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Cross Flow Filtration of Viscoplastic Suspensions, a Robust Mathematical model

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The flow of suspension in conduits with large aspect ratios has always been a topic of pivotal importance in a wide range of applications, including but not limited to cardiovascular flows, slurry transport, filtration, etc. Rheological complexities of suspensions, such as its dependency on the volume fraction of solids, possibility of formation of solid cake, and the migration of particles have challenged researchers in their studies. In addition, the presence of particles modifies local strain rates and shear rate, subsequently, which necessitates meticulousness for if the suspending fluid has shear-dependent rheology. Besides, as the carrying fluid exhibits yield stress behavior,the possibility of plug formation may affect the flwo characteristics, such as shear-induced migration of particles, which necessitates a proper track down of yield surface.

The occurrence of cross-flow filtration, in which only the liquid content can pass through the walls, makes the dynamics of the solid phase, and so the suspension, and also the yield surface more complicated.

This paper proposes a mathematical model for the cross-flow filtration of viscoplastic suspensions, in a continuum framework. Using the Suspension Balance Model and homogenization approach, we consider the particle migration, and local shear effects, respectively. Our model takes the transition from suspension flow into a packed bed formation and the possibility of interstitial flow into account.

We base our model on Transversal Flow Equilibrium (TFE) to accurately depict the yield surface, while considering the effect of the reduction of the flow-rate due to the filtration. TFE allows considering the plug area as strictly unyileded.

Different in-flow conditions, including constant flow rate and pressure, are explored in this model, allowing the exploration of various phenomena such as dispersion and stoppage mechanisms.

This paper investigates the flow and penetration of a viscoplastic suspension in a long permeable parallel/converging plate geometry under different conditions, and discusses the effect of different parameters on the penetration length and time, and the stoppage mechanisms in various scenarios over relevant ranges.

References

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