



Short communication

## Analogy between momentum and heat transfer in liquid–solid fluidized beds



Darko Jaćimovski<sup>a</sup>, Radmila Garić-Grulović<sup>a,\*</sup>, Željko Grbavčić<sup>b</sup>, Nevenka Bošković Vragolović<sup>b</sup>

<sup>a</sup> Institute for Chemistry, Technology and Metallurgy, University of Belgrade, Belgrade, Serbia

<sup>b</sup> Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, Serbia

### ARTICLE INFO

#### Article history:

Received 4 July 2014

Received in revised form 5 November 2014

Accepted 7 November 2014

Available online 15 November 2014

#### Keywords:

Fluidized bed  
Momentum transfer  
Heat transfer  
Mass transfer  
Analogy

### ABSTRACT

Wall-to-bed heat transfer in particulate fluidized beds of spherical particles was studied. Experiments were performed using spherical glass particles of 0.80–2.98 mm in diameter with water in a 25.4 mm I.D. copper tube equipped with a steam jacket.

Heat transfer data related to the fluid–particle interphase drag coefficient were obtained and compared with previous results for wall-to-bed mass transfer in fluidized beds [Bošković et al., Powder Technol., 79 (1994) 217].

All the data for momentum, heat and mass transfer in particulate fluidized beds of spherical particles, showed the existence of an analogy among these three phenomena.

© 2014 Elsevier B.V. All rights reserved.

Heat transfer in liquid–solid systems is a very important parameter to be considered in the design of equipment for different industrial applications. The design of equipment with fluidized beds is mainly based on the knowledge of the hydrodynamics and heat transfer between wall and fluidized beds. Numerous studies on wall-to-liquid heat transfer in particulate fluidized beds have been realized [1–6]. In these studies, the influence of different parameters, such as liquid velocity, particles size and voidage on heat transfer in fluidized beds was investigated.

The subject of the present research was the effect of particles on the wall-to-bed heat transfer. An attempt was made to establish analogy between heat transfer coefficients and fluid–particle interphase drag coefficient.

In a previous study, Bošković et al. [7] found that an analogy between mass and momentum transfer in liquid–solid fluidized beds exists. In addition, the dimensionless mass transfer factor in liquid-fluidized beds of active and inert particles and the dimensionless drag coefficient [8] were shown to be the same.

$$j_D^* = \beta^* \quad (1)$$

where  $j_D^*$  and  $\beta^*$  are given by,

$$j_D^* = \frac{j_D - j_{D1}}{j_{Dmf} - j_{D1}} \quad (2)$$

$$\beta^* = \frac{\beta}{\beta_{mf}} = 1 - C_2 + \frac{1}{\lambda} \sqrt{1 - \left( \lambda \frac{\varepsilon - \varepsilon_{mf}}{1 - \varepsilon_{mf}} + C_1 \right)^2} \quad (3)$$

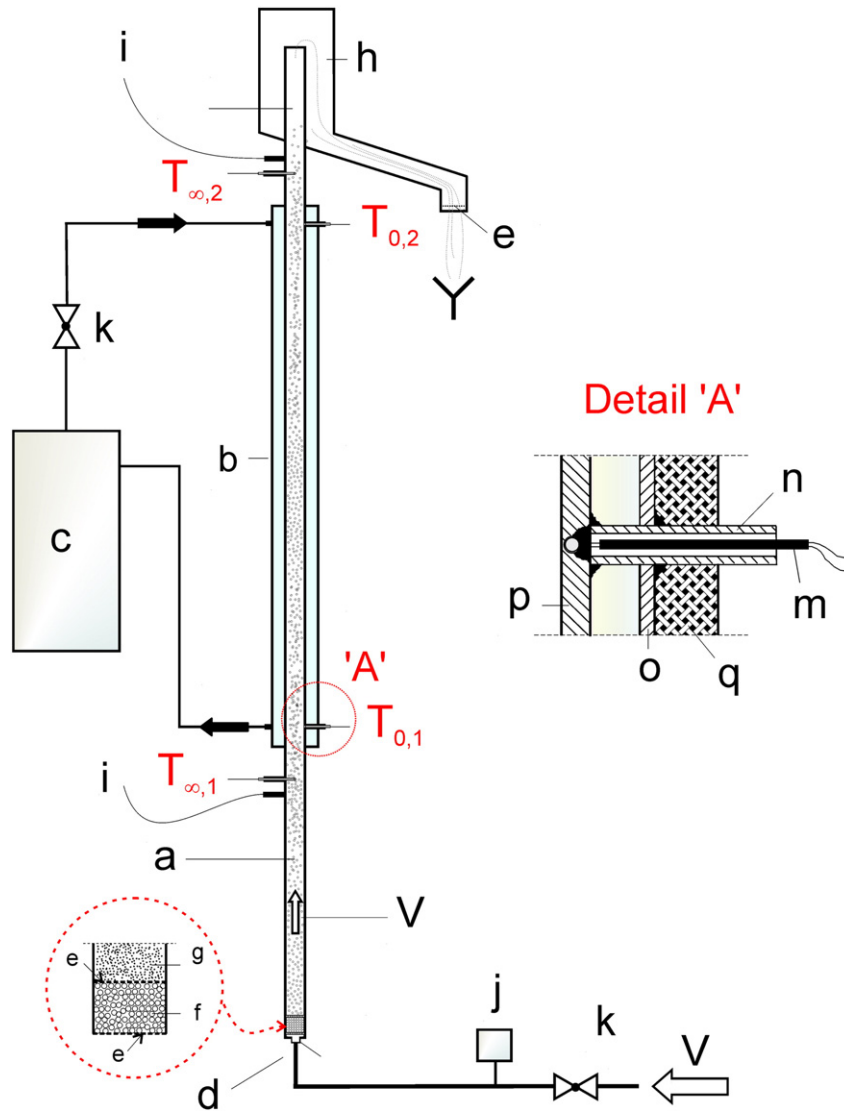
Wall-to-bed heat transfer in particulate fluidized beds of spherical particles was studied. Experiments were performed using spherical glass particles of 0.80, 1.11, 1.94 and 2.98 mm in diameter that were fluidized with water in a 25.4 mm I.D. copper tube equipped with a steam jacket. The schematic diagram of the experimental systems is shown in Fig. 1.

