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Filtration and sedimentation in the channel with permeable walls

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Movement of fluid containing solid particles in a fault zone or fractured reservoirs is accompanied by changes in fracture permeability due to the sedimentation of particles on its walls. In groundwater hydrodynamics this phenomenon is known as mudding and extensively utilized during hydrofracture implementation to increase oil recovery. In this work movement and sedimentation of particles during the flow through the channel with permeable walls were considered. For that purpose series of experiments were conducted on the laboratory model of the fracture with porous permeable walls. Constant pressure was applied on the one edge of the modeled fracture, while fluid could leave the experimental setup via two outlets after filtration through porous walls. Filtration and sedimentation was assessed for a wide range of inlet pressures (25-200 mbar), particles mass flow rates (0.28-0.375 g/sec, average particle diameter of 0.3 mm) and fluid viscosities (0.01-0.5 g cm-1 s-1). We observed filling of the fracture by solid particles accompanied by a permeability of the experimental cell decrease. At the fist stage of the gap filling, particles settled on the porous surface of permeable walls. The thickness of the settled particles layer experienced a substantial variation along the fracture length. This thickness depends on balance between Stokes force and friction between the particles, porous walls (or already settled particles) and a glass cell. Thin layer (< 10 characteristic particle sizes) of sediment particles on porous walls did not affect permeability, so that filtration rate did not change. Due to the velocity drop along the fracture length, which is also affected by sedimentation process, particles tend to stop and form a clog. After its formation higher pressure difference was applied and wave-like channel was generated. For all experiments dynamic sedimentation process was assessed using digital images. During one of the experiments fluid filtration was visualized using a staining dye.
As a result, an analytical model of fluid fluxes and sedimentation process was developed. It was shown that if permeability of walls is substantially lower than that of the fracture, flux density is almost uniformly distributed and flow rate linearly decreases along permeable walls. However, due to sedimentation of solid particles on fracture walls overall permeability of the cell decreases. Analytical expression for particles sedimentation was established, confirming that for specified geometrics of fracture initial phase of sedimentation does not depend on fluid velocity and viscosity, but determined by particles size and permeability of fracture walls.