Master Thesis Experiment Report VII : Looping System

Jérémie Guy

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Abstract

Changing the system into a loop

1 Context

After adding an acceleration field instead of a constant imposing of velocity given by Zou-He, we want to make the system cyclic.

2 Description

We changed the system so that the fluid goes into a closed loop as illustrated in Figure 1. The acceleration field (illustrated by the yellow box) adds at every iteration a constant force $F = [Fx, Fy]$ to the PDFs. All walls of the system are bounceback nodes as is the central obstacle.

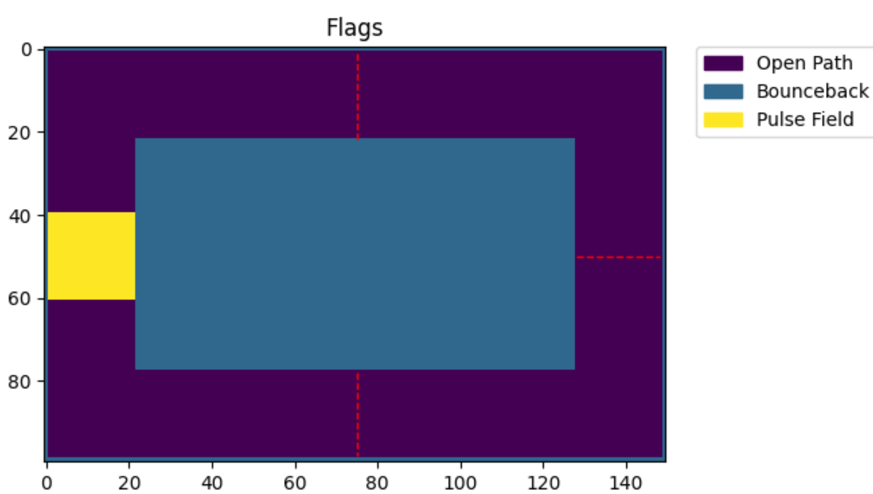

Figure 1: Looping system. Note : the red dotted lines are the sites were we will measure the velocity profiles

3 Experiments

3.1 Experiment 1

3.1.1 Description

We implemented the new geometry on a small 150x100 system, with each tube diameter being 21. F is set as $F = [0, 0.0001]$, which implies that only a vertical acceleration is applied to the PDFs. We set the viscosity as $\nu = 0.01$ and the initial density as $\rho = 2.5$ and let the simulation run for 50'000 iterations.

3.1.2 Results

The results are illustrated in Figure 2. As shown in Figure 1 the three velocity profiles have been taken in order from : the top horizontal tube, the right vertical tube and the bottom horizontal tube.

