Comments on "Viscous-dissipation effects on the heat transfer in a Poiseuille flow" by O. Aydin and M. Avci

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This note comments on an article by Aydin and Avci [1]; the paper treats the same problem as that studied analytically by Ou and Cheng [2] and numerically by Hwang et al. [3], namely the effects of viscous dissipation on forced convection in a parallel plate channel. In Aydin and Avci [1] the papers [2-3], that their results differ dramatically from those of [1], are not mentioned. Both of [1] and [2] treat the case of boundaries with constant heat flux (CHF) and constant temperature (CWT), (called the H and the T boundary condition, respectively, by Shah and London [4]). Both the CHF and CWT cases are considered in [2]; not only the developing case but also the fully developed solutions and the results are well documented in relatively old reference books, see pages 176-177 and 183-184 of Shah and London [4] for T and H cases, respectively. Since [1] covers the same ground as [2] and [3] one can question the need for [1].

The presentation of the CHF case in [1] is confusing. The differential equation, Eq. (7) in [1], contains a coefficient *a* that does not appear in the solution, Eq. (10). The authors' definition of the constant *a* leads to an erroneous expression for the longitudinal bulk temperature gradient when compared with Eq. (281) of [4]. In [1] there appears to be no mention of the necessity to satisfy the First Law of Thermodynamics (conservation of energy when one moves from one cross-section to another downstream cross-section; see [5-9]). Mainly for this reason the coefficient multiplied by Br_q appearing in Eq. (20) of [1] differs from that of [2] and [4] as the Nusselt number of [1] reads

$$Nu=70/(17+24Br_q) \quad (1)$$

while that of [4], in Aydin and Avci [1]'s terminology, reads

$$Nu=70/(17+27Br_q) \quad (2)$$

Clearly, this is not a typographical error (as confirmed by Table 2 of [1]).

Moreover, one observes that the results of [1] are internally inconsistent. With the CHF case one can easily verify that the fully developed Nusselt number based on the developing and the fully developed region are different. For example, based on Eq. (20) one expects that Nu_{wm} =14 for Br_q = -0.5 while Fig. 8-b predicts a value for the fully developed Nusselt number which is quite under 14, say Nu_{wm} =13.

When it comes to the CWT case, in the light of [2], as approved by later reports of [10-19] for similar problems, one knows that the fully developed Nusselt number is independent of the amount of internal heat generation (reflected in *Br* in this case). However, this is not what Table 1 of [1] indicates.

Furthermore, examining Fig. 9, one notes that Z=0.7 is still in the thermally developing region (as the Nusselt number is yet to increase). For non-zero values of *Br* one expects the *Nu* plots to merge to each other and become independent of *Br;* see [10-19] for similar problems.

Another source of confusion in [1] is the multiple definitions of the Brinkman number, being Br, Br_e, and Br_q. This could be helpful only if the authors could correlate them; that is actually a very easy task. For example, with the CWT case, the authors had the numerical solution for the developing region and they could numerically obtain $(T_e\text{-}T_w)$ in terms of $(T_c\text{-}T_w)$ at Z=0. As a rough approximation one can use their results of Z=0.1 instead of Z=0 to observe that, based on Fig. 7-b and definition of θ in Eq. (21), for example, with Br_e=-0.5 one has

$$(T_c - T_w) \approx 0.625 (T_e - T_w) \quad (3)$$

leading to

$$Br_e = 0.625 Br \quad (4)$$

One can now compare the results of Table 1 with those of Fig. 9. In view of the above, Br_e=0.5 corresponds to $Br \approx 0.8$ for which, according to Table 1 of [1], the fully developed Nusselt number should be in the range $3.185 < Nu_{wm} < 3.715$ while according to Fig. 9 $7.5 < Nu_{wm} < 10$. In fact, according to [4], one knows that Nu_{wm} =8.75 in the fully developed region.

Besides, according to Fig. 7 of [1], T_c changes with Z. Then the question arises as to whether their Brinkman number defined by Eq. (8) is independent of Z. One knows that when Br is a function of Z then Eq. (17) is not an ordinary differential equation. Such an equation is a partial differential one and the appropriate solution technique is different from the one undertaken by the authors in [1].

Another moot point is that in [1] there is no discussion of grid independence or code validation so that the reliability of the numerical results is in question.

These give us the impression that the results are not dependable and the reader should be careful when it comes to apply the results of [1] in practice. Again, in view of the previously published work by Ou and Cheng [2], one can question the need to cover the same ground again.

