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Research highlight

Technology transition from traditional oil and gas reservoir simulation to the next generation energy development

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Abstract:
Energy transition has been a focus in both scientific research and social concerns in the past decade, thanks to the urgent need of reducing carbon emissions, slowing down the abnormal speed of global climate and achieving a balance between environmental protection and economic development. Although the global energy sector is shifting from the fossil-based energy systems, including oil and gas, to the renewable energy resources like hydrogen, the necessity of conventional energy development has received increasing attentions with regard to the stable supply and maturely developed technologies. The long-history simulation techniques developed for oil and gas reservoir investigations have enabled the deeper explorations into reservoir properties and enhanced significantly the resource recovery. As a main direction in energy transition, the development of hydrogen energy is profoundly influencing the long-term reconstruction of the world's energy supply and application system, and is accelerating the transition and generational evolution in the fields of transportation, power generation, chemicals, and housing. In this paper, three research directions are proposed as the potential focus of technology transition, where traditional oil and gas reservoir simulation technologies can be adjusted and improved to be used to benefit the development of hydrogen energy.

A number of global agreements on sustainable development and carbon emission reduction have been reached, and the world's major economies have all made decisions and arrangements for energy transition. However, the current fast-changing international political situation has brought new challenges to the energy transition procedures. For example, some developed countries are reneging on their carbon neutrality commitments and restarting traditional energy development. Thus, the conventional oil and gas reservoir simulation technologies still have strong scientific values and practical significance. Furthermore, drawing lessons from thousands of years of traditional energy development in the technology transition into the next-generation energy is also an effective approach to accelerate energy transition and avoid repeated research causing unnecessary wasting. The hydrogen industry chain is concluded in a diagram presented in Fig. 1, with all the key processes including production, storage and transportation. The following three directions can be concluded as:

1. On-site hydrogen production from methane:

As the most intuitively similar scenario with conventional reservoir simulations, the on-site hydrogen production in natural gas reservoirs can be directly pushed forward based on the maturely developed flow and transport behavior studies in porous media (Cai et al., 2020). One remarkable advantage of on-site hydrogen production lays down on the direct combination with carbon capture and sequestration processes, as carbon dioxide is the main by-product in the hydrogen production that should be separated and can be collected directly to the storage in recovered reservoirs. As one of the most clean carbon-contained resources, methane recovery has been extended to unconventional reservoirs including shale gas and methane hydrate (Liu et al., 2022). The effect of capillarity has shown its unneglectable impacts on the unconventional reservoir developments, thus the similar technologies considering the capillary effect on multi-phase fluid flow can be developed in the on-site hydrogen production in shale gas reservoirs. Reser-

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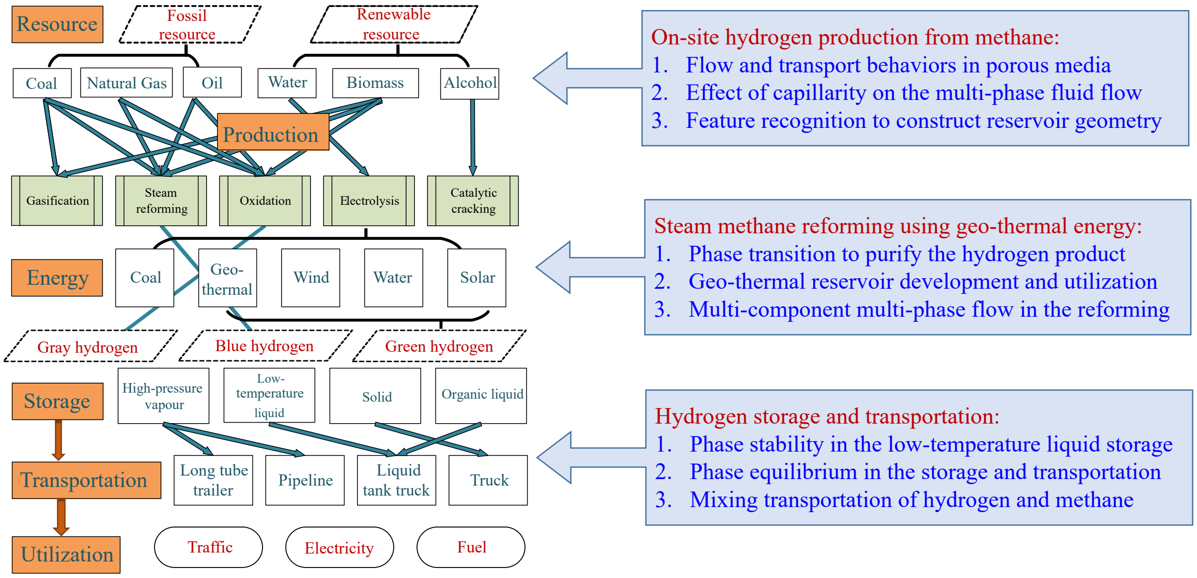

Fig. 1. Hydrogen industry chain and typical technology transitions from traditional oil&gas reservoir simulations.

voir feature recognition to construct the domain geometry has also been emphasized in the establishment of reservoir digital twin (Zhang et al., 2021), and such techniques can also help the definition of the boundary conditions in the simulation of on-site hydrogen production.

2. Steam methane reforming using geo-thermal energy:

Steam methane reforming, also known as SMR, is the most common method for mass production of hydrogen in industry, and the usage of geo-thermal energy can produce the so-called "green hydrogen" with more environmental benefits. Considering the various thermodynamic properties of hydrogen, methane and carbon dioxide, the controlled phase transition can help purify the hydrogen production by separating the by-products in different phases. The multi-component multi-phase flow in the reforming processes can be simulated using certain modules in the compositional reservoir simulators, while it is more attractive in practical meanings that the study in this direction can help develop geo-thermal reservoirs as another energy transition effort.

3. Hydrogen storage and transportation:

Hydrogen can be stored in several different conditions, including as a liquid at low temperatures, a gas at high temperatures, a solid, and dissolved within an organic solvent (Zhang et al., 2022b). Taken into account the extremely low critical temperature of hydrogen, phase stability plays a critical role in the safety management of the liquid storage processes. In addition, multi-component phase equilibrium studies are essentially needed in the industry chain of hydrogen storage and transportation for safety and economic purposes. Depending on the operating conditions, hydrogen can be transported from the location of production to its destination via pipelines, liquid tanker trucks, or long tube trailers. Pipeline transportation mixing with methane is a good choice to utilize the existing natural gas pipelines and to avoid duplicate construction, but the unique properties of hydrogen should be investigated further (Zhang et al., 2022a).

Conflict of interest

The authors declare no competing interest.

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