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Sand Production Modelled with Darcy Fluid Flow Using Discrete Element Method

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Abstract : In the process of recovering oil in weak sandstone formations, the strength of sandstones around the wellbore is weakened due to the increase of effective stress/load from the completion activities around the cavity. The weakened and de-bonded sandstone may be eroded away by the produced fluid, which is termed sand production. It is one of the major trending subjects in the petroleum industry because of its significant negative impacts, as well as some observed positive impacts. For efficient sand management therefore, there has been need for a reliable study tool to understand the mechanism of sanding. One method of studying sand production is the use of the widely recognized Discrete Element Method (DEM), Particle Flow Code (PFC3D) which represents sands as granular individual elements bonded together at contact points. However, there is limited knowledge of the particle-scale behavior of the weak sandstone, and the parameters that affect sanding. This paper aims to investigate the reliability of using PFC3D and a simple Darcy flow in understanding the sand production behavior of a weak sandstone. An isotropic tri-axial test on a weak oil sandstone sample was first simulated at a confining stress of 1MPa to calibrate and validate the parallel bond models of PFC3D using a 10m height and 10m diameter solid cylindrical model. The effect of the confining stress on the number of bonds failure was studied using this cylindrical model. With the calibrated data and sample material properties obtained from the tri-axial test, simulations without and with fluid flow were carried out to check on the effect of Darcy flow on bonds failure using the same model geometry. The fluid flow network comprised of every four particles connected with tetrahedral flow pipes with a central pore or flow domain. Parametric studies included the effects of confining stress, and fluid pressure; as well as validating flow rate – permeability relationship to verify Darcy's fluid flow law. The effect of model size scaling on sanding was also investigated using 4m height, 2m diameter model. The parallel bond model successfully calibrated the sample's strength of 4.4MPa, showing a sharp peak strength before strain-softening, similar to the behavior of real cemented sandstones. There seems to be an exponential increasing relationship for the bigger model, but a curvilinear shape for the smaller model. The presence of the Darcy flow induced tensile forces and increased the number of broken bonds. For the parametric studies, flow rate has a linear relationship with permeability at constant pressure head. The higher the fluid flow pressure, the higher the number of broken bonds/sanding. The DEM PFC3D is a promising tool to studying the micromechanical behavior of cemented sandstones.

Keywords : discrete element method, fluid flow, parametric study, sand production/bonds failure
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