Journal of Petroleum Science and Engineering 168 (2018) 478–494

Contents lists available at ScienceDirect

Journal of Petroleum Science and Engineering

journal homepage: www.elsevier.com/locate/petrol

An experimental study on acid-rock reaction kinetics using dolomite in carbonate acidizing

Hyunsang Yoo[a,1], Youngmin Kim[a,1], Wonsuk Lee[b,**], Jeonghwan Lee[a,*]

[a] Department of Energy and Resources Engineering, College of Engineering, Chonnam National University, 77, Yongbong-ro, Buk-gu, Gwangju, 61186, South Korea
[b] Petroleum and Marine Research, Korea Institute of Geoscience and Mineral Resources, 124, Gwahak-ro, Yuseong-gu, Daejeon, 34132, South Korea

ARTICLE INFO

Keywords:
Carbonate acidizing
Spent acid
Dissolution rate
Diffusion coefficient

ABSTRACT

This study presents experimental results on the reaction kinetics of dolomite with fresh and spent acid in carbonate acidizing. Spent acid is defined as a partially reacted acid involving reaction products, such as calcium and magnesium ions, during an acid-rock reaction. A newly designed apparatus was developed to quantify the effect of spent acid on the acid-rock reaction kinetics at reservoir conditions. A total of 4 runs with 36 experiments at same conditions using the apparatus were repeatedly carried out to investigate the reaction kinetics of dolomite rock under the various concentrations of fresh acid and spent acid. The reaction results showed the dolomite disk was more dissolved in the spent acid than the fresh acid. Moreover, it was observed that the kinematic viscosity was higher, and the pH was lower in the spent acid, when compared with the fresh acid. From the results, it was revealed that the dissolution rate and diffusion coefficient for spent acid were higher than those of fresh acid due to the higher kinematic viscosity and the lower pH of spent acid. This means that the chemical reaction becomes more vigorous due to the long contact time and high acidity of the spent acid at the surface of the dolomite disk. These results suggest that the uncommon ion effect by the impurities, such as ferric oxide and aluminum oxide in clay, which is not related to the reaction of HCl and dolomite, can promote the reactions. A conventional approach using fresh acid could result in significant errors in determining the injection parameters, such as injection rate, volume, and pumping schedule in a carbonate acidizing job, because of the underestimated the dissolution rate and diffusion coefficient. Therefore, the effect of spent acid on acid-rock reaction kinetics should be essentially considered to design the injection conditions in carbonate acidizing.

1. Introduction

The global distribution of carbonate reservoirs is estimated to exceed the 60% of oil and 40% of gas reserves that are held in carbonates. However, it is recognized that recovery factors for carbonate reservoirs are significantly lower than for sandstone reservoirs due to the heterogeneous nature and complexity of geo-tectonics (Schlumberger, 2007). Hydrocarbon productivity of well drilled in carbonate reservoirs can be enhanced by injecting acids into the reservoir to dissolve part of rock mass.

Matrix acidizing is one of the acidizing processes to extend the effective drainage radius of a well by dissolving reservoir rock and creating highly conductive channels that are known as wormholes (Liu et al., 1997). The well productivity strongly depends on the length, diameter, and distribution of wormholes along the wellbore. The configuration of the wormholes can be controlled by an injection rate, which is derived from a diffusion coefficient based on acid-rock reaction. If injection profiles can be controlled, the injection rate is well defined. However, the diffusion coefficient requires to be measured experimentally because it is difficult to obtain due to its complex dependency on interstitial velocity, fluid composition, rock surface properties, and so forth.

The various researches to analyze acid-rock reaction kinetics and diffusion coefficients have been conducted to accomplish successful matrix acidizing (Lund et al., 1973; Lund et al., 1975; Busenberg and Plummer, 1982; Anderson, 1991; Fredd and Fogler, 1998; Taylor and Nasr-El-Din, 2004; Taylor et al., 2006). However, the conventional models in carbonate acidizing have used the diffusion coefficient of fresh acid to predict wormhole propagation process. This diffusion coefficient could not be representative of the wormhole propagation in a reservoir because of reflecting only wormhole propagation close to the injection point. As the wormhole extends deeper into the formation,

* Corresponding author.
** Corresponding author.
E-mail address: jhwan@jnu.ac.kr (J. Lee).
[1] These authors contributed equally to this work.

https://doi.org/10.1016/j.petrol.2018.05.041
Received 1 February 2018; Received in revised form 4 April 2018; Accepted 14 May 2018
0920-4105/

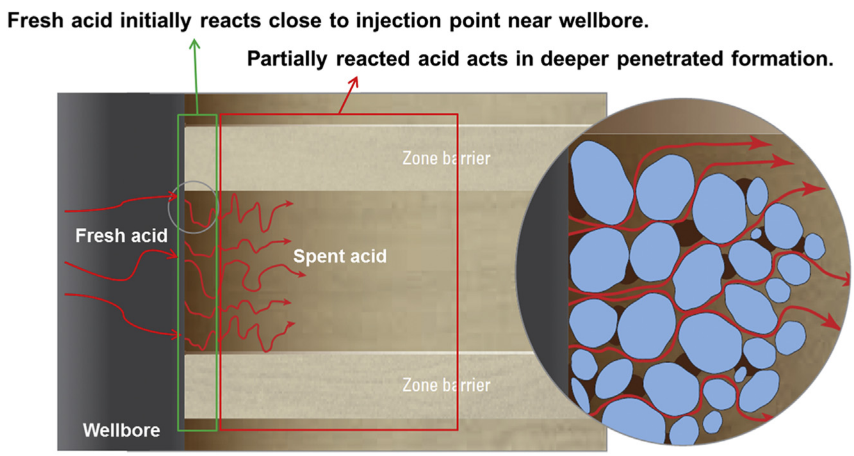

Fig. 1. A concept of acid-rock reaction in a reservoir.

