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There appears to be a change of position on several issues by Nield. We reiterate our points in response to his. (a) Frankly, we see little difference between Nield's statement (a) and "Nield (1991) mentions that if the variable porosities are not accounted for, then use of the Brinkman equation leads to no benefit," especially in light of the conflicting comments on the Brinkman extension made by Nield previously. Nevertheless, it is good to see that Nield is now in agreement with the use of the Brinkman extension, the position which we have invariably held. (b) Our point is not that Nield is wrong. We said his statement can be misleading since it gives an incorrect impression. In some cases, the Brinkman extension could be used without limiting the porosity to higher than 0.6 (c) It does not matter where we have placed our argument. Our point is that his "ideal medium" is by no means a regular porous medium and, as such, the subsequent remarks aren't relevant.

On the 2D issue, Nield has missed the crucial importance of a direct physical interpretation of the relevant averaged quantities. The line averaged physical quantities in the transverse direction that is normal to the flow are used to properly interpret these results. Regarding the effective viscosity, we have never claimed that it "can be determined simply by averaging," nor that averaging won't involve loss of information. The reason we always set the effective viscosity equal to the fluid viscosity is, as we had mentioned at various times, due to the lack of rigorous data and provides good agreement with past experimental data (Lundgren 1972; Neale and Nader 1974).

Regarding the convective term, Nield has changed his position. Initially, Nield states that the convective term should not be there, however, later Nield (1994) justifies its use under some cases. Our position, which has never changed, is the correct one as it stands. This term is responsible for the momentum boundary layer development. This developing length for most applications is small and can be ignored (Vafai and Tien 1981).

With respect to the porous/fluid interface, the arguments stand. The confusion appears to be Nield's as we have not "confused tangential and normal coordinates". In Vafai and Kim (1995) and our other porous/fluid interface works, always a 2D, incompressible, isotropic porous medium in which the effective and the fluid viscosities are equal is considered. Equations are correct as they stand for the cited conditions. We haven't advocated against using the Beavers-Joseph condition, it is just that in our approach we don't need to use this condition (Vafai and Thiyagaraja 1987). Using the generalized equation to model the flow gives consistent results with the use of Beavers-Joseph condition. Incidentally, Nield's comments on the use of this condition appear contradictory to what he is attempting to state in his first paragraph. We don't see the wisdom behind Nield's last set of statements. There is a need for systematic and detailed data.

**References**

- Lundgren, T. S. 1972. Slow flow through stationary random beds and suspensions of spheres. *J. Fluid Mech.*, **51**, 273–299
- Neale, G. and Nader, W. 1974. Practical significance of Brinkman's extension of Darcy's Law: coupled parallel flows within a channel and a boundary porous medium. *Can. J. Chem. Eng.*, **52**, 470–478
- Nield, D. A. 1991. The limitations of the Brinkman-Forchheimer equation in modeling flow in a saturated porous medium and at an interface. *Int. J. Heat Fluid Flow*, **12**, 269–272
- Nield, D. A. 1994. Modelling high speed flow of a compressible fluid in a saturated porous medium. *Transport Porous Media*, **14**, 85–88
- Vafai, K. and Kim, S. 1995. On the limitations of the Brinkman-Forchheimer-extended Darcy equation. *Int. J. Heat Fluid Flow*, **16**, 11–15
- Vafai, K. and Thiyagaraja, R. 1987. Analysis of flow and heat transfer at the interface region of a porous medium. *Int. J. Heat Mass Transfer*, **30**, 1391–1405
- Vafai, K. and Tien, C.L. 1981. Boundary and inertia effects on flow and heat transfer in porous media. *Int. J. Heat Transfer*, **24**, 195–203

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