Acknowledgments

Financial support provided by The University of Queensland in terms of UQILAS, Endeavor IPRS, and School Scholarship is appreciated.

References

[1] Aydin, O., Avci, M., Viscous-dissipation effects on the heat transfer in a Poiseuille flow, Applied Energy 83 (2006) 495-512.

[2] Ou, J.-W., Cheng, K.C., Effects of pressure work and viscous dissipation on Graetz problem for gas flows in parallel-plate channels. Wärme- und Stoffübertragung 6 (1973) 191-198.

[3] Hwang, C.L., Knieper, P.J., Fan, L.T., Effects of viscous dissipation on heat transfer parameters for flow between parallel plates. Z. Angew Math. Phys. 16 (1965) 599-610.

[4] Shah, R.K., London, A.L., Laminar flow forced convection in ducts, Advances in Heat Transfer Supplement 1, New York: Academic Press; 1978.

[5] Nield, D.A., A note on a Brinkman-Brinkman forced convection problem, Transport Porous Media 64 (2006) 185–188

[6] Hooman, K., Gurgenci, H., Merrikh, A.A., Heat transfer and entropy generation optimization of forced convection in a porous-saturated duct of rectangular cross-section, Int. J. Heat Mass Transfer 50 (2007) 2051-2059.

[7] Nield, D.A., Kuznetsov, A.V., Xiong, M., Effects of viscous dissipation and flow work on forced convection in a channel filled by a saturated porous medium, Transport Porous Media 56 (2004) 351-367.

[8] Hooman, K., Pourshaghaghy, A., Ejlali, A., Effects of viscous dissipation on thermally developing forced convection in a porous saturated circular tube with an isoflux wall, Appl. Math. Mech. – English edition 27 (2006) 617-626.

[9] Nield, D.A., Hooman, K., Comments on “Effects of viscous dissipation on the heat transfer in forced pipe flow. Part 1: both hydrodynamically and thermally fully developed flow, and Part 2: thermally developing flow” by O. Aydin, Energy Conv. Manag. 47 (2006) 3501-3503.

[10] Ranjbar-Kani, A.A., Hooman, K., Viscous dissipation effects on thermally developing forced convection in a porous medium: circular duct with isothermal wall, Int. Comm. Heat Mass Transfer 31 (2004) 897-907.

[11] Hooman, K., Gurgenci, H., Effects of viscous dissipation and boundary conditions on forced convection in a channel occupied by a saturated porous medium, Transport Porous Media, in press (doi:10.1007/S11242-006-9049-4)

[12] Hooman, K, Gorji-Bandpy M., Laminar heat transfer to a highly viscous fluid flow in entrance region of a porous saturated circular tube with uniform wall temperature, Appl. Math. Mech. – English edition 26 (2005) 578-593.

[13] Hooman, K., Haji-Sheikh, A., Nield, D.A., Thermally developing Brinkman-Brinkman forced convection in rectangular ducts with isothermal walls, Int. J. Heat Mass Transfer, in press. (doi:10.1016/j.ijheatmasstransfer.2007.01.011)

[14] Hooman, K., Ejlali, A., Entropy generation for forced convection in a porous saturated circular tube with uniform wall temperature, Int. Comm. Heat Mass Transfer 34 (2007) 408-419.

[15] Ou, W.J., Cheng, K.C., Viscous dissipation effects on thermal entrance region heat transfer in laminar and turbulent pipe flows with uniform wall temperature, AIAA Paper No. 74-743 or ASME Paper No. 74-HT-50, 1974, 1-7.

[16] Nield, D.A., Kuznetsov, A.V., Xiong, M., Thermally developing forced convection in a porous medium: parallel plate channel with walls at constant temperature, with longitudinal conduction and viscous dissipation effects, Int. J. Heat Mass Transfer 46 (2003) 643-651.

[17] Haji-Sheikh, A., Minkowycz, W.J., Sparrow, E.M., A numerical study of the heat transfer to fluid flow through circular porous passages, Num. Heat Transfer A 46 (2004) 929-955.

[18] Haji-Sheikh, A., Minkowycz, W.J., Sparrow, E.M., Green's function solution of temperature field for flow in porous passages, Int. J. Heat Mass Transfer 47 (2004) 4685-4695.

[19] Haji-Sheikh, A., Sparrow, E.M., Minkowycz, W.J., Heat transfer to flow through porous passages using extended weighted residuals method–A Green's function solution, Int. J. Heat Mass Transfer 48 (2005) 1330-1349.