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Experimental Investigation of Acid Injection on Fracture Opening in Calcite and Dolomite Reservoirs

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Introduction

Acid fracturing is one of the conventional techniques for increasing oil production in carbonate reservoirs. This is done to reduce the effect of formation damage in the damaged formations or stimulation in non-damaged formations. The matrix acidizing operation is a stimulation method, in which acid is injected at low injection pressure. This method is preferred for removing near-wellbore damage by creating wormholes around the wellbore that extends beyond the damaged zone. In recent years, many researchers studied acid fracturing or acidizing operations [1-5]. The kinetic reaction of HCl was investigated by Lund et al [6]. Their results showed that the reactivity depends on the temperature. Reaction kinetics was studied using rotating disc machine by Anderson [7]. Their findings are contrary to the results obtained from Lund et al, which the results showed that the reaction kinetics are less dependence on temperature. The modeling study of acid fracturing in a dolomite formation was investigated by Ben and Ecodonomids [8]. These researchers were demonstrated that the etching process in dolomite structures was bell-like with maximum current conduction at distances away from the well. They attributed this treatment to lower temperatures close to the well, which makes the process of acid dissolution in dolomite formations as a reaction limited [8].

Although there are a large number of acid combinations in the oil industry for acid fracturing, small amounts of these acids are involved in reservoir stimulation included strong acids like hydrochloric acid, organic acids (also called weak acids) such as acetic acid, citric acid, and formic acid. The advantage of weak acids is that they can reduce formation damage so that the acid with low pH can react with carbonate formation or with calcium content in sandstone formation and can minimize formation damage. Generally, accurate input data are necessary to obtain consistent results. The most precise method for collecting these data is by conducting lab tests on fluids and rocks during field and laboratory operations. Furthermore, the amount of fracture opening has an essential influence on the ability of fracture in transporting oil that can lead to an increase in the amount of oil production. In this study, acetic acid at two injection flow rates is injected into carbonate rocks, and its effect on fracture opening is investigated.

Materials and Methods

Two types of carbonate rocks (dolomite and calcite) are used. The rock samples were selected from the outcrop mountains of the Shiraz province. The dolomite rock sample has a porosity of 14.46% and a permeability of 279 mD. The calcite rock sample has low porosity and negligible permeability. The reactivity of these two rocks is different from acid due to the existence of various minerals. Acetic acid, which used in the experiments, is produced by Merck Company. The injection system is designed in a way that it can simultaneously measure the pressure drop in the system. The injection system is shown schematically in Figure 1.

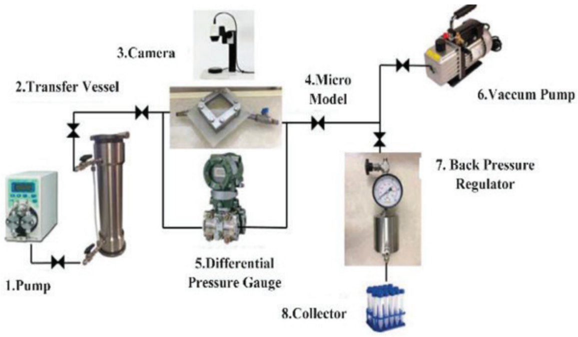

Fig. 1 The flooding setup of this study.

A fretsaw is used to create a fracture in the rock. The advantage of the fretsaw is that the fracture can be created with the thickness in the order of millimeter size. For preparing acetic acid at a concentration of 8 wt.%, according to acetic acid density (1.05 g/cm^3), 7.61 ml acid was added to 92.39 ml of water, and the resulting solution was placed on a magnetic stirring for an hour. Finally, what was achieved was a 100 ml acetic acid of 8 wt. %.

Results and Discussion

To investigate the effect of acetic acid injection flow rate on fracture opening, acid was injected at a concentration of 8 wt.% with two flow rates (0.3 and 0.9 ml/min). The results of fracture opening are shown in Figure 2. Here, the rock reaction index with acid is the slope of the graph. The higher the slope of the figure was, the more significant fracture opening occurred. As shown in Figure 2, the slope of 0.3 ml/min injection flow rate is higher than 0.9 ml/min. Therefore, when the injection flow rate is low, acid moves with lower speed, so it has more time to be in contact with the fracture surface. Thus, the acid reaction rate is higher, and the opening rate is higher.

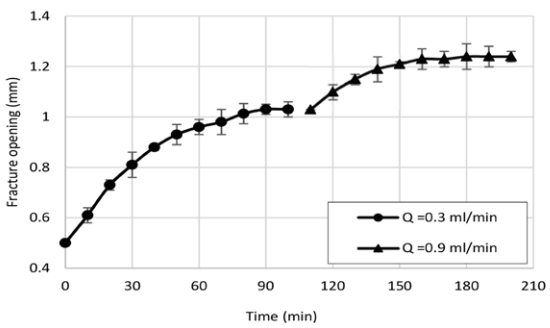

Fig. 2 Fracture opening changes in the calcite rock sample.

