Electronic Supplementary Information (ESI) for Soft Matter

# Merging fluid and solid granular behavior

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In this Electronic Supplementary Information (ESI), we provide the numerical data obtained at the steady state in our DEM simulations. In particular, the volume fraction, $\nu$, dimensionless pressure, $p/\left(\rho_p d^2\dot{\gamma}^2\right)$, shear stress, $s/\left(\rho_p d^2\dot{\gamma}^2\right)$, granular temperature, $T/\left(d^2\dot{\gamma}^2\right)$ and coordination number $C$ are reported for five values of the dimensionless particle stiffness $k/\left(\rho_p d^3\dot{\gamma}^2\right)$: $10^3$, $10^4$, $10^5$, $10^6$ and $10^7$ (Tab. 1-5, respectively). In the simulations, we have used normal coefficient of restitution $e_n = 0.7$, tangential coefficient of restitution $e_t = -1$, interparticle friction coefficient $\mu = 0$ and normal spring stiffness $k_n = k$.

Table 1: Summary of measured steady state quantities for $k/\left(\rho_p d^3\dot{\gamma}^2\right) = 10^3$

| $\nu$ | $p/\left(\rho_p d^2\dot{\gamma}^2\right)$ | $s/\left(\rho_p d^2\dot{\gamma}^2\right)$ | $T/\left(d^2\dot{\gamma}^2\right)$ | $C$ |
|---|---|---|---|---|
| 0.200 | 0.234942 | 0.103128 | 0.555758 | 0.166381 |
| 0.250 | 0.265588 | 0.117213 | 0.394930 | 0.209494 |
| 0.300 | 0.331448 | 0.148527 | 0.314988 | 0.273373 |
| 0.350 | 0.445152 | 0.200126 | 0.275619 | 0.369064 |
| 0.400 | 0.642769 | 0.285643 | 0.258288 | 0.519074 |
| 0.450 | 1.023252 | 0.443855 | 0.265733 | 0.783821 |
| 0.500 | 1.839065 | 0.749744 | 0.293879 | 1.261998 |
| 0.520 | 2.457556 | 0.966064 | 0.319781 | 1.568773 |
| 0.540 | 3.437453 | 1.281308 | 0.359457 | 1.981529 |
| 0.560 | 4.981236 | 1.726183 | 0.415063 | 2.506194 |
| 0.580 | 7.445717 | 2.381977 | 0.490317 | 3.140327 |
| 0.600 | 11.140037 | 3.260685 | 0.580537 | 3.829470 |
| 0.620 | 16.326774 | 4.371615 | 0.681840 | 4.518889 |
| 0.630 | 19.529057 | 4.989191 | 0.732009 | 4.853679 |
| 0.634 | 20.893332 | 5.264431 | 0.752643 | 4.979053 |
| 0.636 | 21.603690 | 5.388448 | 0.762954 | 5.045281 |
| 0.638 | 22.325605 | 5.538356 | 0.772385 | 5.101963 |
| 0.640 | 23.078818 | 5.642747 | 0.787518 | 5.163304 |
| 0.650 | 26.592465 | 6.315878 | 0.830628 | 5.478336 |
| 0.660 | 31.206236 | 7.049504 | 0.878267 | 5.750006 |
| 0.670 | 35.389524 | 7.785759 | 0.918761 | 6.044560 |
| 0.680 | 40.693236 | 8.589171 | 0.959013 | 6.274154 |

Table 2: Summary of measured steady state quantities for $k/\left(\rho_p d^3 \dot{\gamma}^2\right) = 10^4$

