ABSTRACT

The Linear Stability of a Newtonian Fluid Overlying a Saturated Porous Layer

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Linear stability analysis is applied to a thin horizontal layer of Newtonian fluid superposing a saturated porous layer. The flat lower porous layer is bounded from below by a rigid impermeable surface. The upper fluid layer is assumed to have a free deformable surface. The system is subjected to an isothermal heat flux. Apart from stationary convection modes, oscillatory instability is possible in the upper Newtonian layer. The effects of the thickness and permeability of the lower porous layer on the onset of these unstable modes are assessed.

We first use Marangoni boundary conditions to study the effect of the free deformable upper surface on stability. The fluid layer is taken to be less than 0.1 centimetres thick, and the gravity effect can be ignored. The onset of stationary convection is almost immediate when the effect of the gravity is ignored. By varying the size of the depth ratio, we observe that the system becomes more stable for thicker porous layers when the gravity effect is omitted.

Next we repeat the analysis taking into account the gravity effect as well as surface tension effects. This is the so-called Bénard-Marangoni problem. A complete numerical analysis is carried out, where the critical conditions for the onset of stationary and oscillatory instabilities are documented for the free upper Newtonian layer. The depth ratio of the thickness of the porous layer to that of the Newtonian fluid is found to have a destabilising effect on the onset of stationary convection, but a slight stabilising effect on oscillatory convection. We also find that the permeability of the porous layer can affect the stability characteristics of the system. Low permeability encourages overstability slightly, while making stationary convection less favourable.

In general, we find that stationary convection is much more affected by changes in the characteristics of the porous layer than overstability, and very little can be done to control the onset of oscillatory convection for the parameter range investigated.

Keywords: Donna Marie Giselle Comissiong, linear stability, overstability, stationary convection, oscillatory convection.