The results of the experiments related to the fracture opening in the dolomite rock sample are shown in Figure 3. By reducing the acetic acid injection flow rate, the final fracture opening increases, but the amount of this increase is different in calcite and dolomite. In the dolomite rock sample, the initial opening of the fracture before the injection of acetic acid was 0.78 mm, and after the acid injection, it was 0.91 mm, which shows an increase about 13 mm.

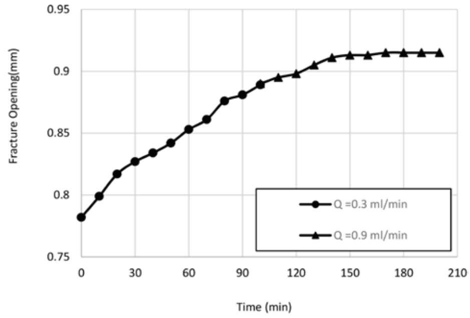

Fig. 3 Fracture opening changes in the dolomite sample.

However, in the calcite sample, the fracture opening before and after acid injection was 0.5 and 1.05 mm respectively, indicating a more significant fracture opening changes. To further investigate, the pH of the effluent acetic acid was measured at regular intervals, which its results are shown in Figure 4.

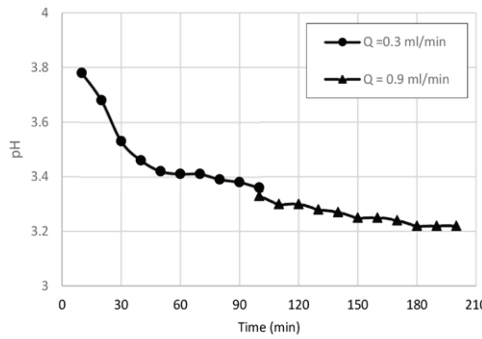

Fig. 4 Effluent pH of flooding setup in the dolomite sample.

As shown, in the early injection time, the slope of the pH figure was higher than that at the end of the injection, and over time it was decreased. In general, the effluent pH in the flow rate of 0.9 ml/min is lower than the effluent pH of 0.3 ml/min injection flow rate. This indicates that the effluent acid of the higher flow rate leaves the fracture without a complete reaction with the rock surface. In other words, acid did not have sufficient time to react with the rock and dissolved fewer minerals. On the other hand, a gradual decrease in pH of the pH curve at the final injection time steps indicates that bypassing time, the amount of reactive minerals with acetic acid at the fracture surface reduces, and finally, the reaction rate decreases.

By comparing the effluent pH for both rock samples in Figure 5, it can be concluded that due to less reactive reactivity in dolomite, its final fracture opening rate will also be lower. In the calcite rock sample, the final effluent pH (4.56) has a higher value than the pH of the dolomite rock sample (3.36). The higher pH indicates more reaction of acetic acid with calcite. This leads to more significant fracture opening changes in the calcite. Therefore, the results of the effluent pH are in agreement with the results of the fracture opening changes.

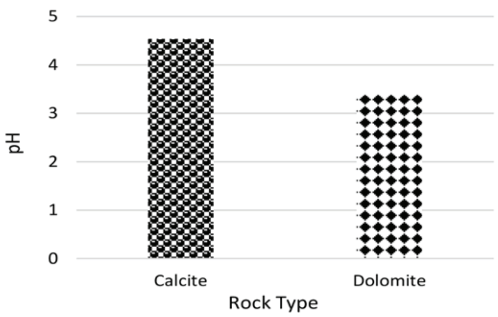

Fig. 5 Comparison of the final effluent pH in the calcite and dolomite samples.

Conclusions

In general, according to the results of the acid injection test, acidic reaction with dolomite is lower than calcite. From the fracture opening test results, it was found out that changes in fracture opening for the response of acid acetic with dolomite had a lower rate of reaction than calcite. The reason for this is that a smaller amount of active minerals in dolomite resulted in a lower reaction rate. However, in the calcite rock sample, the number of active minerals was more, so changes in fracture opening was more indeed. On the other hand, the acid injection flow rate also affected the fracture opening changes. When acid was injected at a low rate, the injected acid passed slowly along the surface of the fracture and had more time to be in contact with minerals. As a result, the fracture opening would be higher. Moreover, the examination of the pH effluents indicated that in the case of dolomite, the acid had the lowest pH value. In addition, the lower pH of the acid indicates a lower amount of fracture opening changes.

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