DISPLACEMENT FLOWS OF SHEAR THINNING FLUIDS IN A VERTICAL ANNULUS

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ABSTRACT

Displacement flows occur in construction of oil and gas wells, when the drilling mud is replaced with a cement slurry all along the annular gap between the steel casing and newly exposed rock formation. A complete and durable layer of cement that seals hydraulically, is the foremost goal of the primary cementing job. Failure to seal the well causes gas leakage, which may come from the target reservoir or an intermediate zone. There is acute current interest in such leakage due to greenhouse gas (GHG) emission implications, both environmentally and politically. Thus, a better understanding of all cementing processes is necessary and important, especially focusing on the rheology and mechanics of fluids.

To properly design, execute and evaluate a primary cement job, one must first understand the rheological properties of the fluids. Drilling muds and cement slurries are typically described as generalized Newtonian fluids, often with a yield stress and some shear thinning behaviour. In our previous studies[1,2,3,4], both experimental and computational directions have been followed, using Newtonian fluid pairs for simplicity. Amongst the main results is the general understanding that having a positive ratio of displacing to displaced fluid viscosity is beneficial in reducing the amount of dispersion within the annular gap. By extension, this implies that rheology does affect displacement, and our aim here is to understand the simplest such scenarios, where the fluids are shear-thinning. Are there practical situations in which rheology has a dominant effect on the displacement, or is it always secondary?

In this work, we present both experimental and computational results of displacement flows in a vertical eccentric annulus, using combinations of shear thinning and Newtonian fluids, as is representative of cement-preflush or preflush-mud pairings. In experimental study, Xanthan gum (XG) is used as the shear-thinning fluid. Glycerol and sugar are used to change the density and viscosity of the fluids. A high-resolution Malvern Kinexus Ultra+ rheometer with parallel plates is employed to characterize the XG solutions, and the result can be fitted to the Power-law model. The experiments were carried out in a dimensionally scaled laboratory set-up[4]. As comparisons, we ran a series 3-D numerical simulations by solving the full Navier-Stokes equations and concentration advection equation. A power law model is used for non-Newtonian

fluids. We have found that using shear thinning fluids yields similar flow trends as the Newtonian fluids, if other parameters are maintained the same. The buoyancy force and eccentricity are still dominant in controlling the displacement efficiency. The shear thinning rheology starts to play a secondary role when the flow rate increases, but is still not distinct from that of purely viscous flows.

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