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A COUPLED THERMOMECHANICAL FINITE ELEMENT MODEL: APPLICATION TO THERMAL ENERGY STORAGE SYSTEMS

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Solar Thermal Electricity (STE) power plants have become an interesting and economic alternative to conventional generation plants, which largely depend on the use of finite natural resources. A fundamental role within the former plants is played by the so-called thermal energy storage (TES) systems, whose main purpose is the balance in the energy demand, especially during the night time. However, the economic viability of TES systems is subjected to the stability of the materials properties of the chosen storage media [1]. In this sense, solid media-based systems (e.g., rock, concrete, or sand) present interesting features in terms of storage capacity and material stability. Therefore, it is of great interest their long-term characterization in order to assess their economic feasibility.

Thermal energy storage is a multiphysical problem that can be tackled with numerical tools, such as the finite element method (FEM). Moreover, in the case of solid media, the thermal and mechanical problems are strongly coupled. In this work, we present a continuum-based damage model, within the FEM framework, to characterize the performance of solid media TES systems. The model presented herein accounts for the loss of conductivity due to mechanical damage (i.e., cracking) through the definition of a thermal damage variable. An explicit-implicit integration scheme, which couples the thermal and mechanical problems via temperature-dependent material properties and thermal strain variable, is followed.

The developed model is applied in the performance assessment of concrete TES modules. The material heterogeneity is taken into account the different phases present at the mesoscale of concrete, including the interface transition zones. From the results, it can be observed that the increase in temperature, especially during the first heating cycle, leads to the pipe debonding, creating a thermal barrier whose effect is an increase of the temperature gradient and thus an increase of the thermal stresses. The apparition of cracks promotes a redistribution of the temperature field, and eventually leading to a radial cracking distribution, which is in agreement with experimental observations [2].

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