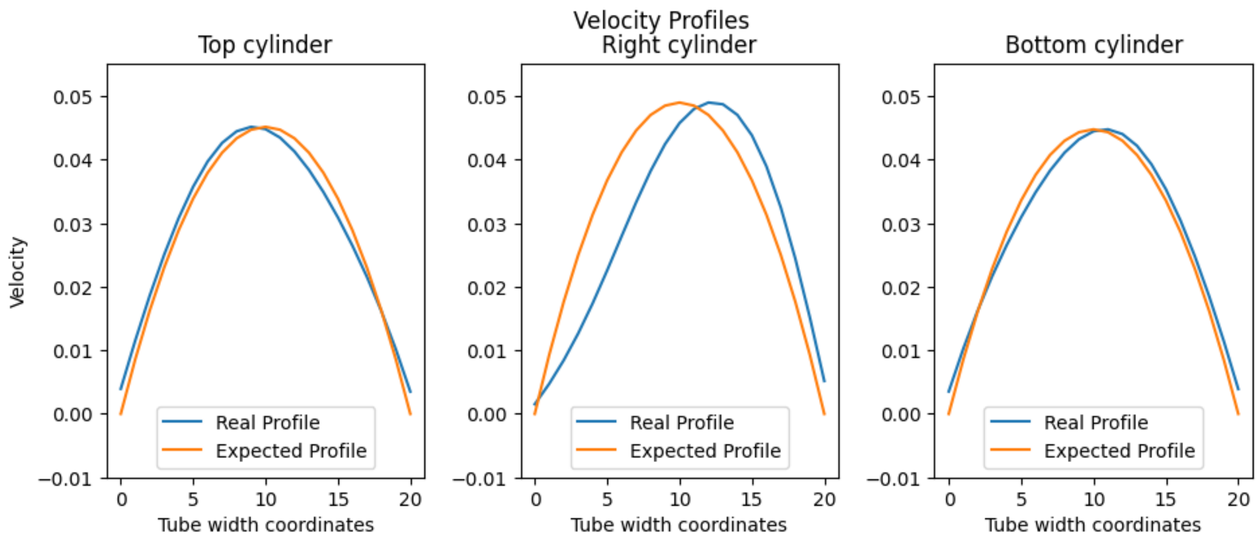

Figure 2: Velocity profiles of the top, right and bottom cylinder

As expected, the three profiles converge to Poiseuille's form. The right cylinder is however slightly shifted and has a bit more velocity as compared with the two others : this could be a side effect of the geometry taken with the chosen dimension of 150x100. We will tst this theory in the next experiment.

3.2 Experiment 2

3.2.1 Description

We tested the same method using this time a bigger square system of dimension 200x200 as illustrated in Figure 3. The simulation runs for 30'000 iterations with the exact same parameters as before. The velocity profiles are measures in the same places as the previous system as Figure 3 shows.

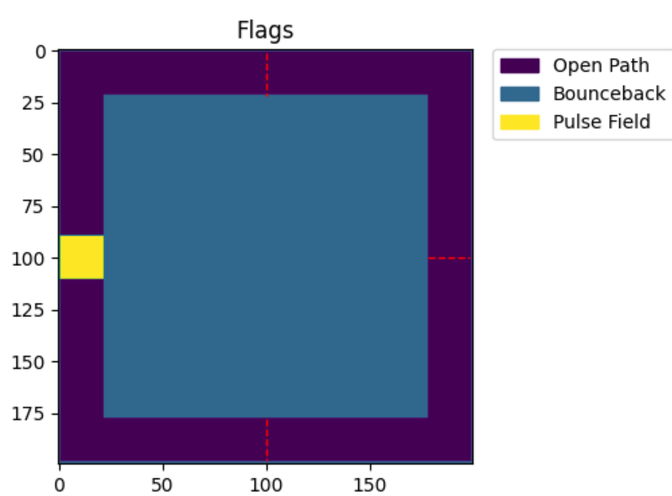

Figure 3: Square system

3.2.2 Results

Figure 4 shows the results. As we expected, all the velocity profiles now converge to a correct Poiseuille flow. This implies that for the fluid to flow correctly, some precautions on the size and shape of the system have to be taken.

