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 of a tank filled with a granular bed through which a heat-transfer fluid circulates. However, in such devices, the tank might be subjected to an accumulation of thermal stresses during cycles of loading and unloading due to the differential thermal expansion between the filler and the tank wall. This research was devoted to investigate the thermo-mechanical behavior of the granular bed inside a packed bed TES tank. To achieve this objective, two approaches were undertaken in this work, i.e. numerical and experimental. A numerical model was defined to describe the tank's behavior under thermal cycling based on the discrete element method (DEM). The evolution of tank wall stresses over thermal cycles, taking into account both thermal and mechanical loads, as well as the kinematics of the granular material at the particles scale (i.e. discrete elements), are studied here. The deformability of the tank itself under thermo-mechanical loads is also included in the numerical model. Simulations were performed for different thermal configurations (i.e. the tank is heated homogeneously along its height or with a moving vertical gradient of temperature) and different boundary condition cases (i.e. rigid wall, tank wall with a higher thermal expansion coefficient than the bed or inversely). The behavior of the tank is dependent on the imposed thermal and boundary conditions. In addition to this, a thermocline prototype was designed and constructed at the CEA laboratory, aiming at studying the stress accumulation over the thermal cycles. The experimental setup, called ESPERA, is equipped with force measurement devices, installed at different height positions on the wall. The force measurement devices were developed and calibrated at the CEA. Their sensitivity was also tested using a different developed setup, P'tit-Pousse. Experimental tests were carried out proving the stress accumulation over the cycles. Eventually, a comparison between the numerical results and the lately-obtained preliminary experimental measurements is proposed.

keywords: Thermal energy storage (TES), Discrete Element Method (DEM), thermal stresses, granular material, experimental tests.