8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

EFFICIENT METHODS FOR HIGH CYCLE FATIGUE ASSESSMENT OF COMPONENTS CONTAINING DEFECTS

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Key Words: *High Cycle Fatigue, Defects, Damage Tolerant Design, Residual Stress Field, Finite Element Postprocessing*

ABSTRACT

Traditionally, dimensioning of machine components against the endurance limit has been based either on nominal or on local stresses. There, the effect of stress concentrations on the endurance limit is accounted for by gradient or averaging (critical distance) approaches; superimposed mean stresses are taken into account via the mean stress dependence of the admissible stress amplitude obtained from the Haigh diagram. This concept is well proven and widely used by design engineers.

However, some limitations arise

- for very sharp notches, where the predictions of the gradient approach become increasingly less accurate as the notch root radius becomes smaller;
- for the effects of initial flaws resulting from the production process, such as forging flaws, oxide skins or gas pores; and
- when accounting for the beneficial effects of residual stresses from thermo-mechanical surface treatments, where a mere mean stress correction has been found to give unsatisfactory results.

By discussing the non-propagating condition of a crack situated at the root of a structural notch, these problems may be overcome effectively [1]. The crack may be present in reality, such as cracks from quenching after thermal surface treatments, or forging flaws; or it may be assumed to be of the size of an intrinsic microstructural length scale, building a bridge to classical averaging (critical distance) approaches for computing the fatigue notch factor and the notch sensitivity of the fatigue strength, respectively.

Here, the case where the length scale of an actual defect approaches the intrinsic length scale characteristic of a material’s fatigue behavior is of particular interest. Traditional fatigue assessment methods are based on the assumption that both length scales are sufficiently different. However, if one aims at applying damage tolerant design approaches to surface-treated components, this assumption is no longer valid.

The present paper aims, in particular, at proposing efficient methods

- for estimating the endurance limit at any material point of a component if the loading, residual stress distribution and the distribution of flaws are given, and
- for estimating the admissible flaw size at any material point of a component if the loading and residual stress distribution are given.

To this purpose, the present work relies on previous work concerning a modified Haigh-Goodman diagram for flawed components based on the approximation by El Haddad for the crack growth threshold diagram, taking into account the influence of the stress ratio on the fatigue limit of the unflawed material as well as on the linear-elastic crack growth threshold [2]. The modified Haigh diagram uses a minimum of easily obtainable material parameters and permits an easy application of damage tolerant design concepts when dimensioning for infinite fatigue life, but has so far been restricted to homogeneous stress states.

The extension to inhomogeneous stress states is performed by means of a Green's function concept [3]. To this purpose, an approximate analytical description of the structural stresses near arbitrary stress concentrations [4] as well as of the residual stresses is fitted from nodal, or integration point, results from finite element simulations of the component under investigation. The use of results from submodels at different length scales is also possible by these means.

An implementation of this method into a finite element postprocessing software is presented, along with practical applications.

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