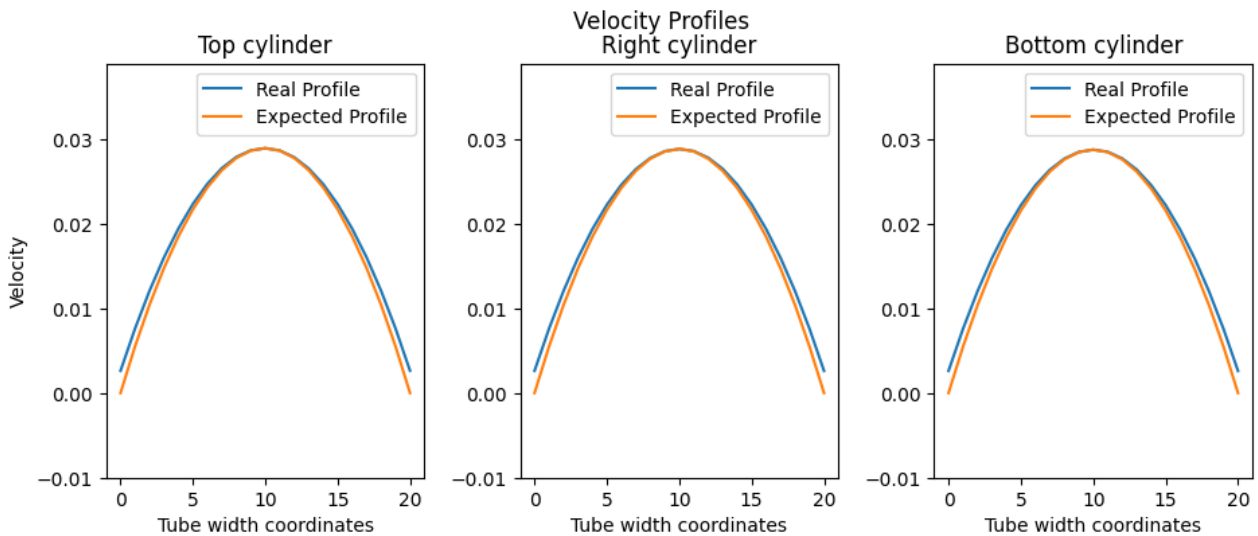

Figure 4: Velocity profiles of the top, right and bottom cylinder

3.3 Experiment 3

3.3.1 Description

For the next experiment, we added a clot in the upper tube of the system as illustrated in Figure 5. The representation on the figure is the same as before, with this time only two velocity profiles measured. The parameters are the same as the previous experiment expect the acceleration force: we changed F to $F = [0, -0.0001]$ so that the fluid flows upwards and reaches the clot faster to make the system converge faster. We let the simulation run for 30'000 iterations.

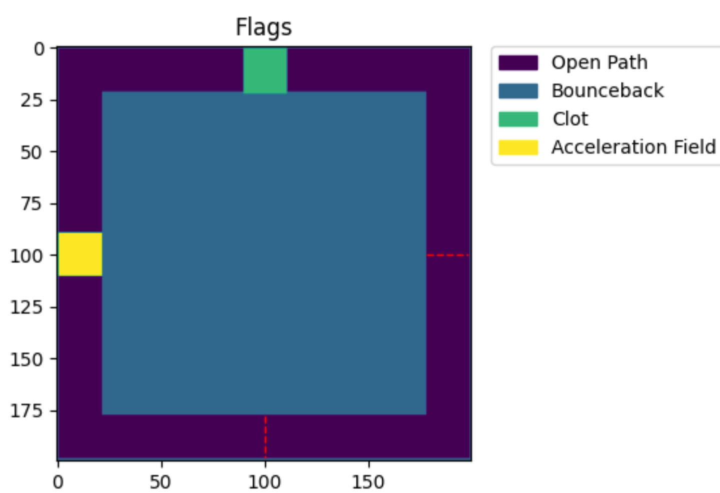

Figure 5: Square System with a clot in the upper tube section

3.3.2 Results

The velocity profiles are illustrated in Figure 6. The system converged at approx. 15'000 iterations and the results displayed are from the last iteration. We can see that both profiles have the expected Poiseuille's parabola. Next the graphics shown in Figure 7 are in order : the full system's velocity norm, the mean of each vertical slice of the velocity on the section determined by the red dotted lines, the mean of each vertical slice of the density on the same section and finally the flow obtained by multiplying the velocity and density $flow(x) = u(x) * \rho(x)$. The blue dotted lines represent the clot.

