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Symmetry analysis and exact solutions of a model describing viscous fingering induced by a chemical reaction

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We study a mathematical model describing viscous fingering induced by the chemical reaction $A + B \to C$, introduced in [T. Gerard and A. De Wit, Phys. Rev. E, 2009]. The model couples the concentrations of the reactants, $u(t, x, y)$ and $v(t, x, y)$, and their product, $w(t, x, y)$, with the pressure $p(t, x, y)$ and the two-dimensional velocity field $U = (U_1, U_2)$, and is given by

$$\nabla \cdot U = 0,\ \kappa \nabla p = -\mu(w)U,\ u_t + U \cdot \nabla u = d_1 \triangle u - kuv,$$
$$v_t + U \cdot \nabla v = d_2 \triangle v - kuv,\ w_t + U \cdot \nabla w = d_3 \triangle w + kuv.$$

The above system is investigated by means of the classical Lie symmetry approach. A Lie symmetry classification is obtained for different parameter cases, and the resulting symmetries are used to construct exact solutions. In the case of radially symmetric stream functions, several families of exact solutions are derived. These solutions make it possible to analyze the evolution of the reactant and product concentrations in both space and time and provide an analytical description of the corresponding viscous-fingering dynamics.

The presented results were obtained in collaboration with R. M. Cherniha.

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