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LETTER TO THE EDITORS

Comments on "The optimal spacing of parallel plates cooled by forced convection"

IN THEIR recent paper on the optimal spacing between plates cooled by forced convection, Bejan and Sciubba [1] showed that when $Pr \gtrsim 1$ the spacing is governed by the new dimensionless group:

$$p = \frac{\Delta P \cdot L^2}{\mu \alpha}. \tag{1}$$

In this group, ΔP, L, μ and α are the pressure difference between the two ends of the channel, the flow length, and the viscosity and thermal diffusivity of the fluid. More recently, the same group appeared in the solutions to other electronic cooling problems involving forced convection, where it was labeled Π instead of p (e.g. ref. [2], p. 328).

The authors failed to mention that there have been two earlier instances in which groups similar to equation (1) have been identified and named. In 1988, in a scale analysis of the wall jet problem, Bhattacharjee and Grosshandler [3] defined the group

$$Be = \frac{\Delta P \cdot L^2}{\mu \nu} \tag{2}$$

where ν is the kinematic viscosity. They named this group 'the Bejan number' in view of Bejan's contributions to the scale analysis of convection.

An independent proposal was made in 1989 in the field of second law (exergy) analysis of heat exchangers, where Paoletti *et al.* [5] associated the symbol *Be* and the 'Bejan number' name with the ratio $S_{\text{gen},\Delta P}/S_{\text{gen},\Delta T}$, also known as the irreversibility distribution ratio [6]. In this ratio, $S_{\text{gen},\Delta P}$ and $S_{\text{gen},\Delta T}$ are the duct entropy generation rates due to the end-to-end pressure drop and the wall-stream temperature difference. It can be shown that this ratio too is proportional to the group formed in equation (1).

A third and most recent coincidence is that the group defined in equation (1) governs all the phenomena of contact melting and lubrication, in both internal and external contact configurations [7].

In summary, the dimensionless group $\Delta P \cdot L^2/(\mu\alpha)$ is the essential number in at least four areas of heat transfer: electronic cooling, scale analysis of forced convection, second law analysis of heat exchangers, and contact melting and lubrication. In each area this group is tied to Bejan's own work, and on two unrelated occassions it has been given the Bejan name. It seems appropriate then to follow Bhattacharjee and Grosshandler's proposal [3], but to modify it just slightly and define the Bejan number as in equation (1),

$$Be = \frac{\Delta P \cdot L^2}{\mu \alpha}. \tag{3}$$

In the case of air cooled electronic packages ($Pr = 0.72$) there is almost no difference between equations (2) and (3). The definition (3) is preferrable to equation (2) because of the many applications documented in the electronic cooling and contact melting literatures, and because in these applications the Prandtl number is of order 1 or greater. To paraphrase Bhattacharjee and Grosshandler [3], the *Be* group defined by equation (3) is the forced convection ($Pr \gtrsim 1$) analog of the Rayleigh number for natural convection in $Pr \gtrsim 1$ fluids.

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