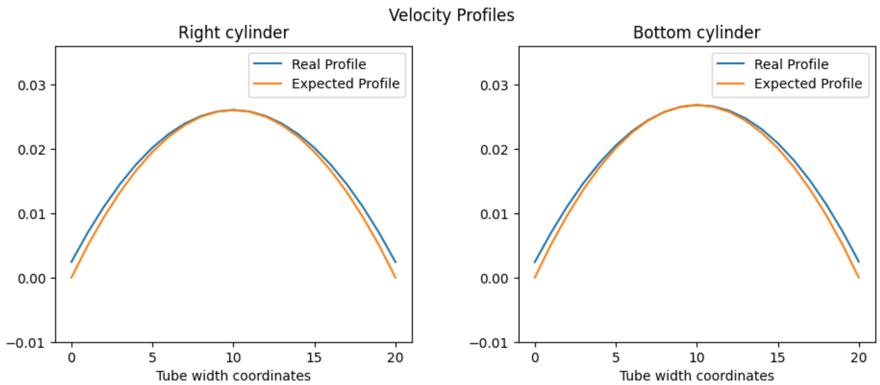

Figure 6: Velocity Profiles for a square system, with a clot

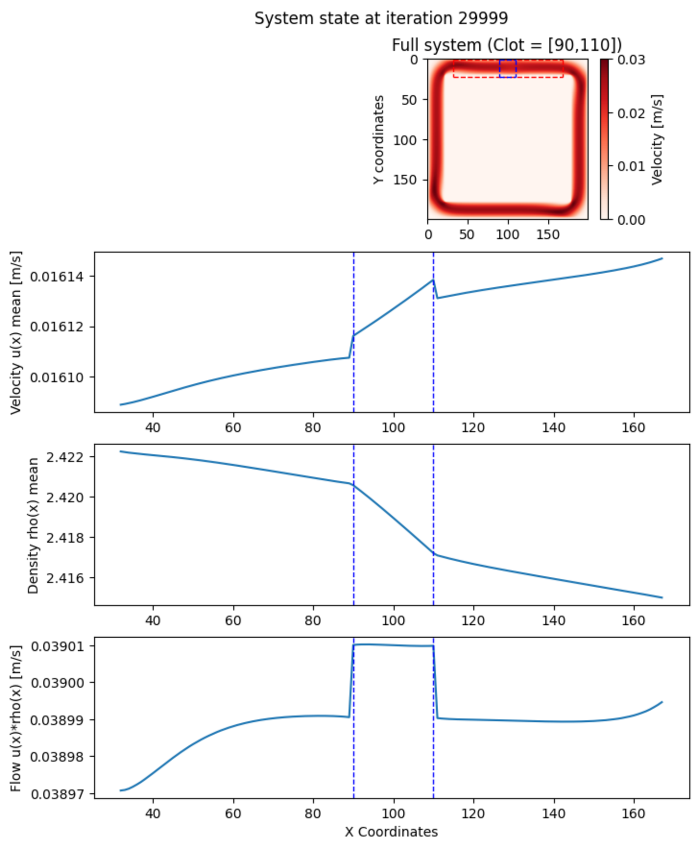

Figure 7: Clot velocity, density and flow for a square system with clot

On Figure 7 we can see that inside the clot the velocity is slightly increasing while the density is slightly decreasing, making the flow constant with a precision of $1e-4$: those are the expected results which follow, at the very least visually, Darcy's law on porous media. We can notice a decrease of the flow on the extremities of the surveilled tube section : this is a direct consequence of the geometry. The fluid does not have enough space to fully become linear inside each of the straight tube sections. To assess if the theory is correct, we will run the same experiment on a rectangular system.

3.4 Experiment 4

3.4.1 Description

As mentioned above, we will change the system into a rectangle of dimension 260x200, as illustrated in Figure 8. The system being bigger, it converges slower so we increased the iterations to 50'000.

