Time and space multiscale modeling of the high cycle fatigue of thermoplastic polymer solids and structures

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The prediction of the high cycle fatigue (HCF) of solids and structures made of thermoplastic polymers faces a double challenge because those materials continue to dissipate energy and exhibit a frequency dependent response even under large numbers of cycles. On the one hand classical simplified methods based on linear elasticity are not applicable, and on the other hand direct structural analyses are so computationally prohibitive that they are not possible in practice. We propose a so-called hybrid formulation, which is theoretically sound, experimentally motivated and computationally efficient [1]. The microstructure is viewed as being made of a viscoelastic (VE) matrix phase with small concentrations of process-induced pores and viscoelastic-viscoplastic (VEVP) weak spots, which have almost no visible influence on the structural response but are responsible eventually for fatigue failure. The structure is first computed as being VE, using a formulation enabling to compute accurate strain and stress fields at a very reduced cost, which is also independent of the number of cycles [2]. Next, the full VEVP solution at any points of interest is computed with a time homogenization formulation which uses fast and slow time scales and asymptotic time expansions to compute complete solutions at extremely limited cost [3]. The space homogenization of the heterogeneous microstructures is performed via an incremental-secant mean-field homogenization model [4]. HCF is thus modeled via a combined time and space multiscale formulation [*in preparation*]. The number of cycles to failure at the macroscale is predicted when microscale damage in the weak spots reaches a critical value. Predictions of the hybrid formulation are compared against full reference solutions and their accuracy verifed. Numerical simulations for one million cycles are presented and the low computational cost of the hybrid formulation illustrated. First comparisons of HCF predictions against experimental results are presented.

References

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