| $\nu$ | $p/\left(\rho_p d^2 \dot{\gamma}^2\right)$ | $s/\left(\rho_p d^2 \dot{\gamma}^2\right)$ | $T/\left(d^2 \dot{\gamma}^2\right)$ | $C$ |
|---|---|---|---|---|
| 0.200 | 0.239205 | 0.106725 | 0.550503 | 0.054813 |
| 0.250 | 0.276281 | 0.122196 | 0.393941 | 0.070244 |
| 0.300 | 0.348642 | 0.158886 | 0.315481 | 0.092023 |
| 0.350 | 0.465862 | 0.215828 | 0.275625 | 0.124473 |
| 0.400 | 0.676403 | 0.309074 | 0.254802 | 0.180054 |
| 0.450 | 1.060903 | 0.471786 | 0.254966 | 0.279676 |
| 0.500 | 1.911529 | 0.826375 | 0.270529 | 0.486684 |
| 0.520 | 2.615479 | 1.088301 | 0.291918 | 0.647978 |
| 0.540 | 3.831324 | 1.520142 | 0.328693 | 0.903100 |
| 0.560 | 6.437990 | 2.343001 | 0.399776 | 1.352436 |
| 0.580 | 12.523880 | 4.090963 | 0.536589 | 2.096784 |
| 0.600 | 28.197296 | 7.864387 | 0.802913 | 3.187979 |
| 0.620 | 63.395662 | 15.028613 | 1.219510 | 4.366442 |
| 0.630 | 90.035044 | 19.745010 | 1.456724 | 4.891566 |
| 0.634 | 102.666463 | 22.121499 | 1.553021 | 5.085384 |
| 0.636 | 109.179503 | 23.286849 | 1.608156 | 5.178923 |
| 0.638 | 116.084014 | 24.140719 | 1.651068 | 5.272760 |
| 0.640 | 122.769207 | 25.198054 | 1.705943 | 5.355511 |
| 0.650 | 157.343054 | 30.582846 | 1.924566 | 5.782143 |
| 0.660 | 203.511144 | 37.024106 | 2.148040 | 6.133889 |
| 0.670 | 245.825537 | 43.124529 | 2.349487 | 6.485831 |
| 0.680 | 300.964068 | 49.547237 | 2.521318 | 6.756794 |

Table 3: Summary of measured steady state quantities for $k/\left(\rho_p d^3 \dot{\gamma}^2\right) = 10^5$

| $\nu$ | $p/\left(\rho_p d^2 \dot{\gamma}^2\right)$ | $s/\left(\rho_p d^2 \dot{\gamma}^2\right)$ | $T/\left(d^2 \dot{\gamma}^2\right)$ | $C$ |
|---|---|---|---|---|
| 0.200 | 0.241428 | 0.108570 | 0.543630 | 0.017753 |
| 0.250 | 0.278552 | 0.126415 | 0.392905 | 0.022594 |
| 0.300 | 0.351964 | 0.161171 | 0.314589 | 0.029670 |
| 0.350 | 0.477694 | 0.219933 | 0.273076 | 0.040755 |
| 0.400 | 0.685554 | 0.318180 | 0.252738 | 0.058722 |
| 0.450 | 1.081814 | 0.491962 | 0.248999 | 0.093042 |
| 0.500 | 1.864913 | 0.824706 | 0.255639 | 0.162584 |
| 0.520 | 2.513597 | 1.071019 | 0.268573 | 0.221985 |
| 0.540 | 3.656958 | 1.502096 | 0.293246 | 0.326832 |
| 0.560 | 6.085880 | 2.354844 | 0.344352 | 0.541056 |
| 0.580 | 12.784651 | 4.375863 | 0.462589 | 1.021208 |
| 0.600 | 40.463774 | 11.463297 | 0.795484 | 2.139451 |
| 0.620 | 196.788428 | 43.262171 | 1.867153 | 4.023546 |
| 0.630 | 396.324077 | 77.243801 | 2.788652 | 4.856156 |
| 0.634 | 495.184615 | 92.030928 | 3.163740 | 5.065659 |
| 0.636 | 555.923377 | 101.259968 | 3.361877 | 5.222647 |
| 0.638 | 629.920288 | 113.051389 | 3.614110 | 5.411202 |
| 0.640 | 693.979225 | 122.525143 | 3.820721 | 5.523332 |
| 0.650 | 1026.926498 | 166.670169 | 4.718021 | 6.047363 |
| 0.660 | 1487.286922 | 222.807657 | 5.682130 | 6.447426 |
| 0.670 | 1920.393069 | 273.270325 | 6.338657 | 6.842727 |
| 0.680 | 2436.413902 | 327.387775 | 7.004498 | 7.155652 |

Table 4: Summary of measured steady state quantities for $k/\left(\rho_p d^3 \dot{\gamma}^2\right) = 10^6$