The fluid bed (a, Fig. 1) was the 27.4/25.4 mm OD/ID, 1360 mm long copper tube, equipped with a 700 mm long steam jacket (b). The heating section (b) was located far enough (320 mm) from the inlet nozzle (d) of the fluid bed. Water was introduced at the bottom of the bed.

The pressure gradient was measured using piezometers (i) and temperature was measured using Ni–Cr thermocouples. The wall temperature was determined at two points, at the inlet and at the exit of the heating zone;  $T_{01}$  and  $T_{02}$ . The junction points were filled with tin at about 0.2 mm from the inside of the tube wall, as shown schematically in Fig. 1 (detail A). The temperature of the fluidized bed was measured with thermocouples located along the tube axis ( $T_{\infty 1}$ ,  $T_{\infty 2}$ ). It was assumed that at the inlet and at the outlet of the heating zone, the particles and the fluid had the same temperature [2]. The heat transfer coefficient in the fluidized bed was calculated as [3]:

$$\alpha = \frac{G_f c_{pf} (T_{\infty 2} - T_{\infty 1})}{D_c \pi L_H \Delta T_{ln}} \quad (4)$$

\* Corresponding author. Tel.: +381 11 3370 500; fax: +381 11 3370 408.  
E-mail address: [garić@tmf.bg.ac.rs](mailto:garić@tmf.bg.ac.rs) (R. Garić-Grulović).



**Fig. 1.** Schematic diagram of the experimental fluidization system: (a) – fluid bed copper column, 25.4 mm i.d.; (b) – heating section, 700 mm in length; (c) – steam generator, 30 kW; (d) – inlet nozzle, 20 mm i.d.; (e) – screen; (f) – distributor; (g) – fluidized bed; (h) – overflow; (i) – pressure taps; (j) – flow meter; (k) – valve; (m) – Ni–Cr thermocouple; (n) – copper tube 8/6 mm; (o) – jacket wall; (p) – column wall; (q) – thermal insulation; V – inlet flow rate.

The mean logarithmic temperature difference in Eq. (4) is defined as:

$$\Delta T_{\ln} = \frac{(T_{0,2} - T_{\infty,2}) - (T_{0,1} - T_{\infty,1})}{\ln \frac{(T_{0,2} - T_{\infty,2})}{(T_{0,1} - T_{\infty,1})}} \quad (5)$$

A total of 156 data points for heat transfer coefficients were collected in the experimental runs. The characteristics of the particles and the employed range of experimental conditions are given in Table 1. Water was used as the fluidizing medium, and its characteristics were determined as temperature dependencies [9]:  $\mu = f(T_m)$ ,  $\rho_f = f(T_m)$  and  $c_{pf} = f(T_m)$ .

The variation in the wall-to-bed heat transfer factor and the dimensionless drag coefficient in dependence on the bed voidage for the 2.98 mm diameter particles are illustrated in Fig. 2 from which it is evident that the heat transfer factor decreased with increasing bed voidage. It could be registered that this plot is very similar to the variation of the dimensionless fluid–particle interphase drag coefficient with bed voidage.

The present experimental data for heat transfer factor, analogous to the work of Bošković et al. [7], can be represented as (Eq. (1)):

$$j_H^* = \beta^* \quad (6)$$

where  $j_H^*$  is

$$j_H^* = \frac{j_H - j_{H_1}}{j_{H_{mf}} - j_{H_1}} \quad (7)$$

**Table 1**  
Particle characteristics and range of experimental conditions (at 293.15 K).

	0.80	1.11	1.94	2.98
$d_p$ (mm)	0.80	1.11	1.94	2.98
$\rho_p$ (kg/m <sup>3</sup> )	2923	2641	2507	2509
$U_t$ (m/s) <sup>a</sup>	0.148	0.185	0.299	0.370
$U_{mf}$ , m/s <sup>a</sup>	0.008	0.013	0.028	0.043
$U/U_{mf}$	5.224–17.401	3.797–9.417	1.679–6.311	1.883–4.080
$\varepsilon_{mf}$	0.398	0.416	0.447	0.462
$\varepsilon/\varepsilon_{mf}$	1.638–2.393	1.569–2.175	1.126–2.039	1.319–1.883

<sup>a</sup> Calculated from Kunii and Levenspiel [10].

Download English Version:

<https://daneshyari.com/en/article/235717>

Download Persian Version:

<https://daneshyari.com/article/235717>

[Daneshyari.com](https://daneshyari.com)