

## Supplementary material to

### BED EXPANSION IN TURBULENT BED CONTACTOR: EXPERIMENTS AND PREDICTION

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#### Appendix A

Table A1. Operating conditions.

| Experimental series                  | Packing (I and II)          |                | Relative static bed height $H_{st}/D_c$ | % free area ( $\phi$ ) | Flux (kg/m <sup>2</sup> .s)      |         |
|--------------------------------------|-----------------------------|----------------|---|------------------------|----------------------------------|---------|
|                                      | $\rho_P$ kg m <sup>-3</sup> | $d_P$ m        |   |                        | Liquid (L)                       | Gas (G) |
| I, II, III<br>IV, V, VI              | $\rho_{PI}=868$             | $d_{PI}=0.01$  | 0.75<br>0.5                             | 32; 56; 82             | 4.57; 10.23; 15.84; 20.94; 27.90 | 0+10    |
| VII, VIII, IX<br>XI<br>XIII, XIV, XV | $\rho_{PI}=736$             | $d_{PI}=0.015$ | 1.0<br>0.75<br>0.5                      | 56<br>32; 56; 82       |                                  |         |

#### Appendix B

Table B1. Statistical results of comparison of all bed expansion experimental data. (Series: I–IX, XI, XII–XV) with predictions based on authors' correlations (Eqs. 10–21).

| N° Eqs. | Equations for ( $H_d/H_{st}$ ) |  | Errors statistical indicators |      |       |                |
|---------|--------------------------------|--|-------------------------------|------|-------|----------------|
|         | Auteurs                        |  | MAPE (%)                      | RMSE | VEcv  | $\rho_{(x,y)}$ |
| Eq. 10  | Levsh <i>et al.</i> [15]       |  | 76.90                         | 2.27 | 42.77 | 0.88           |
| Eq. 11  | Tichy & Douglas [20]           |  | 24.75                         | 0.62 | 67.31 | 0.97           |
| Eq. 12  | Rama <i>et al.</i> [26]        |  | 36.18                         | 0.86 | 37.30 | 0.65           |
| Eq. 13  | Blyakher <i>et al.</i> [28]    |  | 75.09                         | 2.17 | 33.62 | 0.67           |
| Eq. 14  | O'Neil <i>et al.</i> [30]      |  | 48.21                         | 1.17 | -     | 0.79           |
| Eq. 15  | Uysal [32]                     |  | 148.57                        | 4.24 | 28.43 | 0.81           |
| Eq. 16  | Khanna [33]                    |  | 21.86                         | 0.68 | 59.58 | 0.63           |
| Eq. 17  | Lyashuk [34]                   |  | 56.31                         | 1.59 | 53.37 | -              |
| Eq. 18  | Shackley [35]                  |  | 78.06                         | 2.02 | 26.76 | 0.41           |
| Eq. 19  | Gimenes & Handley [36]         |  | 61.84                         | 1.23 | 45.74 | 0.44           |
| Eq. 20  | Aktsel'rod and Yakovenko [37]  |  | 87.06                         | 1.66 | 8.23  | 0.37           |
| Eq. 21  | Azhar-UI Haq [38]              |  | 36.57                         | 0.74 | 46.73 | 0.84           |

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Table B2. Results of comparison of bed expansion data with predictions based on Eq. 9 and liquid holdup (Eqs. 22–41) and gas holdup (Eqs. 42–47)

