Initiation to PAM-RTM
Law of Darcy
Application: central injection of a square plate

Objective

There two goals of this exercise. It consists first of all in the learning of the software PAMRTM. For this reason, the explanations relating to the software will be detailed and embellished with numerous screenshots.

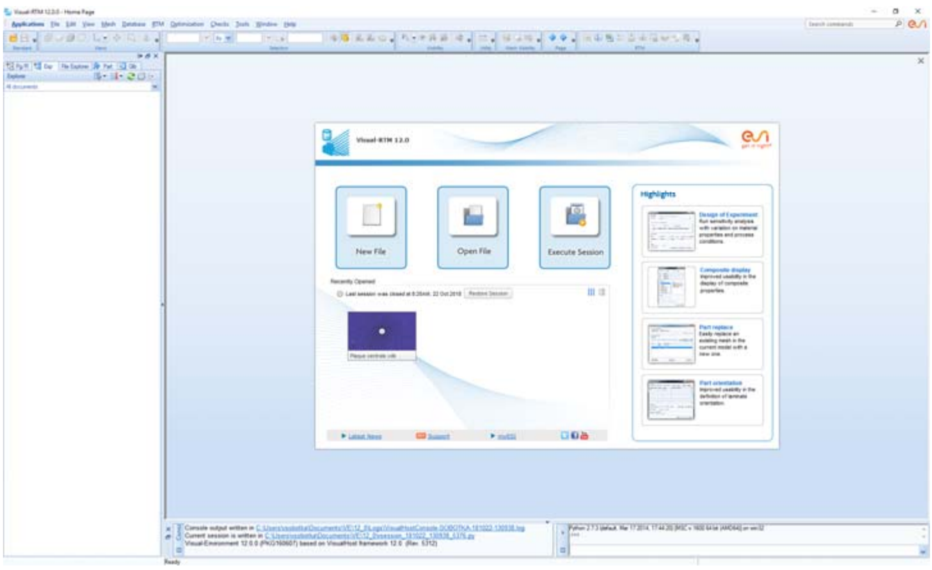
The second objective concerns the study of the law of Darcy and more specifically the comparison between analytical results given by the law and those obtained from simple simulations. To reach this objective, a simple configuration will be study in this exercise. It will consist of the central filling of a 2D preform. The simple geometry of the piece will make it possible to compare the numerical results with the analytical results deduced from Darcy's law.

