Invitation à la soutenance publique de thèse

Pour l’obtention du grade de Docteur en Sciences de l’Ingénieur

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Master de recherche en génie mécanique

Time and space (4D) homogenization for viscoelastic-viscoplastic solids under large numbers of cycles

The principal objective of this thesis is to predict the response of inelastic materials under a large number of cycles, while simulating a much smaller number.

For coupled viscoelastic-viscoplastic (VE-VP) homogeneous solids subjected to large numbers of cycles, a two-scale time homogenization formulation and the corresponding algorithms are proposed. The main aim is to predict the long time response while reducing the computational cost considerably. The method is based on the definition of macro and micro-chronological time scales, and on asymptotic expansions of the unknown variables. First, the VE-VP constitutive model is formulated based on a thermodynamical framework. Next, the original VE-VP initial-boundary value problem is decomposed into coupled micro-chronological (fast time scale) and macro-chronological (slow time-scale) problems. The former is purely VE, and solved once for each macro time step, whereas the latter problem is nonlinear and solved iteratively using fully implicit time integration. For micro-scale time averaging, one-point and multi-point integration algorithms are developed. Several numerical simulations on uniaxial and multiaxial cyclic loadings illustrate the computational efficiency and the accuracy of the proposed methods.

For composite materials, a multiscale computational strategy is proposed for the analysis of structures, which are described at a refined level both in space and in time. The proposal is applied to two-phase VE-VP composite materials subjected to large numbers of cycles. The main aim is to predict the effective long time response while reducing the computational cost considerably. The proposed computational framework is a combination of the mean-field space homogenization based on the generalized incrementally affine formulation for VE-VP composites, and the asymptotic time homogenization approach for coupled VE-VP homogeneous solids under large numbers of cycles. The time homogenization method is based on the definition of micro- and macro-chronological time scales, and on asymptotic expansions of the unknown variables. Firstly, the original anisotropic VE-VP initial-boundary value problem of the composite material is decomposed into coupled micro-chronological (fast time scale) and macro-chronological (slow time-scale) problems. The former corresponds to a VE composite, and is solved once for each macro time step, whereas the latter problem is a nonlinear composite and solved iteratively using fully implicit time integration. Secondly, mean-field space homogenization is used for both micro- and macro-chronological problems to determine the micro- and macro-chronological effective behavior of the composite material. The response of the matrix material is VE-VP with $J_2$ flow theory assuming small strains. The formulation exploits the return-mapping algorithm for the $J_2$ model, with its two steps: viscoelastic predictor and plastic corrections. The proposal is implemented for an extended Mori-Tanaka scheme for a number of polymer composite materials subjected to large numbers of cycles.

An extension of the two-scale time homogenization approach to VEVP homogeneous materials coupled with ductile damage (VE-VP-D) under large numbers of cycles is proposed. An asymptotic approach allows to decouple the boundary problem into macro-chronological and micro-chronological problems. A different multiscale decomposition is introduced to account for irreversible inelastic deformation. The method is applied to the fatigue of thermoplastic polymers.

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