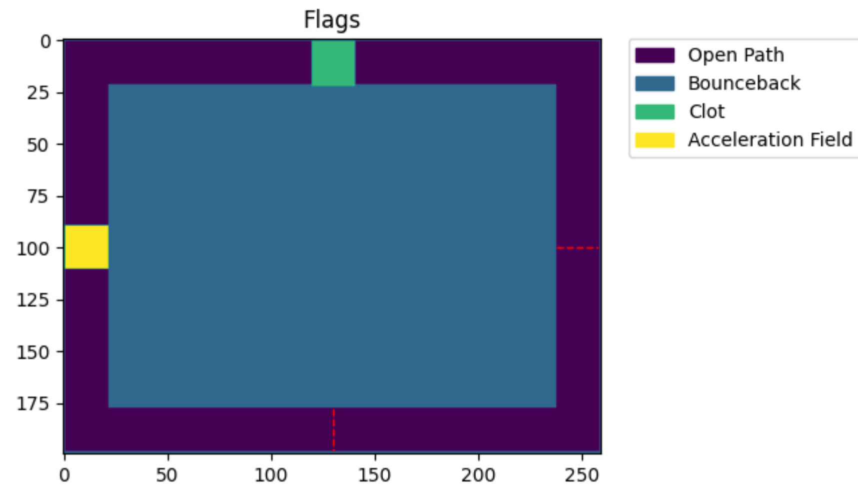

Figure 8: Rectangular system with a clot in the upper tube section

3.4.2 Results

We can see in Figure 10 that the velocity profiles are once again following Poiseuille's flow curve. On the clot velocity, density and flow illustrated in Figure 10, we can see that the dropping effect mentioned above is less significant and further away from the clot : this certifies that the privous drops are a side effect of the topology.

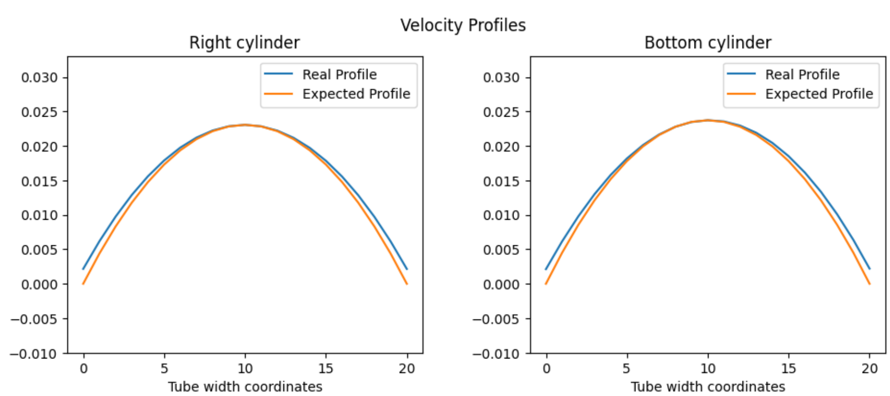

Figure 9: Velocity Profile for a rectangular system, with a clot

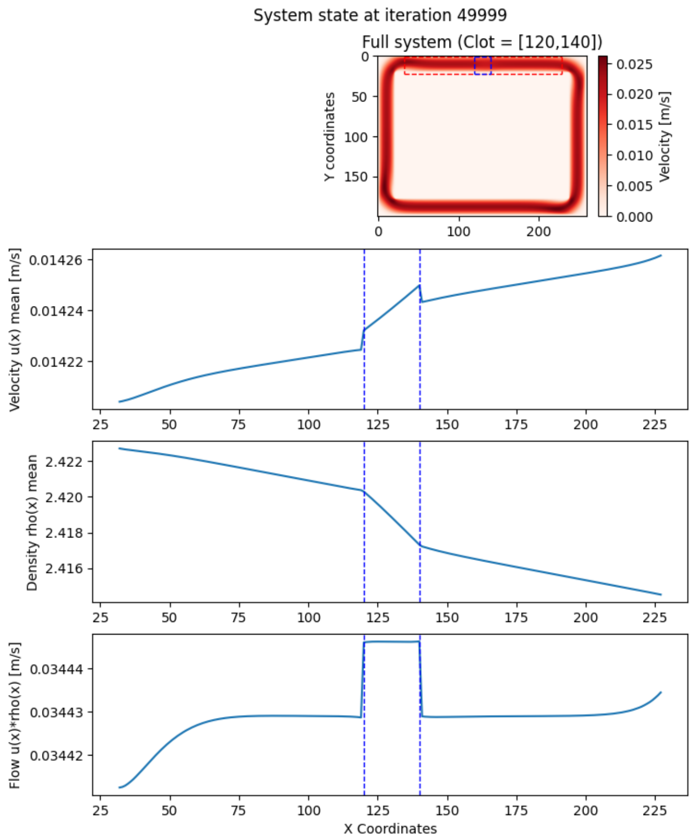

Figure 10: Clot velocity, density and flow for a rectangular system with clot

4 Conclusion

5 References