EVALUATION OF FATIGUE DAMAGE DEVELOPMENT SUPPORTED BY NONDESTRUCTIVE TECHNIQUE

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Abstract: *This paper presents an attempt to use the Electronic Speckle Pattern Interferometry (ESPI) and Digital Image Correlation (DIC) for damage evaluation and its monitoring on specimens made of the P91 steel and aluminide coated nickel super-alloys subjected to monotonic or cyclic loading.*

1. Introduction

In most cases, fatigue damage has a local character and it is based on damage development leading to generation of cracks appearing around structural defects or geometrical notches. An identification of these areas and their subsequent monitoring requires a full-field displacement measurements performed on the objects surfaces.

2. Results and discussion

In this work, a development of fatigue damage was investigated using destructive and non-destructive methods in materials commonly applied in power engineering or automotive industry. The fatigue tests for a range of different materials were interrupted for selected number of cycles in order to assess a damage degree induced. As destructive methods the standard tensile tests were carried out after prestraining due to fatigue. Subsequently, an evolution of the selected tensile parameters was taken into account for damage identification. The ultrasonic or magnetic techniques were used as the non-destructive methods for damage evaluation. In the final step of the experimental programme microscopic observations were performed. The results show that ultrasonic and magnetic parameters can be correlated with those coming from destructive tests. It is shown that good correlation of mechanical and selected non-destructive parameters identifying damage can be achieved for the materials tested.

The work additionally presents simulation of fatigue crack initiation for cyclic loading within the nominal elastic regime. It is assumed that damage growth occurs due to action of mean stress and its fluctuations induced by crystalline grain inhomogeneity and free boundary effect, Ustrzycka et al. [1]. The macrocrack initiation corresponds to a critical value of accumulated damage.

Fatigue investigations were carried out on the MTS 810 testing machine on plane specimens. These tests included specimens with three types of nickel alloy structure and with a layer thickness of 20 and 40 μm. Due to the continuous record of DIC displacement maps, the tests were performed at high stress amplitude values (600, 650 MPa), so as to shorten the test time to several hours. The load frequency was 20 Hz, and the image was recorded every 5 seconds, i.e. the map was recorded every 100 cycles. Figure 1 presents DIC images from selected fatigue cycles. The amplitude of the alternating stress was 600 MPa. The specimen broke after 46 364 cycles. The first signs of localization are visible after 45 thousands loading cycles. The increase in deformation at this stage is connected with the formation of a crack in the aluminide layer, which propagates into the material until the cohesion is lost. On this basis, the moment of crack formation can be estimated. Similar program was also carried out for P91 steel, however, in this case a damage development was analyzed using the ESPI system.

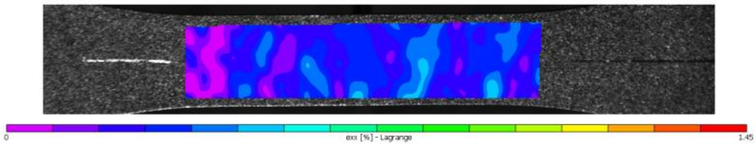
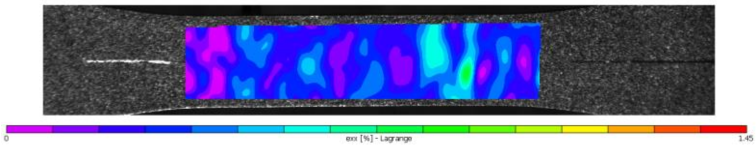
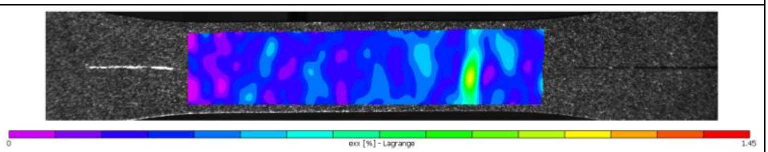
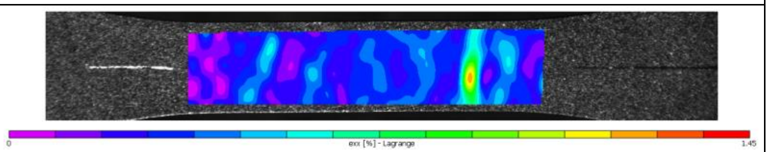
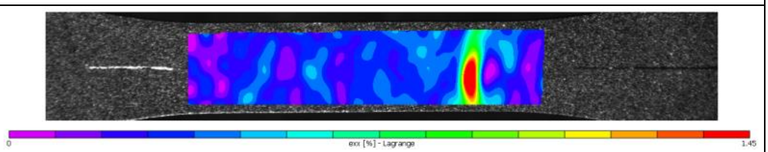
10 000 cycles	
45 000 cycles	
46 000 cycles	
46 100 cycles	
46 300 cycles	

FIGURE 1: Images from selected fatigue cycles obtained on specimen with layer thickness of 20µm

3. References

[1] Ustrzycka A., et al., Experimental analysis and modelling of fatigue crack initiation mechanisms, *J. Theor. Appl. Mech.*, **55**, 2017, pp. 1443-1448.

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