Before you start

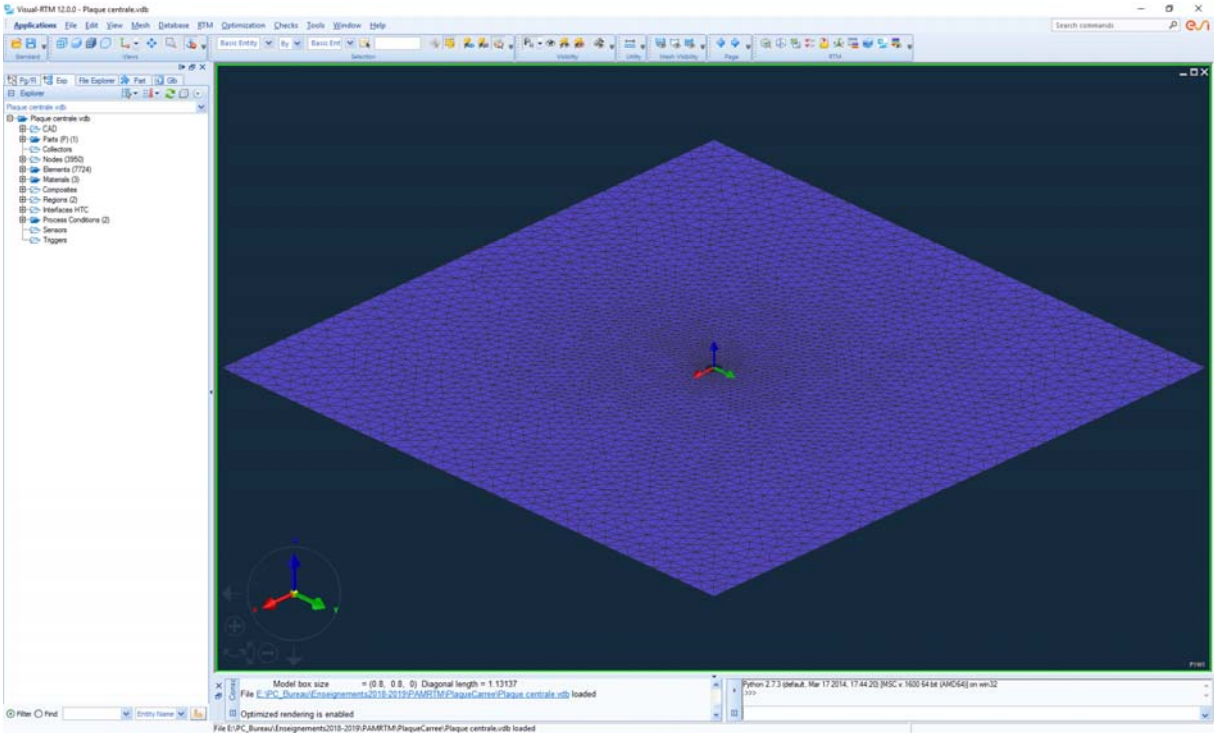
- Create a local folder on C:\. The software won't work if you try to work on Z:\.
- In your file name: no blank or accentuation
- Get the mesh (**Plaque centrale.vdb**) from Madoc and copy it in your directory

PAM-RTM Software

Launch **Visual-RTM 15.0**



Open the file: **Plaque centrale.vdb**



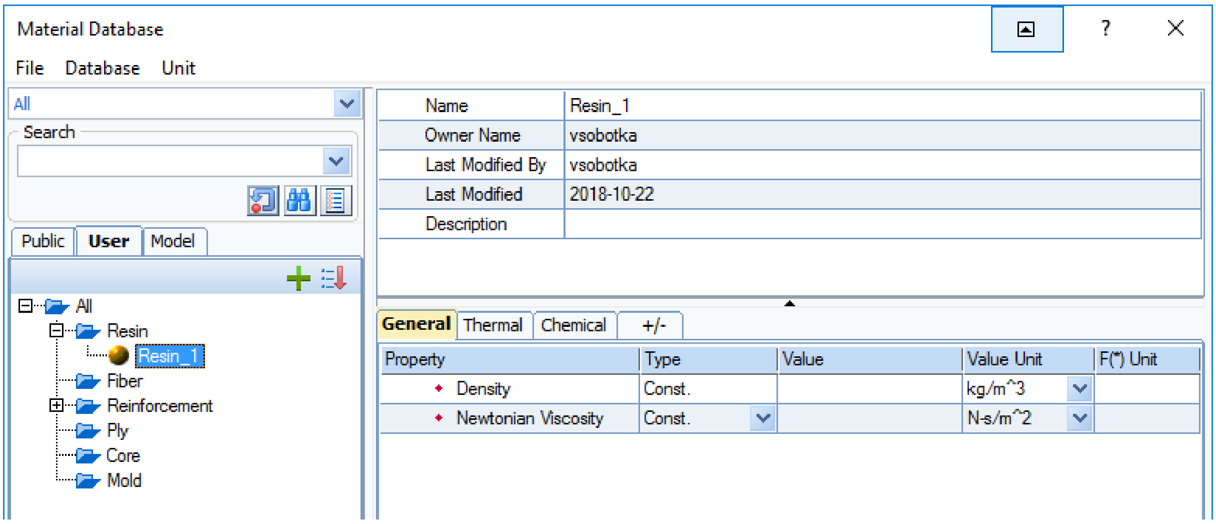
To perform the simulation, you need:

