Invasion of fluids into a gelled fluid column: yield stress effects

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Abstract

We study the invasion of a Newtonian fluid into a vertical column of yield stress fluid through a small hole, using both experimental and computational methods. This serves as a simplified model for understanding invasion of gas into cemented wellbores. We find that the invasion pressure must exceed the static pressure by an amount that depends linearly on the yield stress of the fluid and that (for sufficiently deep columns) is observed to increases with the height of the yield stress column. However, invasion pressures far less than the Poiseuille-flow limit are able to yield the fluid, for sufficiently small hole sizes. Observed experimental behaviours in yielding/invasion show a complex sequence of stages, starting with a mixing stage, through invasion and transition, to fracture propagation and eventual stopping of the flow. Precise detection of invasion and transition pressures is difficult. Invasion proceeds initially via the formation of a dome of invaded fluid that grows in the transition stage. The transition stage appears to represent a form of stress relaxation, sometimes allowing for a stable dome to persist and at other times leading directly to a fracturing of the gel. The passage from initial invasion through to transition dome is suggestive of elasto-plastic yielding, followed by a brittle fracture. Computed results give qualitative insight into the invasion process and also show clearly the evolution of the stress field as we change from local to non-local yielding.

Key words: Well integrity, gas migration, yield stress fluid