Fatigue Life Prediction Based on AMPS Strain-Life Approach

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Abstract

Fatigue damage occurs at stress/strain concentration points/zones when components are under cyclic loading, even when loads are much smaller than the material stress strength. Fatigue may eventually lead to a sudden fracture failure without warning after some duration. Many important fatigue studies have been performed to avoid unexpected loss, and numerous fatigue prediction methods have been proposed. From a microscopic view, fatigue comes from crack propagation and growth. Cracks normally start from stress/strain concentration points/zones mainly located on the surface of the components, and stress/strain conditions and material properties have great impact on fatigue life.

In the past, stresses of the concentration zone have been calculated by nominal stresses and multipliers such as stress concentration factors, and then the results are compared with the known stresses versus life data of the same material to get fatigue life estimate. With the help of finite element analysis (FEA), the use of multiplier is eliminated and replaced with much more accurate stresses from FEA analysis. Stress-Life Approach [1] is used in High-Cycle fatigue life prediction when stress is always lower than elastic limit. When stress of the critical zone is beyond the elastic limit, Stress-Life Approach may produce errors, and Strain-Life Approach should be adopted.

Strain-Life Approach mainly focuses on Low-Cycle fatigue life prediction cases in which components are loaded beyond yield strength. The method proposes that strain is the main cause for fatigue damage, and elastic strain and plastic strain have different effects on fatigue life. The method computes the strain history and mean stress of each reversal, and the number of reversals to failure for each reversal are calculated. After that, material damage is calculated using Strain-Cycle curve (Ɛ-N curve). The Ɛ-N curve is obtained by ideal tests where sets of nominal strains (Ɛ) and life (N) are recorded. When mean stress is non-zero, Morrow Correction is applied to quantify the impact of mean stress. The fatigue life can then be calculated by damage and load duration.

This paper details the research on Strain-Life Approach Fatigue FEA. The fatigue life is obtained based on stresses and strains calculated by Strain-Enriched Finite Element Analysis (Sefea)[2] developed by AMPS Technologies company. This paper introduces the philosophy of Strain-Life Approach and how to realize it by Fatigue FEA codes. It also discusses important issues of FEA application in fatigue life prediction, such as stress nodal/element averaging and S-N curves. Finally, the paper uses examples to compare FEA results with published simulations or test results.

Keywords: Fatigue; Finite Element Analysis; Strain Life Approach; Low-Cycle Fatigue.

References

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