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Letter to the Editor

Comments on "Numerical investigation of laminar natural convection on a heated vertical plate subjected to a periodic oscillation" by X.R. Zhang, S. Maruyama and S. Sakai

The periodic free convection heat transfer can take place in different forms, such as (a) periodic free convection subjected to periodic surface temperature oscillation with time, (b) free convection with gravity fluctuation known as g-jitter, and (c) the present problem of vibrating surfaces. In these kinds of problems, the unsteady continuity, momentum and energy equations must be solved with the assumed initial and boundary conditions. Zhang et al. [1] studied the free convection problem when the vertical plate itself oscillates. However, in this case, it is of practical importance to know the force required to oscillate the vertical plate. Therefore, it is necessary to add/consider the results for the local instantaneous friction coefficient and space-time average friction coefficient, which can be defined respectively as:

$$Cf_{x,t} = \frac{\tau_w}{\frac{1}{2}\rho u_c^2} = \frac{2\nu(\partial u/\partial y)_{y=0}}{u_c^2} \tag{1}$$

$$\overline{Cf} = \frac{1}{2\pi L}\int_0^{2\pi}\int_0^L Cf_{x,t}\,\mathrm{d}x\,\mathrm{d}\phi \tag{2}$$

where all the symbols are identical to that used by Zhang et al. [1]. As regarding u_c the characteristic velocity, it is defined by many authors as the maximum flow velocity in the boundary layer, where in the free convection of stationary plate $u_c = \sqrt{g\beta x(T_w - T_\infty)}$ (see for example Cebeci [2]). In the present problem, however it can be assumed that $u_c = 2\pi f x_o$, which is the maximum velocity in most of the cases considered (refer to Fig. 6 in [1]).

Zhang et al. [1] have assumed that the plate temperature is raised suddenly with simultaneous sudden plate movement in its own plane; in this case the Nusselt number and the friction coefficient will become infinity. After some periods of plate oscillation the Nusselt number and the friction coefficient oscillation become periodic. The results presented by Zhang et al. [1] in Fig. 5b show the periodic oscillation of the Nusselt number only whereas no mention has been made in respect of the condition for the periodic oscillation state of the Nusselt number. In this context it may be mentioned that such condition has been specified by Saeid [3] and Saeid and Mohamad [4] for periodic free convection problems with surface temperature oscillation. It is recommended that in the present problem it can be assumed that the periodic state is achieved when the space-time average Nusselt number and the space-time friction coefficient defined in Eq. (2) eventually become constant or the difference in these values for two different periods is within small tolerance.

In the mathematical formulation of the problem in [1], the solution domain is considered to be two-dimensional rectangular geometry in which the vertical plate of zero thickness is kept in the center of the solution domain. This is unnecessary duplication of the solution domain, since the flow will be symmetrical around the vertical plate. It is possible to consider half of the solution domain and keep the vertical plate at one of the sides of the two-dimensional rectangular geometry. The boundary conditions in this case would be that the gradient of all the dependent variables are zero across the axis of symmetry except the control volumes representing the vertical plate.

In the Method of solution, Zhang et al. [1] have selected to solve the original Eqs. (1)–(3) and not the dimensionless set. Furthermore, the time step taken to be 0.01 s in all the cases as uppermost value on balance of convergence and computational time. This value gives excellent results in Figs. 2 and 3 in [1], however, for high frequency the period of the oscillation will be small and hence the time step need to be smaller than 0.01 s and vice versa. Usually in the periodic convection problems, the time step is made to be function of the frequency of the boundary condition oscillation. It may be noted that such time step is used by Saeid [3] and Saeid and Mohamad [4] for periodic free convection problems where:

$$\Delta t = 1/(Nf) \tag{3}$$

where Δt is the time step, N is the total number of time steps in one period ($N = 1000$ is used in [3] and [4]) and f is the frequency of the plate oscillation in Hz.

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