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# A Mixed 3D Finite Element for Highly Deformable Thermoviscoplastic Materials Under Ductile Damage

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**Abstract :** In this work, a mixed 3D finite element formulation is proposed in order to analyze thermoviscoplastic materials under large strain levels and ductile damage. To this end, a tetrahedral element of linear order is employed, considering a thermoviscoplastic constitutive law together with the neo-Hookean hyperelastic relationship and a nonlocal Gurson`s porous plasticity theory The material model is capable of reproducing finite deformations, elastoplastic behavior, void growth, nucleation and coalescence, thermal effects such as plastic work heating and conductivity, strain hardening and strain-rate dependence. The nonlocal character is introduced by means of a nonlocal parameter applied to the Laplacian of the porosity field. The element degrees of freedom are the nodal values of the deformed position, the temperature and the nonlocal porosity field. The internal variables are updated at the Gauss points according to the yield criterion and the evolution laws, including the yield stress of matrix, the equivalent plastic strain, the local porosity and the plastic components of the Cauchy-Green stretch tensor. Two problems involving 3D specimens and ductile damage are numerically analyzed with the developed computational code: the necking problem and a notched sample. The effect of the nonlocal parameter and the mesh refinement is investigated in detail. Results indicate the need of a proper nonlocal parameter. In addition, the numerical formulation can predict ductile fracture, based on the evolution of the fully damaged zone.

**Keywords :** mixed finite element, large strains, ductile damage, thermoviscoplasticity
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