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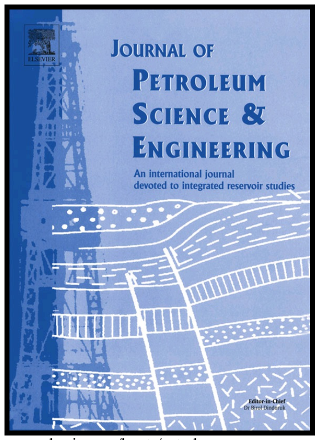

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A new approach to DEM simulation of sand production

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ABSTRACT:

This paper presents a model for the investigation of sandstone degradation and sand production mechanisms coupled with fluid flow analysis using the Discrete Element Method (DEM). The model was used to investigate the effects of in-situ stresses and flow rate on sand production.

We developed a linked DEM-fluid flow model for sanding analysis. The model calculates seepage forces and applies them on solid particles in the DEM model. The model accounts for permeability and porosity changes due to sandstone deformation and sand production. The DEM model was verified against poro-elastoplastic analytical solutions. Subsequently, the model was used for sanding simulation from a block-shaped sample under different far-field stress and pressure conditions. The boundary stresses and fluid pressures were varied to study their influence on sandstone degradation and sand production.

The creation of a borehole in a solid block resulted in the development of uniform or V-shape breakouts around the borehole. The failure zone around the borehole expanded after the application of fluid flow and sand grain detachments. Fluid flow was observed to influence the size and mode of failure in the breakout zone and sand production. Boundary stress dominated the sanding response at higher boundary stress conditions. However, much lower sanding occurred under higher boundary stresses but low boundary fluid pressures. High tangential stresses around the borehole caused by high confining stress resulted in strong frictional interlocking that alleviated sand production. Massive sanding was observed at lower far-field stress but higher boundary pore pressure.

Keywords: Discrete Element Method; Fluid flow coupling; Permeability and porosity alterations; Sand production

1. Introduction

Sanding is the production of formation sand driven by de-cementation of the formation sand around the borehole and the flow of reservoir fluid during the oil recovery process. Problems associated with sand production include erosion of pipelines and surface facilities, wellbore intervention costs, and environmental impacts. Large amounts of sand production in a short period of time may clog up wells, damage well equipment, and destabilize wellbores due to loss of materials (Climent et al., 2014). On the other hand, controllable sand production may increase wellbore productivity and reduce wellbore completion costs (Saucier, 1974). Therefore, understanding sand production mechanisms and the ability to predict and manage the rate of sand production are important.

While both experimental and analytical models of sand production are necessary to understand the phenomenon, numerical models are essential for realistic predictions (Rahmati et al., 2013a). Sand production in oil wells is often analyzed using continuum models. However, the process of sandstone de-cementation involving the development of cracks and micro-cracks in the inter-granular bonding material and grain detachments due to seepage forces are intrinsically problems of a discontinuum and are not compatible with the assumptions of continuum mechanics.

An alternative approach that overcomes some of these limitations is adopting the discrete element method (DEM) for this problem. In order to apply the DEM in the sanding problem, it is necessary to calculate fluid flow and pore water pressure in the discontinuum. In this work, we linked a three-dimensional DEM model with fluid flow calculations to simulate sand production. Coupling the DEM model with continuum fluid computation allows the simulation of solid-fluid interactions.