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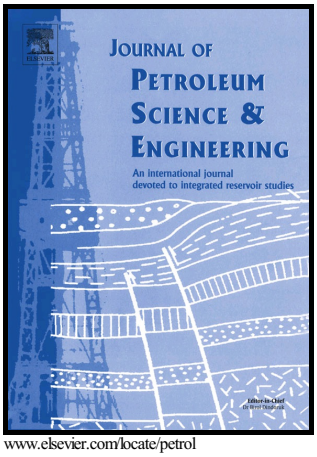

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Modelling and simulation of wormhole formation during acidization of fractured carbonate rocks

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Abstract

Acidizing is a commonly used stimulation treatment for carbonate reservoirs, performed by injecting acid into the near-wellbore rocks to remedy drilling damage, or to create, by mineral dissolution, deeply-penetrating, narrow, high-permeability channels, termed wormholes. Wormhole formation in un-fractured matrix has been widely studied by numerical modelling, but little work has been done for fractured cases, which may cause wormholes to propagate quite differently. In this study, a continuum model with explicit fractures is developed, where the governing equations are discretized by the finite-volume method. This model produces the correct dissolution patterns on a 2-D un-fractured domain discretized by Delaunay triangulation. Then it is used to examine wormhole formation in cases with single and multiple fractures, including consideration of characteristics such as fracture orientation, pattern and aperture. Fractures oriented along the flow direction can dominate the wormhole propagation, while fractures perpendicular to the flow not only change the number of branches, but also the orientation of the wormhole. Because of the positive feedback associated with fractures, the flow+dissolution process typically uses only some of the available fracture pathways. Perhaps the most significant result is that the optimum injection rate is almost unchanged from that of the same un-fractured medium.

Keywords: Reactive flow; Acidization; Wormhole; Fractured carbonate rocks; Discrete fracture; Finite volume method.

1. Introduction

Many subsurface operations – such as drilling, cementing, well completion, and production – can result in damage to the rock formation near the wellbore, decreasing the permeability and resulting in a reduction in oil or gas production. Acidizing is one type of treatment that is employed to increase the permeability around the wellbore. During this process, acid is injected into the rock under a pressure that is lower than the pressure that would cause the rock to fracture. The acid reacts with and dissolves some of the rock components, which can – in favourable cases – overcome some of the induced damage, or just enhance the local permeability. In carbonate rocks, acidizing can not only reduce the damage, but it also can create conductive channels that extend some distance into the rock mass, known as wormholes, whose hydraulic conductivity is several orders of magnitude larger than that of the porous medium.

A large number of experimental observations and numerical simulations (Fredd and Fogler, 1998;