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NEW NETWORK MODELS FOR YIELD STRESS FLUID FLOWS IN POROUS MEDIA

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ABSTRACT

In this work, new network models are developed to address the flow of yield stress fluids in porous media. The analogous flow behavior in a Hele-Shaw cell is exploited to develop the network models, through implementing a 2D gap-averaged (2DGA) model and constructing a regular network of pores and throats. Although the network structures were typically developed through a tessellation process in order to divide the pore space into non-overlapping regions, in this work, the constructed network is built to represent the Hele-Shaw cell geometry. Since the flow in a Hele-Shaw cell is inherently not 2D, the efficient construction of a network is a challenge. We introduce a novel flow law that relates the flow rate to the pressure difference along a throat, which also incorporates the effects of flow rheology, e.g. the yield stress, and the Hele-Shaw geometry. We develop optimization problems using a variational formula and implementation of an augmented Lagrangian method. We consider a staggered mesh constructed by the primal and dual graphs that connect the streamfunction and pressure nodes, respectively. For the network modeling, the pressure nodes represent the pores while the throats are the cell edges connecting the pressure nodes. We introduce two network models I and II, which differ in their optimization problems. In network I, the optimization problem is conducted along the throats while in network II it is solved at the pores. Although the network model I provides a more intuitive framework for network modeling, for our specific flow problem, its predictions do not converge to the results obtained from a continuum model. On the other hand, the predictions of network II show an excellent convergence to those of the continuum model. This is mainly associated with the distinct optimization problems solved for the two developed network models. In addition, the constructed network structure may contribute to the underpredictions made by the network I, since for our specific flow problem the main pressure gradient is perpendicular to the vertical throats. The ability of network I to handle the optimization problem at each throat independently is a significant strength of this model, which, when combined with an optimized network structure, may provide accurate predictions. Such a strength can be further exploited to conduct the network modeling for more complex unstructured and 3D network structures.