Numerical critical-damage load order model to predict fatigue crack growth under variable amplitude loads

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The critical damage model developed in [1] uses physically-based hypotheses that don't need any fitting parameter: crack tips recognized as sharp notches with variable radii depending on the CTOD induced by each load cycle under VAL; crack growth steps with variable increments; distributed damage ahead of the crack tip; fracture of the element adjacent to the crack tip due to the fatigue damage it accumulated during its entire life; and notch-tip strain concentration effects described by a proper rule, depending on the dominant stress state around the crack tip. But that model cannot deal with sequence effects under VAL at lower **R**-ratios, if crack closure behind the crack tip can significantly affect the residual stress profile ahead of the crack tip.

A more general model is proposed here, using strip-yield routines to calculate cycle-by-cycle the stress and strain profiles both *before* and *ahead* of the crack tip and accumulate damage *ahead* of the crack tip based on the current stress and strain profiles, considering eventual crack closure effects. A real-time **εN** algorithm [2] takes care of rainflow counting, to obtain $\Delta\varepsilon$ and σ_m (or σ_{max}) in each material element at each load cycle. Contrary to the strip-yield model [3], crack extension does not require an empirical **da/dN** equation that is a function of ΔK_{eff}. Instead, crack extension is a result of the material elements that reach the critical fatigue damage specified by Miner's or any other damage accumulation rule, properly applied to **εN** procedures considering memory effects. The cycle-by-cycle interaction between strip-yield and critical damage routines is then be able to consider both closure and residual stress effects in the same numerical model: closure reduces the strain range $\Delta\varepsilon$ calculated at each material or volume element ahead of the crack tip for each counted cycle, while residual stresses mainly affect the associated peak stress σ_{max}. Since the strip-yield routines are able to calculate stresses and strains, both before and ahead of the crack tip, both closure and residual stress effects (and their mutual interaction) can be accounted for with this sensible methodology. The main advantages of this combined *critical-damage-strip-yield* approach are: (i) it does not need Elber's assumption that cracks never grow while closed or partially closed, as in the original version of the strip-yield model; (ii) both closure and residual stress effects are considered, including their mutual interaction.

[1]