| $\epsilon_{l,st}$ | Authors                             | Eqs    | Kito                         | Bensebia                     | Kito                         | $\epsilon_g$                           |   | Vunjak-Novakovic <i>et al.</i> [49]<br>Eq. 47 |  |
|-------------------|-------------------------------------|--------|------------------------------|------------------------------|------------------------------|--|---|---|--|
|                   |                                     |        | <i>et al.</i> [17]<br>Eq. 42 | <i>et al.</i> [25]<br>Eq. 43 | <i>et al.</i> [39]<br>Eq. 44 | Gel'perin <i>et al.</i> [43]<br>Eq. 45 | Soundarajan & Krishnaiah [48]<br>Eq. 46 |   |  |
|                   |                                     |        |                              | MAPE (%)                     |                              |  |   |   |  |
|                   | Vunjak-Novakovic <i>et al.</i> [14] | Eq. 22 | 26.50                        | 43.94                        | 375.41                       | 452.96                                 | 37.78                                   | 443.60  |  |
|                   | Chen & Douglas [19]                 | Eq. 23 | 20.26                        | 16.86                        | 269.28                       | 305.30                                 | 15.66                                   | 300.60  |  |
|                   | Balabekov <i>et al.</i> [21]        | Eq. 24 | 33.83                        | 24.40                        | 224.97                       | 266.82                                 | 25.23                                   | 236.48  |  |
|                   | Ushida <i>et al.</i> [23]           | Eq. 25 | 33.04                        | 16.07                        | 246.67                       | 286.68                                 | 15.79                                   | 273.40  |  |
|                   | Handl [24]                          | Eq. 26 | 15.33                        | 18.57                        | 296.62                       | 350.73                                 | 16.46                                   | 342.00  |  |
|                   | Rama <i>et al.</i> [26]             | Eq. 27 | 26.35                        | 48.68                        | 397.30                       | 459.22                                 | 42.54                                   | 467.04  |  |
|                   | Lyashuk [34]                        | Eq. 28 | 33.64                        | 24.24                        | 225.54                       | 248.60                                 | 25.04                                   | 237.65  |  |
|                   | Shackley [35]                       | Eq. 29 | 28.02                        | 48.36                        | 397.99                       | 417.82                                 | 46.22                                   | 460.43  |  |
|                   | Gimenes & Handley [36]              | Eq. 30 | 27.16                        | 39.58                        | 460.69                       | 389.23                                 | 30.02                                   | 475.91  |  |
|                   | Aksel,rod & Yakovenko [37]          | Eq. 31 | 30.65                        | 49.65                        | 385.77                       | 477.21                                 | 44.07                                   | 458.38  |  |
|                   | Kito <i>et al.</i> [39]             | Eq. 32 | 23.09                        | 44.62                        | 374.26                       | 450.01                                 | 38.87                                   | 445.26  |  |
|                   | Paterson & Clift [40]               | Eq. 33 | 53.13                        | 85.92                        | 481.88                       | 591.65                                 | 81.03                                   | 575.21  |  |
|                   | Petrov & Tassaev [41]               | Eq. 34 | 24.75                        | 20.00                        | 292.16                       | 280.99                                 | 17.05                                   | 306.68  |  |
|                   | Soundarajan & Krishnaiah [42]       | Eq. 35 | 34.94                        | 59.61                        | 467.87                       | 471.32                                 | 51.41                                   | 530.72  |  |
|                   | Gel'perin <i>et al.</i> [43]        | Eq. 36 | 22.68                        | 17.31                        | 256.36                       | 290.02                                 | 16.47                                   | 283.19  |  |
|                   | Gel'perin <i>et al.</i> [43]        | Eq. 37 | 27.18                        | 45.77                        | 391.47                       | 449.56                                 | 39.04                                   | 456.93  |  |
|                   | Gel'perin <i>et al.</i> [44]        | Eq. 38 | 33.93                        | 24.53                        | 225.13                       | 247.43                                 | 25.37                                   | 236.65  |  |
|                   | Bruce & Krishnaiah [45]             | Eq. 39 | 33.92                        | 24.53                        | 225.12                       | 247.43                                 | 25.37                                   | 236.64  |  |
|                   | Barile & Meyer [46]                 | Eq. 40 | 33.04                        | 23.79                        | 227.58                       | 250.95                                 | 24.41                                   | 240.60  |  |
|                   | Tarat <i>et al.</i> [47]            | Eq. 41 | 55.39                        | 80.59                        | 603.11                       | 527.70                                 | 69.80                                   | 644.63  |  |

## Appendix C

Table C1. Operating conditions of authors' data of bed expansion [1,2,3]

| Authors                      | Column diameter<br>$D_c$ (m) | Hst<br>(mm) | Liquid Flow L<br>velocity<br>( $\text{kg}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ ) | Gas velocity<br>$u_g$ ( $\text{m}\cdot\text{s}^{-1}$ ) | Open area<br>of lower<br>grid $\phi$ (%) | Particle properties |   | MAPE Error (%)   |                  |                  |
|------------------------------|------------------------------|-------------|--|--|--|---------------------|---|------------------|------------------|------------------|
|                              |                              |             |  |  |  | $d_p$<br>(m)        | $\rho_p$<br>( $\text{kg}\cdot\text{m}^{-3}$ ) | Eqs.<br>(26, 43) | Eqs.<br>(35, 47) | Eqs.<br>(36, 43) |
| Tichy & Douglas [20]         | 0.14                         | 140         | 13.20  | 0-3  | 78                                       | 0.012               | 683   | 6.44             | 6.70             | 17.47            |
| Balabekov <i>et al.</i> [21] | 0.175                        | 110         | 8.33,<br>13.89,<br>20.83   | 0-4  | 40                                       | 0.016               | 850   | 18.23            | 20.67            | 26.57            |
| Mbua [50]                    | 0.29                         | 290         | 9.40,<br>14.10,<br>33.50   | 0-4  | 87                                       | 0.038               | 157   | 14.02            | 18.84            | 20.14            |

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