PRF #: 59356-ND9
Project Title: Computational Investigation of Acid-Rock Interactions in Matrix Acidizing and Acid Fracturing
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1 Executive Summary

This project investigates the acid-rock interactions in the process of matrix acidizing and acid fracturing, which are commonly employed by industry to enhance well productivity. Year 1 efforts focused on studying how the wormhole grows in matrix acidizing and how the wormhole deforms during the production period. A novel acidizing simulator has been developed to model the wormhole growth and can reproduce dissolution regimes observed from coreflooding experiments. The coupled reservoir flow-geomechanics simulations have been conducted to analyze the mechanical stability of the wormholes under the reservoir depletion condition. The simulation results imply that the stress relaxation effect in the wormhole region helps keep wormholes from collapse. Details regarding these efforts and findings are described below.

2 Research Narrative

Matrix acidizing is a technique to improve permeability and enhance production especially for carbonate reservoirs, which involves injecting acid to dissolve minerals to create highly conductive channels knowns as wormholes. Nevertheless, the carbonate rock after dissolution reaction is susceptible to mechanical failure under reservoir depletion since its mechanical strength becomes weaker. In order to design acidizing operations, coupled hydro-chemo-mechanical modeling has been developed for investigating wormhole growth and stability in matrix acidizing of carbonate reservoirs.

2.1 Modeling Wormhole Growth in Matrix Acidizing

A new acidizing simulator is developed to model wormhole growth by using enriched Galerkin finite element methods (EG). The simulation results can reproduce different dissolution patterns observed from coreflooding experiments, which is shown in Fig. 1 and Fig. 2. The dissolution regime is dependent on the injection rate. At the low injection rate, the acid transport is piston-like displacement, which leads to the face dissolution. At the high injection rate, the acid can be transported almost everywhere, which results in the uniform dissolution. At the intermediate injection rate, a dominant channel is dissolved and formed, which is called wormhole dissolution. Acidizing simulation in near wellbore region is shown in Fig. 3 and Fig. 4. The simulations are performed on three different meshes: (a) static coarse mesh, (b) static fine mesh, and (c) adaptive mesh. The adaptive mesh means that the mesh is refined around the wormhole interface adaptively along the wormhole growth. In this example, the adaptive mesh refinement can provide 4 times speedup compared with the static fine mesh while preserving the accuracy.

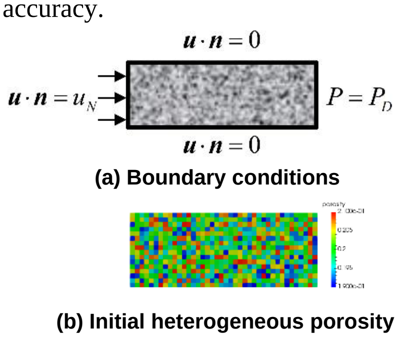


Fig. 1 Simulation setup of core flooding

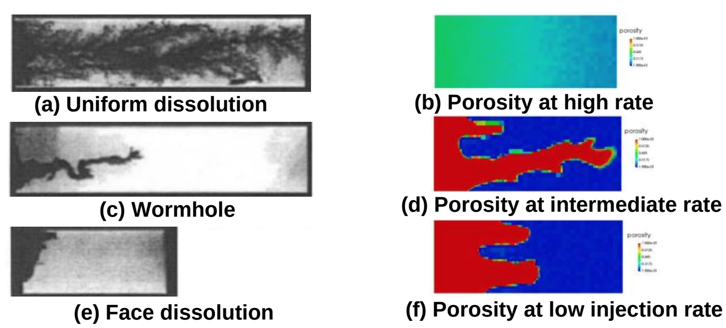


Fig. 2 Porosity of experiments (Fredd & Fogler 1998) [(a), (c), (e)] and simulations [(b), (d), (f)]

