Modelling thermal performance degradation of high and low-temperature solid thermal energy storage due to cracking processes using a phase-field approach

Solid heat storage is an attractive solution for a wider utilisation of solar power for domestic and commercial applications alike. Thermal efficiency and long-term stability are of major concern both scientifically and industrially. There are many aspects that influence the thermal performance of a specific solid thermal energy storage (TES), such as the energy storage capacity of its storage material, the characteristics of its heat transfer fluid, and the mechanical integrity of the solid storage medium. In the present study, we develop a thermo-mechanical phase-field approach to fracture in order to examine the thermal performance degradation of the solid sensible heat storage (SHS) caused by potential thermally induced cracking of the heat storage medium around the embedded heat exchangers. Two representative solid SHS structures are examined: one applied in a low-temperature setting, the other used at high temperature levels. In both cases, fracturing caused by the mismatch of thermal expansion coefficients of the storage medium and the heat exchanger occurs under certain conditions. The open fractures form a space that will be filled by a fluid whose nature is determined by the system concept and which may well have a low thermal conductivity. Hence, heat transfer can be disturbed in the damaged regions, causing high temperature anomalies, which further may lead to significant fluctuations/loss of heating power during the heating phase. In the two specific scenarios investigated here, the highest loss of heat flow was estimated to be 7.7% in the water-saturated low-temperature SHS and 20.5% in the high-temperature SHS.