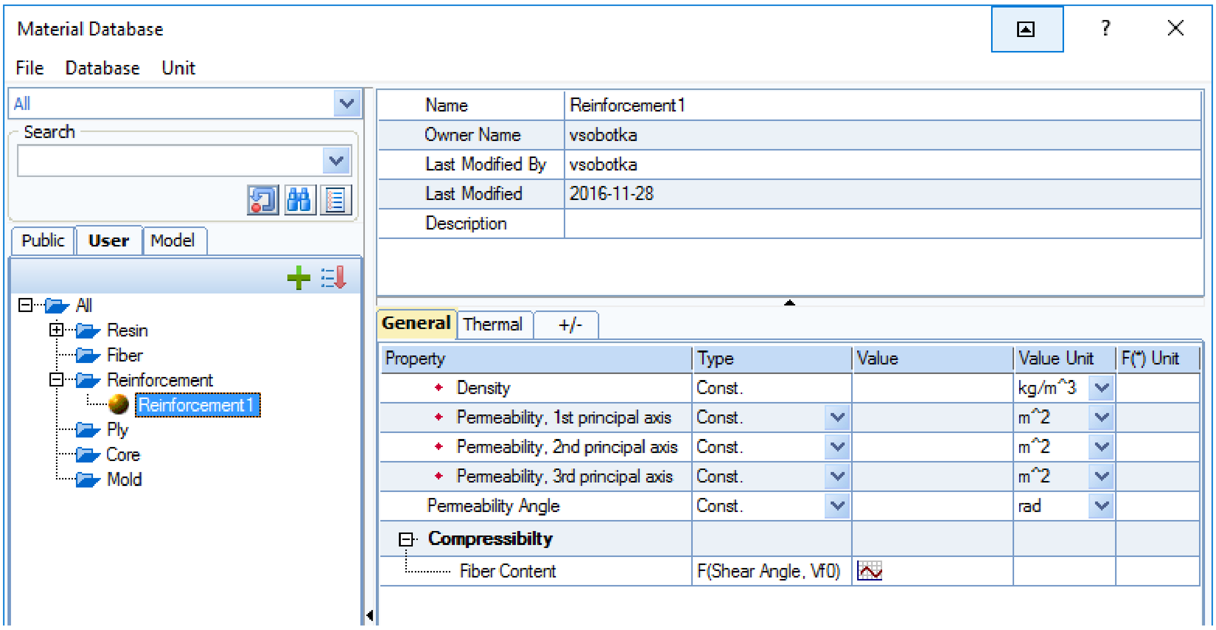
- ✓ To define material properties.
- ✓ To associate a material with a geometry.
- ✓ To define the location of your boundary conditions
- ✓ To define the values of the boundary conditions.
- ✓ To define the type of simulation you want to perform.

In this first exercise, the goal is to perform an isothermal injection.

Definition of the material properties

You have to create a new **resin** and a new **reinforcement**





The properties of the material are given below:

Reinforcement

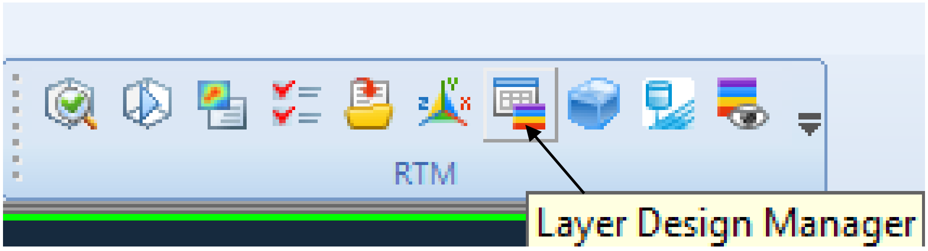
The reinforcement used is a glass fabric whose density is equal to **2560kg.m^{-3}**. We consider an isotropic material whose permeability is equal to **K=10^{-10}m^2**.

