words: 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 include 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 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 prediction of crack initiation under cyclic loading, especially under multiaxial stress conditions. It is well known that the process of the 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 specimen tested. Indication of the crack initiation location within the gauge length is practically impossible using the conventional extensometers. Such problem may be effectively solved by application of DIC full-field optical method.

Results

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 $R_{0.2}$ 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 localisation area after just one cycle (Fig.1a). The subsequent evolution of fatigue damage to 100 000 cycles enabled to clearly indicate the area of potential crack initiation (Fig.1b) and its development (Fig.1c-d) up to specimen fracture.

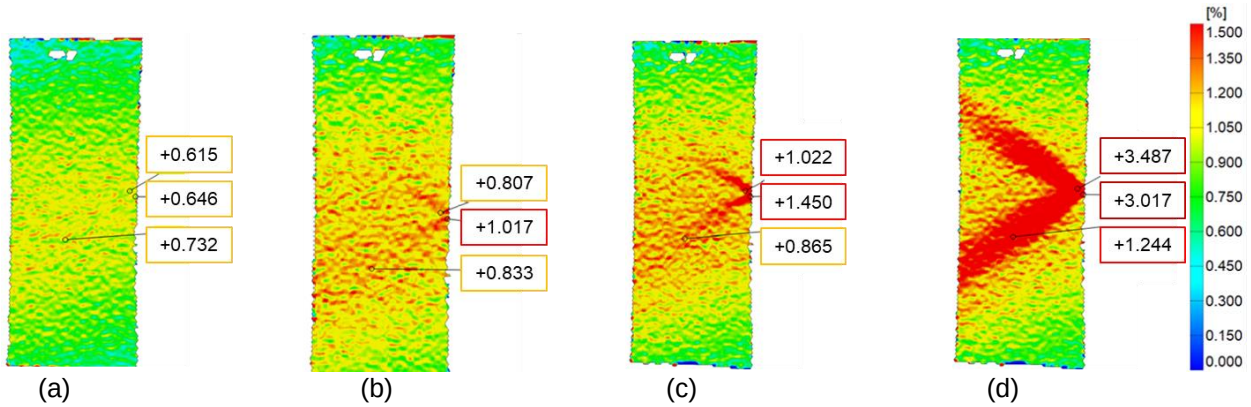

Fig. 1. DIC measurements performed for the stress amplitude equal to 500 MPa with unified scale after : 1 cycle (a); 100 000 cycles (b); 250 000 cycles (c); 301 251 cycles (d).