Int. J. Heat Mass Transfer. Vol. 27, No. 1, pp. 153–154, 1984
Pergamon Press Ltd. Printed in Great Britain

LETTERS TO THE EDITORS

COMMENTS ON 'A MECHANISTIC THEORY FOR HEAT TRANSFER BETWEEN FLUIDIZED BEDS OF LARGE PARTICLES AND IMMERSED SURFACES'

IN THE paper [1] the authors assume that in the absence of radiation the total heat transfer coefficient is the sum of conductive and convective components. Such use of heat transfer coefficients is not a good practice since heat transfer coefficients are meaningful only if the associated temperatures (or temperature differences) used in their definitions are known. If heat transfer coefficients are defined separately and temperature differences are not considered, summation can be confusing or even meaningless.

When several components of heat transfer are considered the preferred way is to sum up the heat fluxes. It can be then shown that the heat transfer coefficients and the associated dimensionless groups are only additive if the temperature differences used in their definitions are identical.

That mistakes can arise is apparent from the paper [1] where the temperature difference used in the definition of the conductive heat transfer coefficient is $T_s - T_{gp}$ but the temperature differences used in the definitions of the total and the convective heat transfer coefficients are most likely $T_s - T_b$. The latter temperature difference is not specified in the paper, but it is the temperature difference usually used and, furthermore, it is difficult to imagine that the former difference which contains one unknown parameter (τ_1, the particle residence time on the surface) would be employed.

The desire of the authors to eliminate the particle residence time from the calculations is the probable reason for using the temperature difference $T_s - T_{gp}$ in the definition of the conductive heat transfer coefficient. Since the particle residence time also appears in the conductive heat flux, their definition ensures that the particle residence time has a negligible influence on the conductive heat transfer coefficient.

The above manipulations and the whole level of the highly sophisticated mathematical treatment is incongruous compared with the relative crudity of the various assumptions used. Some clarifications are also required. For example, it is not clear if the conductive component is small as stated in the paper, or comparable with the convective component as stated elsewhere in the paper. Furthermore, the choice of the bed voidage is also confusing. Since the authors discuss in some detail the importance of the bed voidage variation in the vicinity of the surface, it seems inconsistent not to use the surface values in equations (3) and (38) which describe the behaviour near the surface.

Nevertheless, the paper does give very good agreement between the experimental results and the model. There are two possible reasons. First, the model contains an adjustable constant [C in equation (41)], and this constant was determined empirically. Secondly, and what is probably more important, the conductive contributions to heat transfer can be re-interpreted as follows:

The conductive heat flux, q_{cond}, can be written as:

$$q_{cond} = 1.06 \frac{k_g}{\delta} (T_s - T_b) f(\varepsilon),$$

where $f(\varepsilon)$ is a function of the bed voidage. This is equivalent to steady-state conduction across an approximately defined gas gap in the vicinity of the surface, with the outer gap temperature equal to the bulk bed temperature, T_b. (This would also imply that the first layer of particles does not heat up appreciably.)

Combination of such conductive mechanism with the authors' convective mechanism may give good agreement with experimental results, but it seems theoretically suspect.

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REFERENCE

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IT IS well known that the linear addition of the heat transfer coefficient or fluxes due to conduction, convection and radiation to get the total heat transfer coefficient or total heat transfer flux is an approximate procedure and more so for an unsteady-state than for a steady-state heat transfer process. In the context of the process considered in our paper [1] this is reasonably valid. It may be pointed out that this assumption has been generally made by workers in the field of fluidization and has been invariably substantiated by the reasonable agreement found between experiments and calculations made on a realistic model.

It is true that in the calculation of h_{cond} the temperature difference employed is $(T_w - T_{gp})$ on the basis of the stated assumption of our model [1] that for large particles all the resistance to heat transfer is confined to the first row of particles and the gas film thickness at the heat transfer surface. However, the detailed calculations revealed that the use of T_{gp} (instead of T_b) makes only a small difference, see equation (24) of ref. [1], and the gas film thickness plays a very significant role and is primarily responsible for the heat transfer resistance. It is, therefore, not quite inconsistent with the definitions of heat transfer coefficients based on $(T_w - T_b)$. Further, the choice of temperature is not critical to the calculation of Nu according to equation (40) of ref. [1] in this particular case where it appears only through the dimensionless parameters.

The use of the temperature difference, $T_w - T_{gp}$, in evaluating the average conduction flux, equation (21) of ref. [1], is considered an appropriate procedure and is not intended to eliminate the appearance of particle residence time in the formulation. The final result of our calculation reveals that h_{cond} is composed of two parts, namely, a steady-state