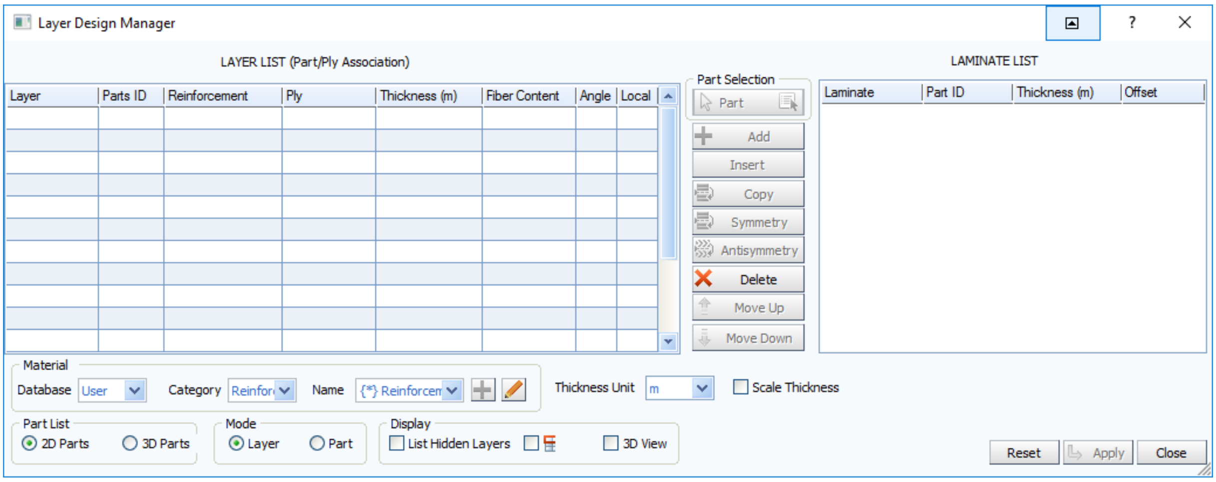
Resin

The density of the resin equal to **1200 kg.m^{-3}**. The viscosity of the resin taken constant and equal to **0.12Pa.s**.

Apply reinforcement to geometry

Open *Layer Design Manager*





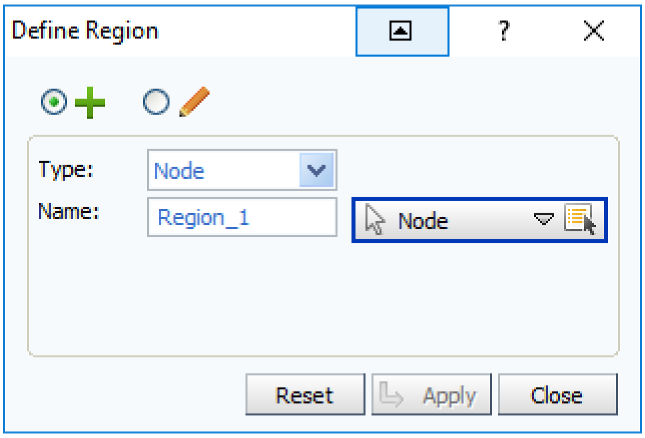
You have to select the part ID associated with the reinforcement you have created.

We will choose a thickness of 5mm for the part and the porosity of 40%.

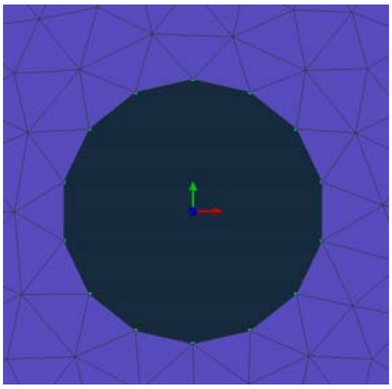
Define of region for boundary conditions

