Fatigue Life Prediction Based on AMPS Stress-Life Approach Fatigue FEA

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Abstract

Fatigue fracture is one of the most crucial failure types in mechanical design and occurs when components are in vibrating or corroding environments that cause small cyclic loads for extended durations. The "small load" leading to fatigue is far below the level of load required to cause failure with one time application. On the microscopic level, fatigue results from crack production and growth. Normally, a crack in the component starts from a critical zone, where there may be a concentration of stress/strain In most cases, it starts from the surface of the component. Local parameters around the critical zone such as stress magnitude, mean stress, and material properties have great impact on fatigue life. Much research and many experiments have been conducted to predict fatigue life, and both simple and sophisticated approaches exist for fatigue analysis and life estimation.

In traditional fatigue analysis, stresses of the critical zone are calculated as the product of nominal stresses and various multipliers such as stress concentration factors. These calculated stresses are then compared with known amplitude stresses with material data which is acquired by tests. Because finite element analysis (FEA) is capable of accounting for local stresses, the use of multipliers in traditional fatigue analysis can be eliminated. With the help of FEA, designers can quickly find stress/strain distribution and stress/strain history in complex cases. By utilizing these FEA results and other user input data, fatigue life calculation codes can generate fatigue life and point out critical zones. Thus is born Fatigue Finite Element Analysis (Fatigue FEA) approach, and it has become a routine in fatigue life design.

Stress-Life Approach[1] is one of the oldest and the most frequently used methods of fatigue analysis. It has been widely adopted for years, and its effectiveness has been confirmed, especially for High-Cycle fatigue life prediction, where a component stays below elastic limit during its service life. Stress-Life Approach does not deal with crack production and growth at all. It assumes that there are certain relationships between the situation of stresses and the expected life, so life can be calculated based on stress history and Stress-Cycle curve (S-N curve). The S-N curve is obtained from ideal tests where sets of nominal stresses (S) and life (N) are recorded, and then log of nominal stresses are plotted against log of life. When mean stress is non-zone, Goodman Relation is applied to quantify the interaction of mean and alternating stresses.

This paper presents research on Stress-Life Approach Fatigue FEA. The fatigue life is calculated based on stresses acquired by Strain-Enriched Finite Element Analysis (Sefea) Technology[2]. This paper introduces the philosophy of Stress-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; Stress Life Approach; High-Cycle Fatigue.

References

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