| $\nu$ | $p/\left(\rho_p d^2 \dot{\gamma}^2\right)$ | $s/\left(\rho_p d^2 \dot{\gamma}^2\right)$ | $T/\left(d^2 \dot{\gamma}^2\right)$ | $C$ |
|---|---|---|---|---|
| 0.200 | 0.240997 | 0.110712 | 0.542786 | 0.005486 |
| 0.250 | 0.285286 | 0.127245 | 0.393289 | 0.007462 |
| 0.300 | 0.347973 | 0.158695 | 0.314593 | 0.009479 |
| 0.350 | 0.487812 | 0.220737 | 0.272417 | 0.013305 |
| 0.400 | 0.701025 | 0.328384 | 0.252236 | 0.018991 |
| 0.450 | 1.054117 | 0.504345 | 0.246853 | 0.028296 |
| 0.500 | 1.835065 | 0.836030 | 0.249521 | 0.051556 |
| 0.520 | 2.459094 | 1.061434 | 0.259626 | 0.071754 |
| 0.540 | 3.539649 | 1.464188 | 0.278913 | 0.108506 |
| 0.560 | 5.766162 | 2.287424 | 0.317835 | 0.187553 |
| 0.580 | 12.055349 | 4.214920 | 0.413838 | 0.409660 |
| 0.600 | 41.481005 | 12.137577 | 0.701306 | 1.148615 |
| 0.605 | 65.253233 | 17.711560 | 0.875353 | 1.534955 |
| 0.610 | 106.876056 | 27.037876 | 1.120896 | 2.001262 |
| 0.615 | 197.302649 | 46.046854 | 1.523431 | 2.631728 |
| 0.620 | 391.976552 | 84.007070 | 2.208526 | 3.358247 |
| 0.625 | 803.442184 | 154.964778 | 3.311855 | 4.097119 |
| 0.630 | 1585.129284 | 279.067958 | 4.980820 | 4.769387 |
| 0.634 | 2403.201354 | 399.027991 | 6.289582 | 5.164167 |
| 0.635 | 2684.443882 | 437.334838 | 6.885728 | 5.258285 |
| 0.636 | 2926.634561 | 475.040850 | 7.149895 | 5.348844 |
| 0.638 | 3560.018222 | 547.873183 | 8.044064 | 5.530090 |
| 0.640 | 4123.181555 | 634.939118 | 8.850524 | 5.660419 |
| 0.650 | 7370.295715 | 1037.449061 | 12.455813 | 6.261044 |
| 0.660 | 11680.402608 | 1483.608749 | 15.902378 | 6.716673 |
| 0.670 | 16435.452806 | 1964.286219 | 18.502284 | 7.076342 |
| 0.680 | 21702.678475 | 2401.395598 | 21.750145 | 7.379358 |

Table 5: Summary of measured steady state quantities for $k/\left(\rho_p d^3 \dot{\gamma}^2\right) = 10^7$

| $\nu$ | $p/\left(\rho_p d^2 \dot{\gamma}^2\right)$ | $s/\left(\rho_p d^2 \dot{\gamma}^2\right)$ | $T/\left(d^2 \dot{\gamma}^2\right)$ | $C$ |
|---|---|---|---|---|
| 0.200 | 0.242585 | 0.102214 | 0.545485 | 0.001765 |
| 0.250 | 0.283350 | 0.128201 | 0.392078 | 0.002291 |
| 0.300 | 0.340522 | 0.158116 | 0.314910 | 0.002822 |
| 0.350 | 0.465374 | 0.205602 | 0.273811 | 0.003982 |
| 0.400 | 0.699502 | 0.331268 | 0.250779 | 0.005899 |
| 0.450 | 1.120364 | 0.500994 | 0.245302 | 0.010071 |
| 0.500 | 1.840210 | 0.839447 | 0.248525 | 0.017071 |
| 0.520 | 2.532813 | 1.123175 | 0.256162 | 0.023502 |
| 0.540 | 3.544851 | 1.490749 | 0.273729 | 0.035264 |
| 0.560 | 5.584651 | 2.280780 | 0.309487 | 0.061977 |
| 0.580 | 11.767423 | 4.319858 | 0.392010 | 0.149072 |
| 0.600 | 40.479041 | 11.845031 | 0.658790 | 0.530188 |
| 0.620 | 504.648534 | 108.158916 | 2.153449 | 2.434020 |
| 0.630 | 4824.238310 | 799.621737 | 7.571104 | 4.504102 |
| 0.634 | 10305.288288 | 1581.602954 | 11.858220 | 5.097600 |
| 0.636 | 15082.792004 | 2183.362941 | 15.798637 | 5.378536 |
| 0.638 | 20808.342189 | 2901.934944 | 19.518591 | 5.612210 |
| 0.640 | 25657.006376 | 3473.088378 | 22.408651 | 5.763377 |
| 0.650 | 58191.181725 | 7142.838075 | 36.532318 | 6.433599 |
| 0.660 | 101401.733582 | 11086.571932 | 50.484634 | 6.880554 |
| 0.670 | 148887.949649 | 15539.824114 | 57.148331 | 7.238029 |
| 0.680 | 202098.496818 | 19406.096112 | 72.691066 | 7.530354 |