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PREDICTING THE FATIGUE LIFE OF NOTCHED COMPONENTS BY LOCAL STRESS CONCEPT: A CLOSED-FORM MODEL BASED ON RELATIVE STRESS GRADIENT

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As it is well known, notches involve stress concentration and a detrimental effect on fatigue. A locally higher fatigue strength can be observed at the notch root. This phenomenon is commonly regarded as the support effect and is confirmed by many experimental studies, mainly by German and Austrian scholars. From the quantitative point of view, this can be expressed as the ratio between the local fatigue limit and the fatigue limit of a smooth specimen (for an axial load). For beams, it is the Kt/Kf ratio (stress concentration factor over the fatigue notch factor). When fatigue involves non-beam structures, for which the aforementioned coefficients cannot be properly introduced, a local fatigue curve must be considered, which makes it possible to scale the material's nominal fatigue resistance (determined by lab testing on specimens) to the actual geometry of the component. This curve can be related to the actual stress distribution through the relative stress gradient (RSG) at the notch. Then, the peak stress at the root can be directly compared to the local fatigue strength to determine the safety coefficient or the expected lifespan.
Siebel and Niemann proposed some formulas based on the actual value of the RSG. However, the estimation of the support effect is generally quite coarse. Eichlseder has proposed a more refined model that makes it possible to interpolate and extrapolate the local fatigue strength through fatigue testing of two different specimen sets under axial and bending loads. Performing tests in these two loading conditions makes it possible to account for two different RSGs (in particular, 0 and 2 over the sample diameter). However, two different testing machines are needed. Furthermore, these values are very close and an extrapolation is often required, which entails inaccuracy. Moreover, the slope of the local fatigue curve is not easy to determine and can also be affected by inaccuracies. Another model has been recently put forward by Zhou et al.: it is essentially a follow-up of the Siebel model and is much more accurate. However, a set of numerical simulations is needed, and the expected lifespan must be iteratively determined, case by case, based on the actual stress level. Olmi et al. developed (in 2013) a modified model, where the local fatigue strength for a given material was interpolated through datasets under the same load type (rotary bending) for different notches and RSGs, over a sufficiently wide range. For this purpose, three sets of specimens with smooth, shallow-notched and sharply-notched geometries can be used. This formulation has been revisited and completed here. A closed-form analytical model makes it possible to work out the local fatigue curve for any value of RSG and for any number of cycles in the investigated range. Moreover, the model can be calibrated through three or just two datasets of specimens with different RSGs. The local fatigue limit for infinite life can be determined as well. Thus, it can be used for the fatigue assessment of whatever non-beam geometry of components made of the investigated material. This method has been applied to different metallic materials, including normalized C40, quenched and tempered 42CrMo4, an Al alloy, and Spheroidal Cast Iron. The model has been successfully validated by comparisons of the predicted lifespans to experimental ones based on own and literature experimental campaigns (errors in the logarithmic scale generally lower than 10%).

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