NEW EXPERIMENTAL ATTEMPTS IN FATIGUE DAMAGE ANALYSIS

Z.L. Kowalewski[1], P. Grzywna[1], D. Kukla[1]

[1]*Institute of Fundamental Technological Research, Polish Academy of Sciences, Pawińskiego 5B, 02-106 Warsaw, Poland*

Abstract

In most cases, fatigue damage has a local character and it is often 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 surfaces of objects taken into account. This paper presents an attempt to use the ESPI method for fatigue damage evaluation and its monitoring on specimens made of the aluminide coated nickel super-alloys and steels commonly used in the power engineering. Flat specimens were subjected to cyclic loading. The fatigue tests were interrupted several times in order to perform a static loading during which the optical measurements were carried out. An analysis of the results captured by the ESPI system allowed indication of places of the greatest stress concentration and demonstration of the damage development process as a function of the increasing number of cycles.

Observation of the fatigue fracture using the light microscope and SEM technique enabled identification of the layer cracks generated just before the decohesion of the specimens of the aluminide coated nickel super-alloys. In the microscopic damage analysis of tests carrying under fatigue conditions usually such damage sensitive strain parameters as the accumulated inelastic strain or accumulated mean strain level well describe a damage development in the subsequent loading cycles. They can be easily determined on the basis of hysteresis loops, [1,2]. In this case however, it has to be emphasized, that the effect observed during microscopic inspections could not be confirmed by the damage sensitive strain parameters mentioned above. Looking at the hysteresis loops representing strain evolution during subsequent cycles of loading, a process of the layer cracking was completely invisible. Detailed analysis of the fatigue test under cyclic loading at stress amplitude of 600 MPa was carried out using the deformation maps worked out by application of the ESPI technique.

All images documenting damage development were recorded by the system including the image after first cycle and several additional images representing different fatigue stages. Analysis of deformation maps enabled identification of strain concentration areas acted as crack growth initiators. One of them became to be dominant and led to the sample fracture. The field strain distributions along the Y axis corresponding to the acting stress direction in the specimen are presented in Figure 1. It shows strain distributions for different stages of the fatigue process, i.e. (a) in the first cycle; (b) after 50000 cycles.

In this work, also 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. As destructive methods the standard tensile tests were carried out after prestraining due to fatigue. Subsequently,

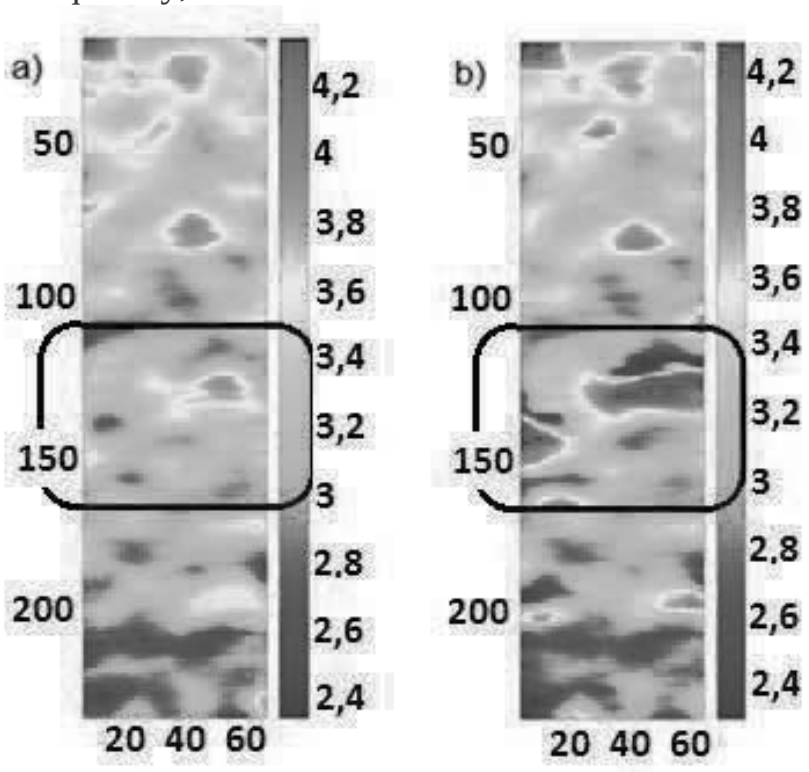

Fig. 1. The field strain distribution along Y axis corresponding to the acting stress direction. Measurements performed: (a) in the first loading cycle; (b) after 50000 cycles

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.

References

[1] G. Socha, Experimental investigations of fatigue cracks nucleation, growth and coalescence in structural steel. lnternational Journal of Fatigue 25(2), 139-147, 2003

[2] D. Kukla, Z. Kowalewski, P. Grzywna, K. Kubiak, Assessment of fatigue damage development in power engineering steel by local strain analysis, Kovove Materialy-Metallic Materials, ISSN: 0023-432X, 52, 5, 269-277, 2014

Authors

Zbigniew L. Kowalewski
e-mail address: zkowalew@ippt.pan.pl, tel.: +48-22-826 98 00

Paweł Grzywna
e-mail address: pgrzywna@ippt.pan.pl, tel.: +48-22-826 12 81 w. 431

Dominik Kukla
e-mail address: dkukla@ippt.pan.pl, tel.: +48-22-826 12 81 w. 262

Acknowledgements

The authors gratefully acknowledge the partial funding by the National Centre for Research and Development, Poland, under Program for Applied Research, grant no 178781, and National Science Centre, Poland, grant OPUS no 2014/15/B/ST8/04368