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A Coupled THMC Model for Simulating In-situ Conversion process in Low-Medium Maturity Shale Oil Reservoir

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Continental shale oil in China is mainly of low-medium maturity, filled with heavy oil of low mobility and organic matter that unconverted. Horizontal drilling and hydraulic fracturing are insufficient to obtain economic production in such reservoir, thus in-situ heating and transform technology should be applied. A multiphase multicomponent thermal-hydraulic-mechanical-chemical (THMC) coupling numerical model considering multistage kinetic reactions and solid-fluid mass conversion is developed to describe the decomposition of solid organic matter, cracking of heavy hydrocarbon, phase behavior and rock property evolution.

During the in-situ process, organic matter (kerogen) decomposition and heavy oil cracking happens, enhancing hydrocarbon mobility. The research focuses on the development of multiphase multicomponent THMC coupling model, with the evolution of porosity and permeability considered. The FVM is used for the space discretization of flow and heat transfer equation, and the open system geomechanics model is discretized with FEM. Then the fixed-stress split method is applied to solve the THMC coupling model. Finally, the impact of important parameters on cumulative production are analyzed.

The impact of parameters including heating temperature, kerogen concentration, well bottom hole pressure, heater pattern and initial water saturation on cumulative production is analyzed. The results are summarized as: kinetic reaction rate is controlled by temperature and different reactions take place at variety heating temperature, influencing the fluid composition; higher kerogen concentration can enhance cumulative hydrocarbon production after in-situ conversion, making it an important parameter to evaluate before production; low bottom hole pressure can extract hydrocarbon products in time to prevent from further cracking and coking; different heater pattern has impact on the ratio of energy output to energy input, and hexagon heater is the most benefit; high water saturation will enhance energy consumption to heat water and reduce the utility ratio of energy, thus dewater process is required to reduce water saturation. It can be concluded that the in-situ conversion process is feasible in low-mid maturity shale oil reservoir, during which kerogen decomposition and hydrocarbon cracking happens. Besides, the operating parameters should be investigated to make the heating process economical.

The proposed model provides an efficient tool for modeling the in-situ conversion process of low-mid maturity shale oil reservoirs. In this paper, the reservoir fluid property variation, in-situ porosity and permeability evolution, and production characteristics are illustrated, which could provide insights on heater design and well operational management. With multiple transport mechanisms and multi stage kinetic reactions incorporated, the hydrocarbon production characteristics and formation property evolution of shale reservoirs can be both accurately captured.

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References

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