Mechanistic modeling of pre-pyrolysis fracturing of oil shale due to thermal stress

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Permeabilities of Green River oil shale are not sufficient, without fracturing, for hydrocarbon fluid to migrate into nearby pathways such as boreholes or open fractures connected to boreholes. Thus understanding the fracturing process and fracturing patterns is critical to reliably predict the permeability evolution during in situ retorting of oil shale. The overall objective of this research is to develop a better fundamental understanding of the pre-pyrolysis fracturing process due to the buildup of thermal stress through physics-based modelling and simulations. In this study, we coupled a discrete element model (DEM) for explicitly simulating rock mechanical deformation, fracture initiation and fracture propagation with a heat conduction model and applied the coupled thermal-DEM model to study the pre-pyrolysis thermal fracturing process. While conventional continuum-mechanics based models provide important information about the spatio-temporal evolutions of stress and strain fields (only valid prior to fracturing), a fundamental challenge is the difficulty of reliably simulating fracture initiation and fracture propagation. The DEM model is calibrated to represent mechanical properties of oil shale including Young's modulus, Poisson ratio, compressive and tensile strengths. The calibrated thermal-DEM model is then used to perform sensitivity studies of thermal expansion coefficient, tensile strength, anisotropy and confining boundaries on the fracturing process. The simulation results indicate that pre-pyrolysis fracturing of oil shale is possible. Under certain conditions, it is possible to develop a large number of microcracks, and to form fracture networks throughout the rock sample. Weak layers of oil shale (i.e., more ductile with smaller Young's modulus) limit fracture propagation. The results also call for a more thorough study of the thermal-fracturing process using more realistic representation of anisotropy of oil shale, temperature dependent thermal-mechanical properties and representative in situ stress.