4.1.14. ASSESSMENT OF FATIGUE DAMAGE AND RESIDUAL LIFE TIME BY FRACTAL ANALYSIS OF THE DEFORMATION STRUCTURE

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Today's commercially available component surveillance systems to assess fatigue damage state and the prediction of the residual service life have a substantial drawback, since they require knowledge about the current material stage or load history. Hence, non-destructive testing (NDT) methods are desired that are able to estimate the fatigue life of component materials practically and reliably. Mesomechanics provides a new approach to evaluate materials damage based on the analysis of deformation structures during fatigue. Stress concentrators occur locally in inhomogeneous materials, which can cause a gliding process along net-plains, formation, and slip-bands, for example. These effects can be accompanied by a three-dimensional rotation of bordering materials, e.g. whole grains. As a result, new stress concentrators will be produced at locations far from the initial point of deformation. When the load process starts, translation-rotational processes are initiated on the microscopic structure level. Then, increasing loads or loading-time similar processes can be observed on higher structure levels, and new structural elements, such as vortices or glide bands may occur. Finally, this results in the development of hierarchical structures. A new NDE approach, based on the hypothesis that the deformation structure is of fractal nature and the corresponding fractal dimension D_F should be a suitable parameter to characterize structure variations at different damage stages is suggested. Various approaches have been discussed to determine this parameter experimentally.

Based on these ideas, a new non-destructive testing method estimating the residual service life of critical steel components has been suggested. This method determines the time-related scaling behavior of Barkhausen noise signals. The analysis of a significant number of materials provided promising results. Especially for ferritic steel components, a characteristic step-like dependence of the fractal dimension D_F as a function of the cyclic load number N divided by the cycle number to fracture N_B was found. An inspection system to estimate the material damage as well as residual life time using the above discussed principles has been developed and will be presented. Several industrial applications of the new approach will be discussed.