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A Unified Model for Predicting Particle Settling Velocity in Pipe, Annulus and Fracture

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Abstract : Transports of solid particles through the drill pipe, drill string-hole annulus and hydraulically generated fractures are important dynamic processes encountered in oil and gas well drilling and completion operations. Different from particle transport in infinite space, the transports of cuttings, proppants and formation sand are hindered by a finite boundary. Therefore, an accurate description of the particle transport behavior under the bounded wall conditions encountered in drilling and hydraulic fracturing operations is needed to improve drilling safety and efficiency. In this study, the particle settling experiments were carried out to investigate the particle settling behavior in the pipe, annulus and between the parallel plates filled with power-law fluids. Experimental conditions simulated the particle Reynolds number ranges of 0.01-123.87, the dimensionless diameter ranges of 0.20-0.80 and the fluid flow behavior index ranges of 0.48-0.69. Firstly, the wall effect of the annulus is revealed by analyzing the settling process of the particles in the annular geometry with variable inner pipe diameter. Then, the geometric continuity among the pipe, annulus and parallel plates was determined by introducing the ratio of inner diameter to an outer diameter of the annulus. Further, a unified dimensionless diameter was defined to confirm the relationship between the three different geometry in terms of the wall effect. In addition, a dimensionless term independent from the settling velocity was introduced to establish a unified explicit settling velocity model applicable to pipes, annulus and fractures with a mean relative error of 8.71%. An example case study was provided to demonstrate the application of the unified model for predicting particle settling velocity. This paper is the first study of annulus wall effects based on the geometric continuity concept and the unified model presented here will provide theoretical guidance for improved hydraulic design of cuttings transport, proppant placement and sand management operations.

Keywords : wall effect, particle settling velocity, cuttings transport, proppant transport in fracture
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