**The Coupled model LBM-LSM2S**

1. **Objectives:**

* The purpose of this program is to determine the reaction of fluid-solid in the porous media with two solid components. It provides the coefficient \alpha and \beta of the Christoffel equation.
* There is only a program for all simulations. The source code file is: alfabeta2solids.f

1. **The necessary files:**

* The source code file .f
* INPUT PARAMETERS:
* ind
* Cube\_abond
* Cube\_ang
* Cube\_bon
* Cube\_sbond
* Velocities9
* Velocities19

It is necessary to place these files in the same directory.

The files namely Cube\_\* and Velocities\* are the configurations of the lattice in the program; they must to be not changed.

The file “**ind**” is the numerical data of the porous medium of size Ncx . Ncy. Ncz. It must have exactly the same form as in the example. The 1st solid is denoted by 0, the 2nd solid by 3 and the pore by 1. In our calculations: clay = 0, pore = 1 and quartz =3.

The file **INPUT PARAMETERS** contains information about the simulation. The meaning of each parameter was noted in this file. An example of this file for the simulations of the coarsened sample X2 of size 150 x 150 x 54:

0.3333333333333333D0 cr2 ! red fluid sound speed power 2

1.D0 rr0 ! pure red fluid density

1.D0 rb0 ! pure blue fluid density

1.D0 B ! interface width parameter (MIN = 0 MAX = 1)

0.000001D0 sig ! surface tension coefficient

0.00625D0 vir ! red fluid cinematic viscosity

0.00625D0 vib ! blue fluid cinematic viscosity

1.D0 wet ! wettability (-1,1) (>0 - red fluid wettable)

1 idir ! direction of the body force (1 - x direction)

10 itm ! main loop number of steps

10000 itw ! intermediate loop numer of steps

1 its ! save parameter every its\*itw

-0.0000001D0 eps ! parameter for permeability convergence test : with - it cannot stop

0 mtype ! 1 - interpolation at interface, 0 - majority rule

0 icon ! read initial state data from archiv ? (1 - yes, 0 - no)

0.D0 sat ! blue fluid saturation used in intialization

1 iipore! pore filled with fluid

1 npores ! number of distinct pores

0.D0 ee ! small number to supress small distributions (min = 0.D0)

150.D0 lsize ! linear size for Reynolds number

0.D0 0.D0 0.D0 bfr ! red fluid body force

0.D0 0.D0 0.D0 bfb ! blue fluid body force

150 ! ncx. x unit cell size

150 ! ncy. y unit cell size

54 ! ncz. z unit cell size

18.369D0 ! Em1 Young

0.35065D0 ! nu1 Poisson

94.5D0 ! Em2. Young modulus

0.0742d0 ! nu2. Poisson's ratio

2.65d0 ! rs. solid medium density

0.1d0 ! dt. integration time step duration

1.d0 ! dl. lattice unit step (distance between two lattice nodes)

8 ! nthread

0.0333333333333333 ! Em. Young modulus

0.d0 ! nu. Poisson's ratio -1 <= nu <= 1/4

0.1d0 ! rs. solid medium density

0.1d0 ! dt. integration time step duration

1.d0 ! dl. lattice unit step (distance between two lattice nodes)

! Notes

! The parameter dt should be < 1 for numerical stability of LSM. The smaller the better.

! dl and dt parameters should be appropriately incorporated into LSM and LBM models.

! In present version of the program, dl should be equal 1. If it = 1, rs gives the real density,

! otherwise only the mass of the node.

! Archiv file name for restart is 'iteration2'.

! Don't stop program when the two files 'iteration' and 'iteration2' at the same time exist.

! If program was stopped and both 'iteration' and 'iteration2' present,

! before restart program select first the larger of 'iteration', 'iteration2'.

! Total number of iterations = itm\*itw

! After each itw iterations program calls check\_state and saves distributions for restart

! After each itw\*its iterations program calls save\_results

1. **Compilation:**

Pgf95 –mp –fastsse –Mvect –mcmodel=medium file.f –o file.exe

1. **Run:**

ulimit –s unlimited

export OMP\_NUM\_THREADS= n (n: number of thread)

nohup ./file.exe &

1. **File outs:**

* **Alpha\_beta:** contains the results: \alpha and \beta
* **Iteration, iteration2**: The formation of lattice nodes, of bonds. They are used for rerun the program when it stopped unexpectedly. Do not stop program when two files 'iteration' and 'iteration2' at the same time exist. To continue the program after a break, one has change the parameter “read initial from iterations” in the file INPUT PARAMETER from 0 to 1.
* **Check\_state\_19**: gives the state of the simulation.
* **Settings\_19**: gives some information about the lattice.
* **Nohup.out** gives some information about possible problems.
* **Stress\_tensor, strain, stress**: some output files of the LSM step.
* **LSM\_icors, LSM\_coord\_field, LSM\_displ\_field, LSM\_force\_field, LSM\_velocity\_field**: they contain the information of each lattice point. They are used for verification if there is a problem with the results.
* **LSM\_disf\*, pressure\*:** information of displacement and pressure at each main iteration. They are used for verification if there is a problem with the results.
* **Color\_filed, ind\_red\_blue**: the files used for the two phase fluids simulations.

1. **Notices:**

* If the Young moduli in the INPUT are given by GPa, the result in the is also in GPa.
* The program is parallelized by OMP but not for the calculations at the interfaces; therefore, the parallelization is not very effective.