Passive Seismic and Surface Deformation Monitoring of Steam Injection

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Abstract/Excerpt

Steam injection for reservoir stimulation is an important factor for economic development of heavy oil reservoirs. Monitoring the steam chamber growth is critical to optimize the heavy oil recovery, to target the stimulation of the reservoir and identify bypassed regions. Steam injection results in geomechanical strains associated with increased pore pressure, thermal stress changes and dramatic changes in material properties associated with heating the reservoir sufficiently to mobilize the heavy oil/bitumen. This geomechanical deformation may be expressed through seismic deformation and the release of seismic energy as fractures adjust to the strain field (e.g., Maxwell, et al., 2003), and also may result in surface expansion or subsidence (e.g., Wolhart, et al., 2005). Monitoring the microseismic activity with sensitive seismometers and surface deformation with precise tiltmeters could allow the steam injection to be tracked with complimentary technologies that respond to different expressions of the geomechanical deformation associated directly with the steam injection. In some fields, this geomechanical deformation also leads to casing deformations and well integrity problems causing operation problems. The combined monitoring of passive seismic and surface deformation may help provide insight into these mechanisms leading to casing deformations and also potentially identify circumstances that may lead to casing failures. Finally, the passive seismic and surface deformation monitoring can also be used to track unwanted steam breakouts. Thus, combined monitoring of passive seismic and surface deformations offers critical information for several reservoir engineering and management issues during steam injection.

Many steam injections are at relatively low injection pressure which may be below the “frac” pressure required to create tensile hydraulic fractures. Nevertheless, fracture activation may still occur as increased pore pressures induce shear movement along pre-existing fractures. This potential mechanism for seismic deformation is further enhanced from thermal stress changes and the material property changes moving the rockmass closer to shear failure. Therefore there are a number of factors which lead to the potential occurrence of microseisms/microearthquakes both for relatively high pressure cyclic steam “huff and puff” injection and lower pressure injections such as steam assisted gravity drainage (SAGD). Similarly, the amount of surface deformation depends on the reservoir strain and depth. Surface deformation can be monitored with various techniques, including INSAR and GPS monuments, although tiltmeters offers more potential precision to monitor small deformation changes. In this paper we present a case study demonstrating the monitoring of a steam injection using both passive seismic and surface deformation.