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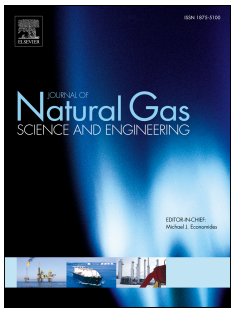

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ACCEPTED MANUSCRIPT

Influence of Acid-Rock Reaction Heat and Heat Transmission on Wormholing in Carbonate Rock

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Abstract

Matrix acidizing is one of the most important technologies to recover or enhance oil/gas recovery by injecting acid fluids to dissolve rocks and increase the permeability near the wellbore. The wormholes with different patterns are generated in the dissolution process. In addition to the injection parameters, acid types and physical properties of rock, the temperature is one of the potential factors to affect wormholing performance, especially for some temperature dependent diverting acids. However, few works concentrated on the influence of reaction heat on wromholing. In this work, the acid-rock molar reaction heat considering comprehensive impact of temperature, pressure and volumetric work of CO_2 was introduced into the heat transfer model, and combined with two-scale model. The models were numerically simulated to highlight the influence of different factors on reaction temperature profiles, wormhole patterns and breakthrough curves under isothermal and non-isothermal conditions with radial coreflood simulations, and the modeling results are in good agreement with the experiments. The simulation results illustrate that molar reaction heat influences the reaction temperature profile to some extent, and can affect wormholing on macro-scale under certain conditions. During the reaction, the highest reaction temperatures are observed at the wormhole tips, which are over 11 K in our simulations. Under isothermal conditions, the temperature and acid concentration strongly affect the wormhole propagation progress, but pressure does not. The field application condition of matrix acidizing considering non-isothermal Influence is also systematically studied. It was found that a colder acid injection or a lower rock temperature will promote the acidizing efficiency when the injection rate is within the appropriate range.

Keywords Carbonate reservoir, Matrix acidizing, Wormhole propagation, Temperature, Numerical simulation

1 Introduction

Matrix acidizing is the most important method to stimulate carbonate reservoir through bypassing the damage zone with wormholes using a small volume of acid. Therefore, nearly all of the studies focusing on recovering or stimulating the production of carbonate reservoirs were based on investigations of the initiation and propagation of wormholes or unstable dissolution fronts. Many mathematical models were developed to describe the wormhole patterns observed in experimental results (Daccord, 1987a and 1987b; Hoefner et al., 1988; Golfier et al., 2002). Those models can be mainly classified as 5 types: the capillary tube model, the fractal model, the network model, the averaged model and the pore-scale model. The capillary tube model (Huang et al., 1997; Buijse, 1997; Gdanski, 1999) and the fractal model (Daccord et al., 1987a and 1987b; Pichler et al., 1992; Frick et al., 1994a) are used to describe the wormhole propagation in marco-scale, missing the mechanism of diffusion and reaction in the pore scale. The pore-scale model (Bekri et al., 1995; Kang and Lichtner, 2005) can describe the diffusion and reaction in the pore scale in detail, with the modeling scale size limited by the highly expensive computation. The averaged model (Liu et al., 1997; Golfier et al., 2002) is both suitable to modeling the diffusion and reaction in the pore-scale, and reaction flow and wormhole propagation in the Darcy-scale. Finally, the network model (Hoefner et al., 1988; Fredd et al., 1999; Budek and Szymczak, 2012) describes reaction flow and dissolution in a network of cylindrical tubes, and the corresponding describing scale is between pore-scale and Darcy-scale. The wormhole patterns under different injection rates calculated by the averaged model and the network model are highly in good agreement with the experimental results: uniform dissolution, ramified wormhole, dominant wormhole, conical wormhole and face dissolution. Hoefner et al. (1988) found that PV_{BT} (pore volume of acid required to reach the breakthrough) calculated by

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