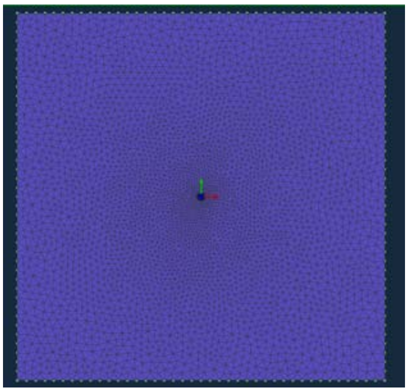
In this part, you need to create 2 regions:

- ✓ 1 for the injection zone
- ✓ 1 for the vent zone



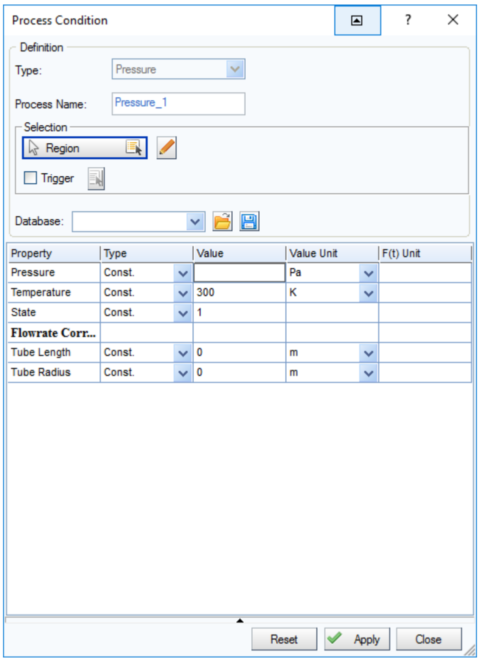
Select the nodes delimiting the region, then click Apply. Repeat the same operation to create a 2nd region for the vent that is located all around the square.

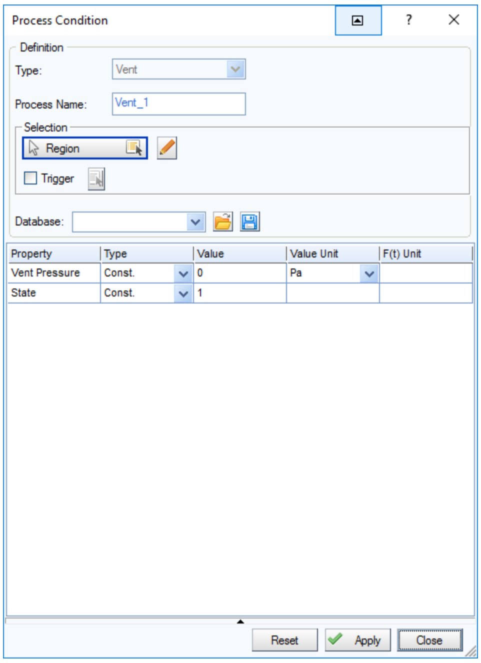




Boundary conditions

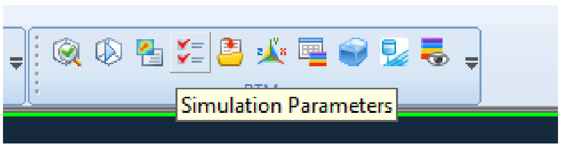
In this 1st simulation, we consider an injection at constant pressure of 1.5bar in the center of the part. The vent is put under vacuum.

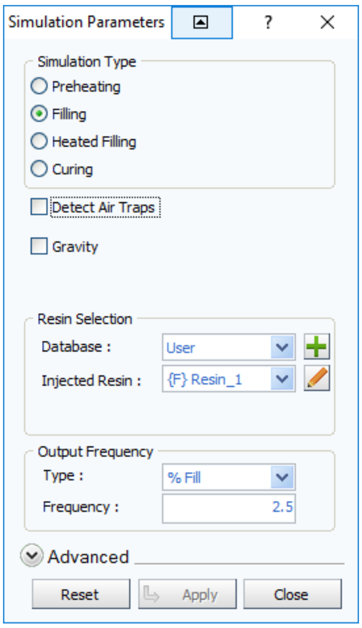




Simulation parameters

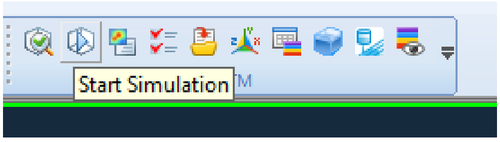
Click on the following button to define the type of simulation as well as the injected resin.





