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Temporal and Spatio-Temporal Stability Analyses in Mixed Convection of a Viscoelastic Fluid in a Porous Medium

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Abstract : The stability of mixed convection in a Newtonian fluid medium heated from below and cooled from above, also known as the Poiseuille-Rayleigh-Bénard problem, has been extensively investigated in the past decades. To our knowledge, mixed convection in porous media has received much less attention in the published literature. The present paper extends the mixed convection problem in porous media for the case of a viscoelastic fluid flow owing to its numerous environmental and industrial applications such as the extrusion of polymer fluids, solidification of liquid crystals, suspension solutions and petroleum activities. Without a superimposed through-flow, the natural convection problem of a viscoelastic fluid in a saturated porous medium has already been treated. The effects of the viscoelastic properties of the fluid on the linear and nonlinear dynamics of the thermoconvective instabilities have also been treated in this work. Consequently, the elasticity of the fluid can lead either to a Hopf bifurcation, giving rise to oscillatory structures in the strongly elastic regime, or to a stationary bifurcation in the weakly elastic regime. The objective of this work is to examine the influence of the main horizontal flow on the linear and characteristics of these two types of instabilities. Under the Boussinesq approximation and Darcy's law extended to a viscoelastic fluid, a temporal stability approach shows that the conditions for the appearance of longitudinal rolls are identical to those found in the absence of through-flow. For the general three-dimensional (3D) perturbations, a Squire transformation allows the deduction of the complex frequencies associated with the 3D problem using those obtained by solving the two-dimensional one. The numerical resolution of the eigenvalue problem concludes that the through-flow has a destabilizing effect and selects a convective configuration organized in purely transversal rolls which oscillate in time and propagate in the direction of the main flow. In addition, by using the mathematical formalism of absolute and convective instabilities, we study the nature of unstable three-dimensional disturbances. It is shown that for a non-vanishing through-flow, general three-dimensional instabilities are convectively unstable which means that in the absence of a continuous noise source these instabilities are drifted outside the porous medium, and no long-term pattern is observed. In contrast, purely transversal rolls may exhibit a transition to absolute instability regime and therefore affect the porous medium everywhere including in the absence of a noise source. The absolute instability threshold, the frequency and the wave number associated with purely transversal rolls are determined as a function of the Péclet number and the viscoelastic parameters. Results are discussed and compared to those obtained from laboratory experiments in the case of Newtonian fluids.

Keywords : instability, mixed convection, porous media, and viscoelastic fluid
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