A Data Driven Artificial Intelligence Framework for Hydrogen Production Optimization in Waterflooded Hydrocarbon Reservoirs

Abdallah AlShehri, Klemens Katterbauer, Abdulaziz AlQasim

Saudi Aramco

Abstract

Hydrogen has become a very promising green energy carrier and it has potential to be utilized in many applications. Thermal EOR methods are among the most commonly used recovery methods. They involve the introduction of thermal energy or heat into the reservoir to raise the temperature of the oil and reduce its viscosity. The heat makes the oil mobile and assists in moving it towards the producer wells. The heat can be added externally by injecting a hot fluid such as steam or hot water into the formations, or it can be generated internally through in-situ combustion of the oil in depleted gas or waterflooded reservoirs using air or oxygen. It is an attractive alternative to produce cost-efficiently significant amounts of hydrogen from these depleted or waterflooded reservoirs. A major challenge is to optimize injection of air/oxygen to maximize hydrogen production via ensuring that the in-situ combustion sufficiently supports the breakdown of water into hydrogen molecules. In-situ combustion or fireflood is a method consisting of volumes of air or oxygen injected into a well and ignited. A combustion zone is propagated through the reservoir from the injection well to the producing wells. The in-situ combustion creates a bank of steam, gas from the combustion process, and evaporated hydrocarbons that drive the reservoir oil into the producing wells. There are three types of in-situ combustion processes: dry forward, dry reverse and wet forward combustion. In a dry forward process only air is injected and the combustion front moves from the injector to the producer. The wet forward injection is the same process where air and water are injected either simultaneously or alternating. This work utilizes a data-driven physics-inspired AI model for the optimization of hydrogen recovery via the injection of oxygen, where the injection and production parameters are optimized, minimizing oxygen injection while maximizing hydrogen production and recovery. Multiple physical and data-driven models and their parameters are optimized based on observations with the objective to determine the best sustainable combination.

The framework was examined on a synthetic reservoir model with multiple injector and producing wells. Historical injection and production were available for a time period of three years for various oxygen injection and hydrogen production levels. Various time-series deep learning network models were investigated, with random forest time series models incorporating a modified mass balance - reaction kinetics model for in-situ combustion performing most effectively. A robust global optimization approach, based on an artificial intelligence genetic optimization, allows for simultaneously optimization of an injection pattern and uncertainty quantification. Results indicate potential for significant reduction in required oxygen injection volumes, while maximizing hydrogen recovery.