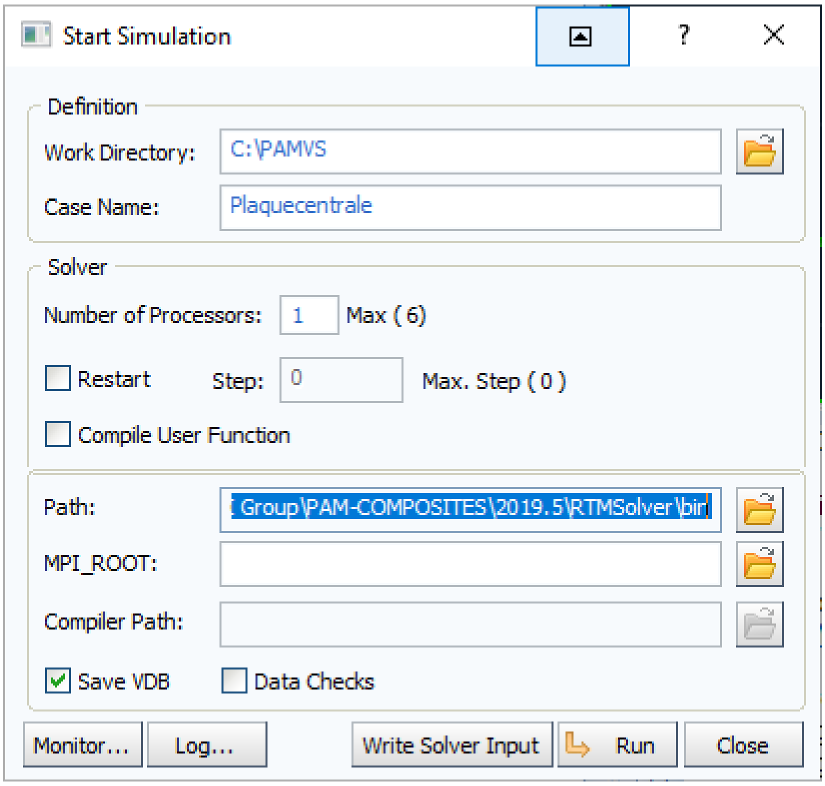
Launch simulation

Click on the following button to open the “start simulation” panel.



Ensure the path used for the solver is well indicated:

C:\Program Files\ESI Group\PAM-COMPOSITES\2019.5\RTMSolver\bin



Then click Run and Log.

The following windows opens. Explain the meaning of the different information.

