Improvements in Stress – Life Approach for Fatigue Damage Assessment of Steel Structures and Components

by

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ABSTRACT

Fatigue is a common problem in steel structures and components when they are subjected to cyclic loading. Fatigue assessments require testing. As fatigue testing (cyclic testing) is costly and time consuming, analytical models with a few monotonic tests are usually used for fatigue assessments. However, still there are areas in fatigue studies where not enough research has been done. Therefore, some of these research areas were studied to close existing research gaps and to solve the problems in metal fatigue to some extent. The main fatigue areas studied were: very high cycle fatigue (VHCF); full range stress – life models (S-N curves); nondestructive methods for developing full range S-N curves; effects of corrosion on full range S-N curves and fatigue damage assessment procedures for steels.

First, a simple strength based model was proposed for predicting the critical size of fracture origins after an extensive study on very high cycle fatigue of steels. Experimental fatigue data of a number of various steels were used in this study. Then, using the proposed model and existing S-N relations, a new fatigue strength prediction formula was proposed for the very high cycle fatigue region (new VHCF model). The applicability of the new VHCF model for low carbon structural steels was verified using laboratory fatigue testing.

Next, a model for a full range S-N curve was proposed for steels using the new VHCF model, existing low and high cycle stress life relationships and a mathematical function. This S-N model proposed (new full range S-N model) describes the entire stress and cycle range from the 1st cycle to very high cycles (gigacycles). The new full range S-N model was verified using experimental fatigue data of seven medium strength steels. Salient features of the new full range S-N model are that it requires only monotonic strength and hardness properties of steels to predict the S-N curves of steels.

Highlighting the importance of nondestructive methods for damage assessments, a nondestructive full range S-N model for steels was proposed using the new full range S-N model. Material hardness was used as the only nondestructive test parameter in this model (hardness based S-N model). The hardness based S-N model too was verified using experimental fatigue data of seven medium strength steels. This hardness based S-N model is

special because it only requires material hardness for predicting the S-N curve and that it is able to describe the entire fatigue range from the 1st cycle to gigacycles fairly accurately.

Corrosion is unavoidable in most structures and components exposed to a corrosive atmosphere. Therefore, the new full range S-N model was modified to take into account the effects of corrosion (corrosion based S-N model). The corrosion based S-N model was verified using three medium strength steels tested in laboratory. Apart from hardness and strength parameters, the only parameter required to predict a full range S-N curve using this model is the fatigue strength of the steel in the high cycle region in the corrosive media.

The S-N models proposed in this study are equivalent to axial, fully reversed, constant amplitude mean S-N curves. Therefore, modifications are necessary for the proposed full range S-N models when using them in real structures with various geometries and loading conditions. Therefore, a new damage assessment procedure was proposed using existing damage assessment methods. This new procedure takes into account the stress concentration effects, different cyclic loading ratios and variable amplitude loading. The proposed assessment procedure was verified using experimental fatigue data. Finally, a connection detail of a steel bridge was used as a case study to show the efficiency of the proposed damage assessment procedure and S-N models against the methods used in design codes.

Keywords: *Fatigue, Steel, Damage assessment, Stress – life model, Tensile strength, Hardness*