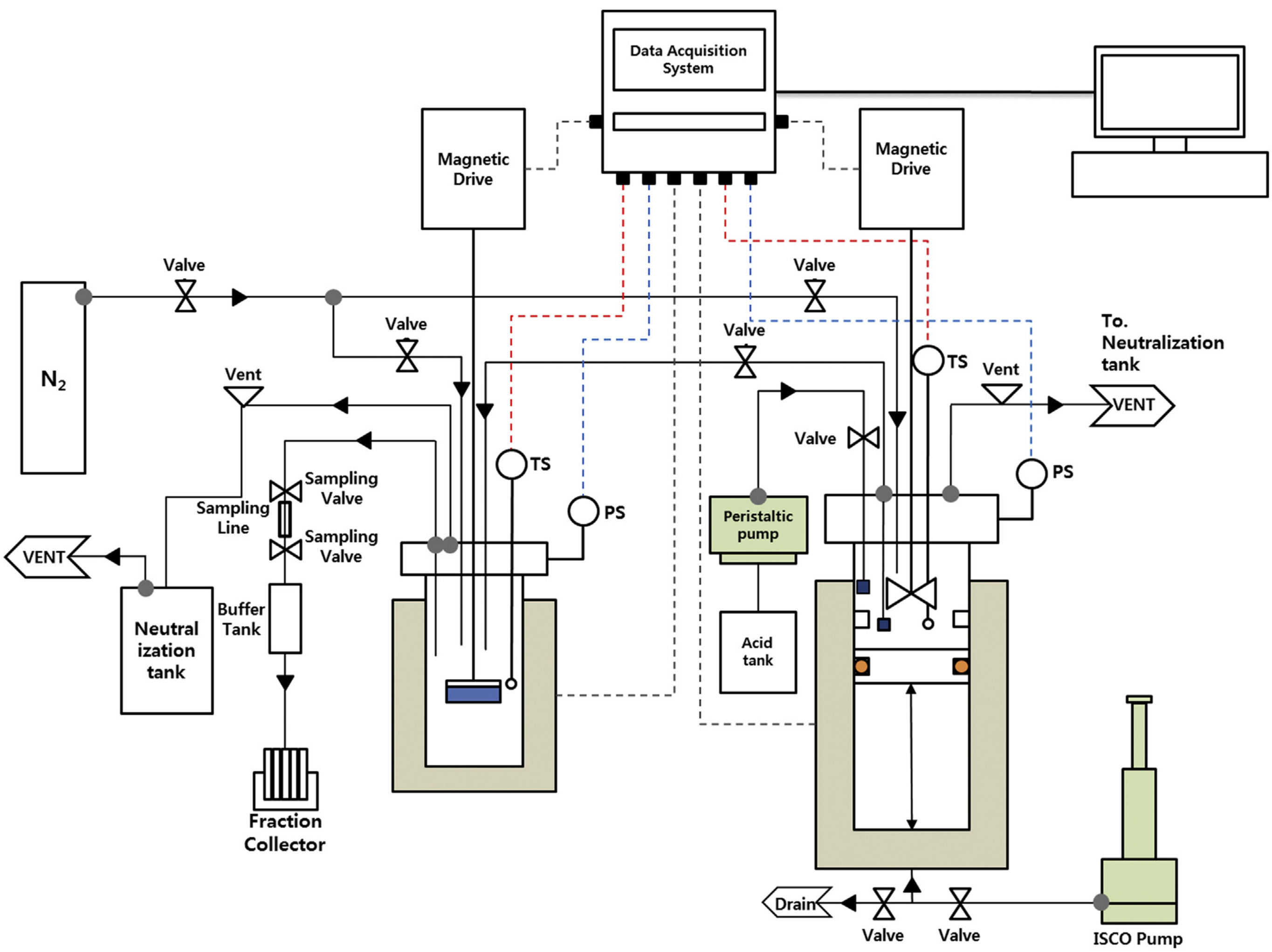

Fig. 2. A schematic of the experimental apparatus.

the front of the wormhole is further reacted with a spent acid, which is a partially reacted acid involving reaction products, such as calcium and magnesium ions, during the acid-rock reaction as shown in Fig. 1. When a job design is implemented in acidizing treatment, the diffusion coefficient using the fresh acid could result in significant errors in determining the injection parameters such as injection rate, volume, and pumping schedule. Thus, the diffusion coefficient reflecting the level of acid spending at the front of the wormhole should be applied to estimate the accurate wormhole growth in carbonate acidizing. Although the effect of spent acid is significantly important in the real situation, only a few studies have previously been conducted.

Qiu et al. (2013) studied the impact of reaction products on reaction kinetics with hydrochloric acid (HCl) using calcium carbonate rocks such as limestone and marble. Rotating disk experiments were