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Intrusion between rigid plates applied to flow between boudins

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The study of ex- or intrusion flow between quasi rigid plates is of relevance to a variety of geological settings: channel flow in orogeny, subduction channels, and flow between boudins. The problem can be solved analytically (Nadai (1963), Jaeger (1969), Dieter (1986), and others), but this solution cannot account for plates of finite length and power-law rheology of the materials, both of which are important for geological systems. Using a numerical modeling approach (FEM) we investigate the main factors that affect the flow of material between rigid plates. Systematic runs where performed to study the validity of the analytical solution and how it compares to the numerical solution. In the numerical setup two boudins of height $2h$ = 0.98 with aspect ratio equal to 5 are separated by a gap of width $2w$. The gap ratio (gap width/boudin height = $h = w$) was varied systematically between 0.01 and 2.0. The (background constraint) effective matrix viscosity μ_{matrix} was kept constant at 1, while the power-law coefficient n_{matrix} was varied between 1, 3 and 10. The viscosity and power-law coefficient of the boudins were kept at constant at μ_{boudin} = 10e5 and n_{boudin} = 1, respectively. The box was deformed with pure shear horizontal extension. The boundaries are geometrically placed far from the gap to avoid any boundary effects. To assure accurate results convergence testing was performed with respect to number of elements in the gap, the convergence of power-law iterations, and compressibility.

The results show that the analytical solutions for flow between rigid plates also hold for relatively large gap ratios. Power-law fluids do not deviate significantly from the analytical solution for a Newtonian fluid for all gap ratios in terms of flow velocities, but do differ in terms of pressure. The pressure and velocity deviation of the power-law fluids are largely unaffected by power-law coefficient. The power-law fluids are characterized by a strong a "plug flow" at small gap ratios and the "plug flow" effect increases with power-law coefficient.

For power-law fluids ($n > 1$) the initial opening of a fracture with very small gap ratio creates large vertical velocities at the fracture tip and a large lateral spreading velocity of the fracture, thus allowing for material from the ambient matrix to be sucked into the fracture. For Newtonian fluids there is a lower gap ratio boundary of 0.05 (for the investigated boudin viscosity) where it becomes harder for material from the ambient matrix to be sucked into the gap. Below this limit the forces become very large for small linear viscous gaps and they cause deformation of the “rigid” boudins and therefore deviations from the analytical solution. However, the analytical solution is generally, and especially if only velocities are analyzed, a good approximation for plates of finite length, i.e. gap ratios, and also non-linear materials. Since the power-law fluids cause much smaller stresses/pressures, it is easier to separate the plates if there is a power-law fluid in between, because less force is needed.

References

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