The influence of low and high-cycle fatigue on dislocations density and residual stresses in Inconel 718

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The fatigue phenomena, as being one of the crucial importance for aircraft exploitation life and the passengers safety, was investigated with different methods for years. The one of the most important is to determine the fatigue state of the material and subsequently the moment of fatigue crack initiation. Many authors investigated the fatigue induced material structural transformations with different methods i.e.: scanning electron microscopy [1], electron transmission microscopy [2], [3], optical microscopy and two-beam interferometry [4] or / and with modelling [5], [6]. Nowadays, as the possibilities of diffraction methods with different types of radiation were developed, the conjoining of the diffraction image with the changes in the material structure can be applied to investigate the fatigue process in materials [7], [8], [9], [10].

The aim of this work is to find out the relationship between the stress and dislocation density evolution aplying the X-ray diffraction methods. The dislocations and the level of their density are responsible factors for the plastic deformation in metals [11]. They multiply and reorgznise during deformation and as a result of cyclic loading so their evolution can be a valuable information for investigation of fatigue strength.

The diffraction methods are the only one non-destrictive method for stress values investigations as well as one of highly versatile technique for quantitative analysis of grain level deformation [12]. In this study X-ray diffraction is employed to aquire the information about the evolution of elastic lattice strains and changes in dislocation density after fatigue cycling of Inconel 718 alloy. The one of the examined specimen is presented in figure 1.

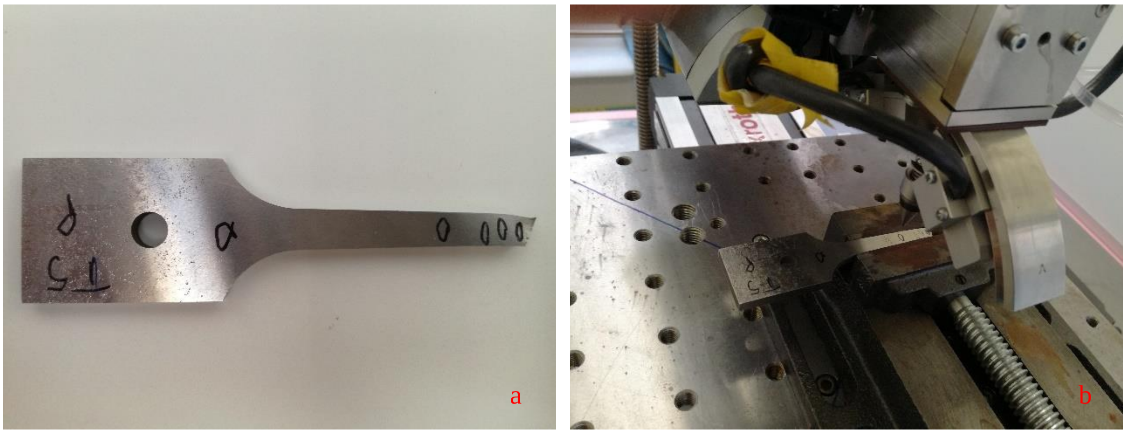

Figure. 1 a) The Inconel 718 specimen after fracture in fatigues test, and b) the same specimen during the X-ray diffraction experiment.

In principle the discusion of the experimental results concerns the fatigue lifing procedures. X-ray diffraction has been employed to asses the damage level under low and high cycle fatigue conditions. This evaluation was supposed to be performed by correlation of X-ray diffraction data with the microstructural changes in the material caused by various fatigue regimes. The objectives of the work were achieved by two X-ray diffraction techniques: the analysis of residual stresses changes after fatigue tests (figure 2a) and the description of changes of full width at half maximum (FWHM) of diffraction peaks which is a measure of dislocation changes density (figure 2b). The figures below present some exemplary changes of residual stresses and the changes in peaks braodening for different points of fatigue specimen after fracture.

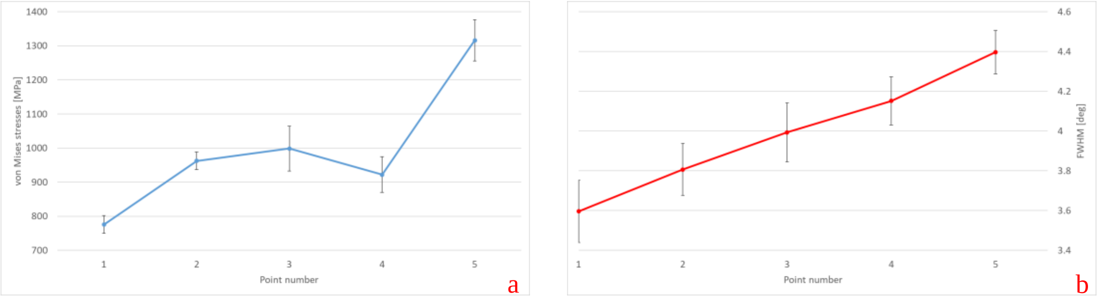

Figure. 2 a) Von Mises stress values and b) changes of FWHM values for different points with respect to the distance form the fracture.

The significant changes of both, the effective stress values as well as the changes of the diffraction peaks can be observed from figure 2. In the present paper a series of X-ray diffraction measurements on samples of Inconel 718 alloy and their results are presented. Thanks to that the successes and limitations of this approach could be discussed and moreover directions for further developments could be suggested.

Keywords: X-ray diffraction, dislocation density, fatigue test, diffraction residual stress measurements.

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