A semi-empirical Model describing the Cavitation Erosion Process of Granular Material

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Radial Jet Drilling (RJD) is applied in the Oil and Gas industry since many years to improve the well productivity of low performing oil wells. Currently this technology is intended to be applied to geothermal reservoirs in order to connect low permeable zones to the mother well. In geothermal industry RJD is usually faced to hard rock formation types which limits its feasibility. In order to estimate the applicability of using a focused high pressure water jet for rock destruction in oil and gas or geothermal industry, the erosion mechanism must be understood properly and adjusted correctly to each specific formation type. It is assumed that different physical processes are interacting to erode the borehole wall, referring to the high pressure water jet exposed from the jetting nozzle and the granular material being penetrated by it. These processes are: the stagnation pressure of the fluid jet, surface erosion due to shear forces exerted from the fluid on the rock surface, pore pressure build up in the near well bore area leading to micro-fracturing and the implosion of cavitation bubbles near the target surface. In order to derive a thorough understanding of the complex interaction of all processes a 2-dimensional simulation model is developed that is equipped with empirical data from additional tests. Therefore the simulation framework is developed which combines the Lattice Boltzman Method (LBM) with the Discrete Element Method (DEM) to predict the erosion process of granular material by a highly cavitating water jet. The flow field is simulated including the high pressure water jet on the rock surface as well as inside the created cavity under submerged conditions. The pore pressure build up is simulated by a specific sub model as well as the direct moment exchange between solid and liquid phase by fully resolved rock grains in the lattice mesh. The physical behavior of the rock specimen is simulated by a Discrete Element Approach (DEM) with an integrated Bonded Particle Model (BPM). The DEM represents the quartz grains of the rock specimen, while the BPM simulates the rock cement with its failure mechanism. The empirical input to the simulation model is delivered by pitting tests and their data evaluation. These tests are performed in order to quantify the impact load of a highly cavitating water jet on a target surface. Based on an appropriate material model this load can be quantified and implemented in the numerical simulation timely resolved. The simulation framework, therefore, represents a unique approach to tackle this complex erosion process of granular material. The different models, simulating the behavior of the fluid and solid, are validated analytically as well as experimentally by one’s self. The quantitative validation is executed by comparing simulated rate of penetrations (ROP) with measured ones during tests with potential geothermal reservoir rocks.
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