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CONVECTIVE FLOW OF A BINGHAM FLUID IN AN INTERNALLY-HEATED ENCLOSURE

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ABSTRACT A Bingham fluid exhibits shear when the shear stress is larger than the yield stress of the fluid. When such a fluid saturates a porous medium, it flows only when the applied pressure gradient exceeds a threshold gradient. There is a rich literature associated with the modelling of the isothermal flows of Bingham fluids in porous media, but very little is presently known about the effect of buoyancy forces apart from the fact that the buoyancy force must be sufficiently large to overcome the yield threshold.

Attention is focussed on the effect of a uniform internal heat generation within a porous rectangular cavity when all four bounding surfaces are held at the same temperature. When the porous medium is saturated by a Newtonian fluid then convection takes place at all nonzero values of the Darcy-Rayleigh number, *Ra*, and at moderate values of *Ra*, convection takes the form of two contra-rotating cells with flow down the cold sidewalls. However, when the enclosure is saturated by a Bingham fluid, then we find that no flow takes place when *Ra* is sufficiently small because buoyancy forces are too weak to overcome the yield threshold. There exists a critical value of *Ra* which depends on the aspect ratio of the enclosure and on the value of *Rb*, which may be described as a convective porous Bingham number. The largest buoyancy force arises halfway up each of the sidewalls and therefore it is at those places that convection begins, while the rest of the cavity remains stagnant. We find that this critical value of *Ra* increases with *Rb*, but decreases with aspect ratio (defined as the ratio of the width and the height). As *Ra* increases further, the proportion of the cavity within which convection flow exists also increases, but stagnant regions still exists and are found within the middle of the two circulations and near the midpoints of the upper and lower surfaces.

The numerical solutions are obtained using a second order accurate finite difference methodology where convergence is accelerated using the Full Approximation Scheme multigrid method. The presence of the yield surfaces, which mark the boundaries of stagnant regions, is modelled by means of a regularisation of the yield threshold (see Rees 2016).

The present study extends the work of Rees (2016) to one involving an internally-heated cavity, and the work of Banu et al. (1998) to one with a yield stress fluid.

Banu, N., Rees, D.A.S., Pop, I. [1998], Steady and unsteady convection in rectangular porous cavities with internal heat generation, *Proceedings of the 11th International Heat Transfer Conference (August 1998 Kyongju, Korea) Vol. 4 pp375-380.*

Rees, D.A.S. [2016], The convection of a Bingham fluid in a differentially-heated porous cavity, *International Journal of Numerical Methods in Heat and Fluid Flow*, Vol. 26, pp. 879-896.