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Utilizing the theory of critical distances in conjunction with crystal plasticity for low-cycle notch fatigue analysis of S960 MC high-strength steel

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Abstract:

In the current study, the elastoplastic reformulation of the theory of critical distances (TCD) is used for low-cycle fatigue analysis of round specimens with circumferential notches made of a direct-quenched high-strength steel. An attempt is made to investigate the effect of microstructural heterogeneity (which is absent in empirical notch analysis methods) on the estimation capability of the TCD approach by embedding microstructural features in the numerical analysis model. To this end, the originally proposed reformulation of TCD for the low-cycle fatigue regime was modified by utilizing a numerical model equipped with the constitutive equations of crystal plasticity for the critical zone of the notch root. Necessary experimental tests and microstructural measurements were performed to enable tuning of the parameters of the crystal plasticity formulation and implementation of the numerical model. In order to keep the complexity of the model at a reasonable level compared to its original form, and to sustain its general applicability, some hypotheses and simplifications were made in implementation of the numerical model, especially in presentation of the grain morphology and post-processing of the results. The current analysis highlights the effect of the material's microstructural features on the fatigue analysis approach under investigation and its main parameter, the material characteristic length. It was seen that conservative estimations of low-cycle fatigue life observed for sharper notches of the material when using conventional TCD fatigue life analysis were slightly improved when material characteristic length calculated with the crystal plasticity-embedded numerical model was used.

Keywords: Crystal plasticity; Finite elements; Critical Distances; Notches; High-strength steel