FFT based accelerated fatigue computation using wavelet transformation based

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Abstract

The context of our study is to numerically quantify the influence of the microstructure on the fatigue life dispersion (Pineau et al. 2016) for a metal or an alloy for regimes ranging from low-cycle fatigue to lifetimes of the order of *10^5*, *10^6* cycles. One of main obstacles, is the computational cost. Solving numerically a fatigue problem, considering high-cycle fatigue, could yield a huge computational cost if not impossible. An accelerated approach has to be considered and it is the main object of the present work. In the literature, the most efficient fatigue simulation acceleration method is the "WATMUS" algorithm (Wavelet Transformation based Multi-time Scaling) (Ghosh et al. 2021). It is based on the combination of two approaches: (1) cycle jump and (2) wavelets transformation (a temporal transformation).
The concept of the cycle jump is to perform an incremental calculation (fine timescale) on one cycle, then skip a certain number of cycles (through an extrapolation scheme) instead of proceeding directly to the next one. It means that the evolution of internal state variables needs to be expressed as a function of the cycle number (cycle timescale). The wavelets transformation (Walker 2008) intervenes in the incremental calculation of each cycle. It provides an orthogonal basis that, in a cycle, separates the different timescales. Applied on the displacement, the so-called "coefficients of displacement" (coefficients of the wavelet transformation) allows expressing the variation of the displacement in cycle timescale. The equilibrium equations will be projected in this basis. The resolution is performed with respect to the "evolving coefficients". In other words, the solution is established considering Nc coefficients in wavelet basis instead of considering Nt solutions in time (where $Nc < Nt$) which could lead to gain in computing efficiency. This is possible because, from one cycle to the next, the solution does not evolve on certain timescales. The results obtained in the literature show that a high number of cycles, up to cycles, can be achieved at a reasonable computational cost.

The WATMUS approach has been applied so far exclusively within the framework of the finite element method (FEM). In the present study, WATMUS is implemented in FFT framework (Moulinec et al. 1994). Indeed, FFT methods have become a fundamental tool (Lucarini et al. 2021) for micromechanics due to the numerical efficiency of these solvers. Until now, it has gained a lot of maturity by becoming more precise and more versatile for several applications. In the context of this study, the performance of spectral methods may provide better efficiency than with FEM. Using the basic scheme of Moulinec & Suquet, we show that the equations are established in a more straight-forward manner comparing to FEM.

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The efficiency and reliability of the approach will be tested on several examples: a simple 1D elasto-visco-plastic problem and a more complicated 3D problem for polycrystalline aggregates where the Meric-Cailletaud crystal plasticity model (Méric et al. 1991) is used.

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