THE DEVELOPMENT DYNAMICS OF THE LOCATED FATIGUE FAILURE IN THE POROUS SILUMIN

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Introduction

Monitoring the phenomena related to the materials' fatigue as the process initiated locally requires the full-field observations of the displacement brought about by the fatigue strain. The Electronic Speckle Pattern Interferometry method enables to determine the distribution of displacement on the sample surface (retaining the stability of the measurement arrangement) and thus indicate the strain and also the stress concentration spots resulting from the defect (structural, geometrical one). It is also possible to assess the development of those distortions in consecutive fatigue cycles until the crack is formed and the sample decohesion takes place. The current measurement of displacements in their location zone enables to carry out a quantitative assessment of the fatigue failure development dynamics in the material evaluated.

Experimental Results

Using ESPI providing a field image of the displacement' distribution for studying samples made from porous silumin enabled to locate the initiation spot of the failure resulting from the cyclic stress and to monitor the development of such failure in the studied material. The porous silumin samples with the minimum cross-section of 18x4 mm were subjected to cyclic tensile stress with the value of 100 MPa, which constituted 64% of the yield point for this alloy. The images of the stress-related distortion distribution were recorded in 1, 2, 3, 5, 1000, 25 000, 100 000, 200 000 and 300 000 cycle using the static stress arrangement based on the manual hydraulic pump. It is impossible to record the images of the displacement during the dynamic stress application for the machine used to carry out fatigue tests, as the vibrations generated by the arrangement exceed ESPI measurement accuracy tenfold. The displacements were recorded for the growing tensile force in a chosen cycle according to the diagram shown in fig. 1. Due to the high stress-related shift values in the sample, it was necessary to carry out the measurements in seven steps, starting from 1.2 KN and ending with 7.2 KN, corresponding to the stress of 100 MPa.

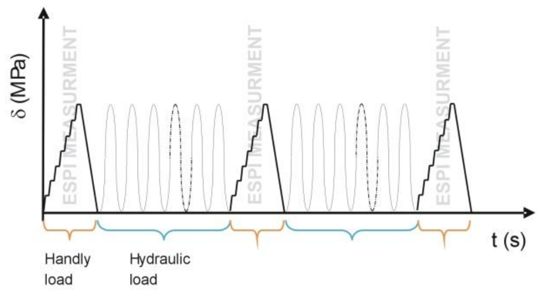

Fig. 1 Diagram presenting sample load in fatigue cycles

Observations of one sample surface showed the result of displacement location already in the initial stress cycles which is best visible on the displacement' maps in the force direction (fig. 2). The process developed in that spot until the sample cracked in 325 642 cycle. Figure 2 presents distortion images for 1, 50 000 and 300 000 cycle. For all those images the distribution strain in Y direction was determined along the X direction perpendicular to the sample axis in the strain concentration spot. On this basis the quantitative growth in the displacement recorded in consecutive tensile stress sequences was determined. The result is shown in diagram in fig. 2 where the change in the value of the maximum distortion obtained in consecutive cycles is presented. The observation of those changes proves that the local strain concentration after the first stress cycle remains stable for the next 200 000 cycles, and then the dynamics of its development rises dramatically, until the sample cracking in 325 642 cycle.

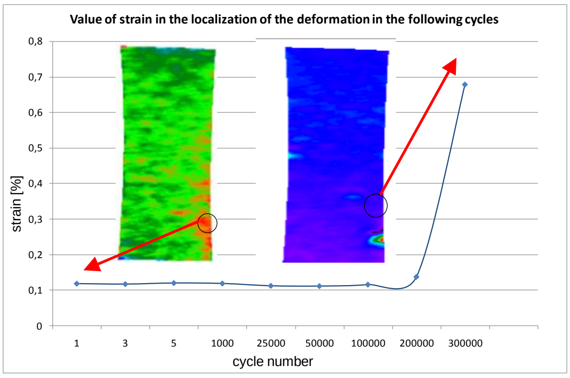

Fig. 2 Distortion location and its development in consecutive cycles

Quantitative changes in the strain values are shown by the sections made in its location spot from the first stress cycle to the 200 000 cycle (Fig.3)

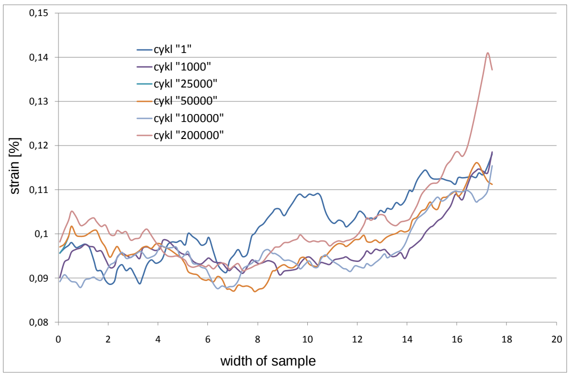

Fig. 3 Lateral profiles of strain changes in the cross-section with the maximum values.

For all the recorded fatigue cycles, the highest sample strain values are located at the right sample edge, where the failure was initiated. The profile for cycle 200 000 indicates the increase in the strain development in that spot. As can be seen in the microscope fractographic images (fig. 4), such a strain situation resulted from the stress concentration in the pore of over 200 μm. In the sample fracture surface numerous pores of similar size were detected (fig. 5), but the location at both sample edges enhanced the failure process initiation in that very spot. This is confirmed by fatigue fringes in various directions around the void (fig. 4).

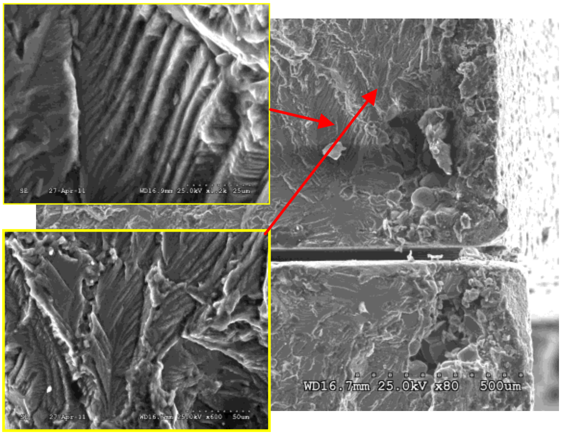

Fig. 4 Sample fracture with the pore visible on both parts and the close-up of fatigue fringes in its vicinity

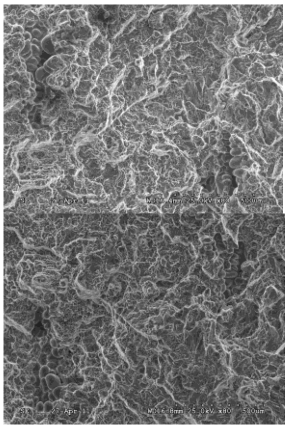

Fig. 5 Some of the numerous pores on the fracture surface

The fatigue process in the porous material such as the studied casting aluminium alloy demonstrates the strain location effect right in the initial stress cycles. This is brought about by numerous stress concentrators in the form of voids. The location effect may be observed, however, only when the voids initiating the fatigue process are located right under the surface and when the field observation methods are applied, such as ESPI.

References

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