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Rock-Bed Thermocline Storage: A Numerical Analysis of Granular Bed Behavior and Interaction with Storage Tank

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Abstract : Thermal Energy Storage (TES) systems are central elements of various types of power plants operated using renewable energy sources. Packed bed TES can be considered as a cost–effective solution in concentrated solar power plants (CSP). Such a device is made up of a tank filled with a granular bed through which heat-transfer fluid circulates. However, in such devices, the tank might be subjected to catastrophic failure induced by a mechanical phenomenon known as thermal ratcheting. Thermal stresses are accumulated during cycles of loading and unloading until the failure happens. For instance, when rocks are used as storage material, the tank wall expands more than the solid medium during charge process, a gap is created between the rocks and tank walls and the filler material settles down to fill it. During discharge, the tank contracts against the bed, resulting in thermal stresses that may exceed the wall tank yield stress and generate plastic deformation. This phenomenon is repeated over the cycles and the tank will be slowly ratcheted outward until it fails. This paper aims at studying the evolution of tank wall stresses over granular bed thermal cycles, taking into account both thermal and mechanical loads, with a numerical model based on the discrete element method (DEM). Simulations were performed to study two different thermal configurations: (i) the tank is heated homogeneously along its height or (ii) with a vertical gradient of temperature. Then, the resulting loading stresses applied on the tank are compared as well the response of the internal granular material. Besides the study of the influence of different thermal configurations on the storage tank response, other parameters are varied, such as the internal angle of friction of the granular material, the dispersion of particles diameters as well as the tank's dimensions. Then, their influences on the kinematics of the granular bed submitted to thermal cycles are highlighted.

Keywords : discrete element method (DEM), thermal cycles, thermal energy storage, thermocline
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