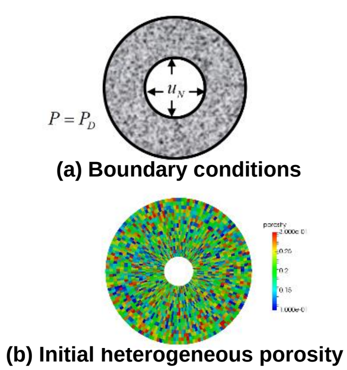


Fig. 3 Setup of acidizing near wellbore

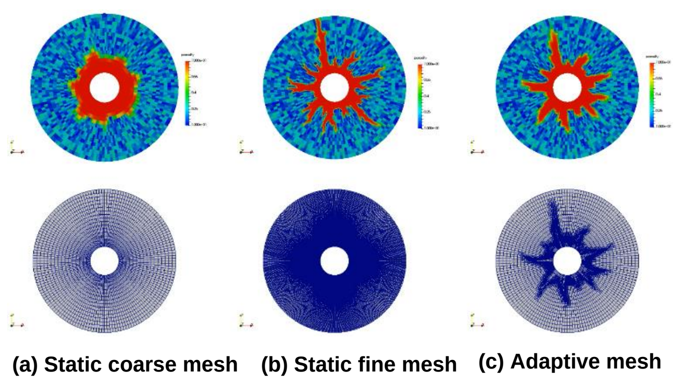
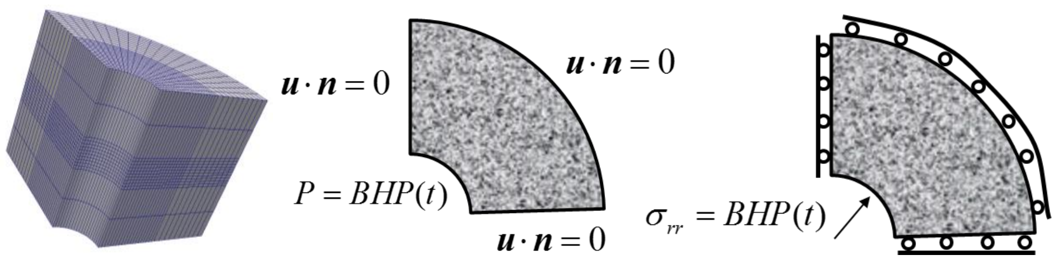


Fig. 4 Meshes and porosity solutions for three cases

2.2 Analysis of Wormhole Stability During Well Production Period

After matrix acidizing, the mechanical stability of wormholes during production is evaluated. Since acidizing job is mainly effective near wellbore, one quarter of a domain in the vicinity of a cylindrical vertical wellbore is selected as the computational domain shown in Fig. 5. The cylindrical face represents the wellbore face. The acidizing simulation, shown in Fig. 6, is only performed on a layer at the middle of the reservoir. Mechanical properties of carbonate rocks, shown in Fig. 7, are updated based on wormhole geometry from the acidizing simulator. The reservoir stress field, shown in Fig. 8, is then obtained by simulating the reservoir depletion process on an in-house coupled reservoir flow-geomechanics simulator. A safety window, shown in Fig. 9, is calculated based on the Coulomb's failure criterion and positive safety window means no occurrence of rock failure. The simulation results imply that most wormholes are not under failure state during production. Even though the mechanical strength of the wormhole region decreases after the dissolution reaction, the stress relaxation in the wormhole region due to its low Young's modulus keeps the damaged rock away from the failure envelope.



(a) Computational mesh **(b) Setup for reservoir flow** **(c) Setup for geomechanics**

Fig. 5 Simulation setup of reservoir depletion

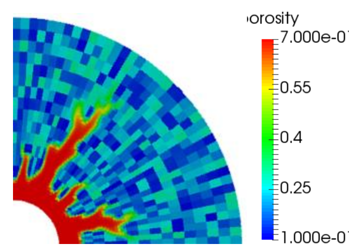
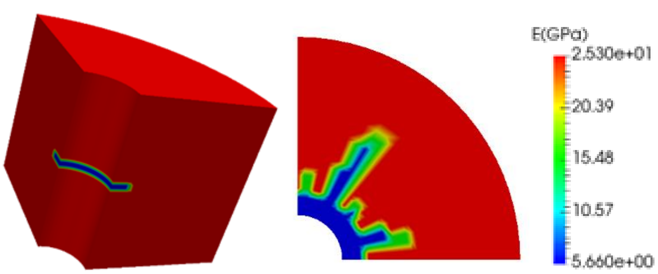


Fig. 6 Porosity after acidizing



(a) 3D region **(b) Wormhole region**

Fig. 7 Updated Young's modulus after acidizing

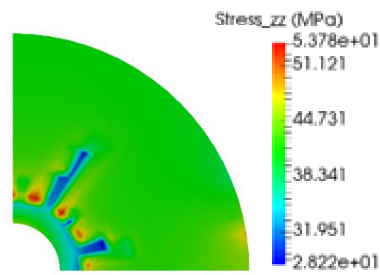


Fig. 8 Vertical stress after production

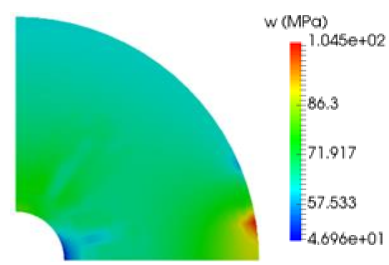


Fig. 9 Safety window after production

3 Impact

The ACS PRF ND grant enabled the PI and graduate student to initiate new research on the matrix acidizing technique for carbonate reservoirs. We have obtained a deep understanding of the wormhole growth in the acidizing process and wormhole stability in the well production process. We think that the coupled hydro-chemo-mechanical modeling approach developed in this study is valuable in optimizing operation parameters for matrix acidizing of carbonate reservoirs. Two conference papers have been published. Our research results have been presented at multiple conferences including SPE Reservoir Simulation Conference, US Rock Mechanics/Geomechanics Symposium, SIAM Geoscience Conference and AAPG Annual Convention. Thanks to the grant, the sponsored PhD student Rencheng Dong makes substantial research progress on his dissertation. He gave presentations on our research at various conferences, which improved his presentation skills, helped develop his professional career and provided feedbacks and possible extensions of our current research.

We would like to thank and acknowledge ACS and the donors of the ACS PRF.