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Coupling crystal plasticity and continuum damage mechanics for creep assessment in super-critical steam-turbine material

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To improve design and safety of super-critical steam-turbine components, long-term high-temperature creep behaviour of a turbine material, such as Cr-based alloy, should be studied carefully. It is well known that turbine components undergo material degradation and premature failure by nucleation, growth and coalescence of microcracks and microvoids as a result of creep damage.

In classical crystal-plasticity-based constitutive models, a flow rule and hardening equations do not have any mechanism to account for global stiffness degradation due to evolving microvoids and microcracks, especially under large deformations. In this study, an anisotropic creep-damage effect on overall deformation behaviour is considered by coupling a crystal plasticity model with a suitable continuum damage model [1]. Damage evolution is derived within a thermodynamic framework, which was proven to be suitable for Cr-based alloys. The coupled model is implemented into the ABAQUS finite-element code by using a user subroutine VUMAT [2]. Numerical simulations show that the developed approach can characterize creep deformation of a super-critical steam-turbine material exposed to a range of different temperatures.

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