Plaque centrale [16.1 KB] - WinTail

```
mpirun: IBM Platform MPI Community Edition:
   09.01.02.01W RTM [11530] Windows 32

(C) Copyright Platform Computing Inc., an IBM Company 1997-2014.
  US Government Users Restricted Rights:
    - Use, duplication or disclosure restricted by
      GSA ADP Schedule Contract with IBM Corp.
Compatible IBM Platform MPI Remote Launch Service version V02.00.00

WARNING: No cached password or password provided.
         use '-pass' or '-cache' to provide password
Intel(R) C++ 64 Compiler XE for applications running on Intel(R) 64, Version 12.1 us


PAM-RTM Version 2016.0, Parallel, Compiled on Jun  7 2016 at 03:43:50
Copyright ESI Group (France) 2004-2016

Executable adapted for MPI-Wrapper MPM!

Running on 16 processors

Calculation is running. It can be aborted by closing this window

 step =1, time=1.000000e-04, DT=1.000000e-04, filled=0, percent=  0.00%
 step =2, time=1.102228e-04, DT=1.022280e-05, filled=0, percent=  0.00%
 step =3, time=1.161597e-04, DT=5.936859e-06, filled=0, percent=  0.00%
 step =4, time=1.220965e-04, DT=5.936859e-06, filled=3, percent=  0.04%
 step =5, time=1.323193e-04, DT=1.022280e-05, filled=13, percent=  0.17%
 step =6, time=1.453442e-04, DT=1.302489e-05, filled=24, percent=  0.31%
 step =7, time=1.595505e-04, DT=1.420624e-05, filled=28, percent=  0.36%
 step =8, time=1.781608e-04, DT=1.861035e-05, filled=34, percent=  0.44%
 step =9, time=1.997092e-04, DT=2.154844e-05, filled=39, percent=  0.50%
 step =10, time=2.268113e-04, DT=2.710212e-05, filled=52, percent=  0.67%
 step =11, time=2.567713e-04, DT=2.996001e-05, filled=65, percent=  0.84%
 step =12, time=2.941196e-04, DT=3.734832e-05, filled=76, percent=  0.98%
 step =13, time=3.377694e-04, DT=4.364972e-05, filled=85, percent=  1.10%
 step =14, time=3.863375e-04, DT=4.856813e-05, filled=96, percent=  1.24%
 step =15, time=4.398997e-04, DT=5.356217e-05, filled=114, percent=  1.48%
 step =16, time=4.964806e-04, DT=5.658090e-05, filled=122, percent=  1.58%
 step =17, time=5.651433e-04, DT=6.866273e-05, filled=136, percent=  1.76%
 step =18, time=6.476884e-04, DT=8.254512e-05, filled=150, percent=  1.94%
 step =19, time=7.428658e-04, DT=9.517745e-05, filled=161, percent=  2.08%
 step =20, time=8.389189e-04, DT=9.605305e-05, filled=186, percent=  2.41%
 step =21, time=9.547737e-04, DT=1.158548e-04, filled=199, percent=  2.58%
 step =22, time=1.082713e-03, DT=1.279397e-04, filled=208, percent=  2.69%
 step =23, time=1.219009e-03, DT=1.362951e-04, filled=226, percent=  2.93%
 step =24, time=1.369404e-03, DT=1.503951e-04, filled=247, percent=  3.20%
 step =25, time=1.553363e-03, DT=1.839593e-04, filled=262, percent=  3.39%
 step =26, time=1.742847e-03, DT=1.894844e-04, filled=281, percent=  3.64%
 step =27, time=1.945439e-03, DT=2.025922e-04, filled=300, percent=  3.88%
 step =28, time=2.156883e-03, DT=2.114439e-04, filled=324, percent=  4.19%
 step =29, time=2.369759e-03, DT=2.128753e-04, filled=335, percent=  4.34%
```

Visualization of results

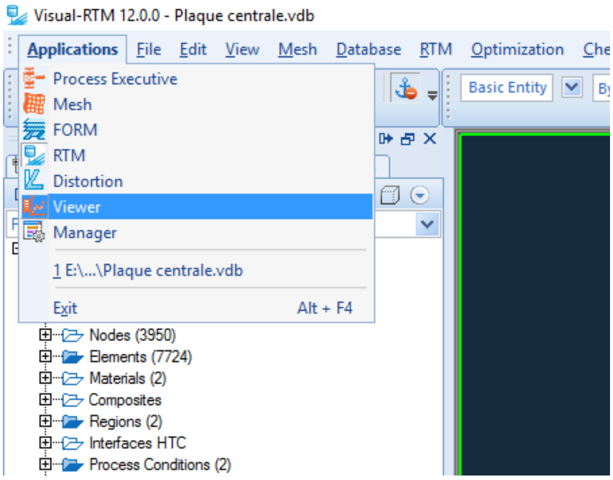
After the end of the simulation, you can check the results.

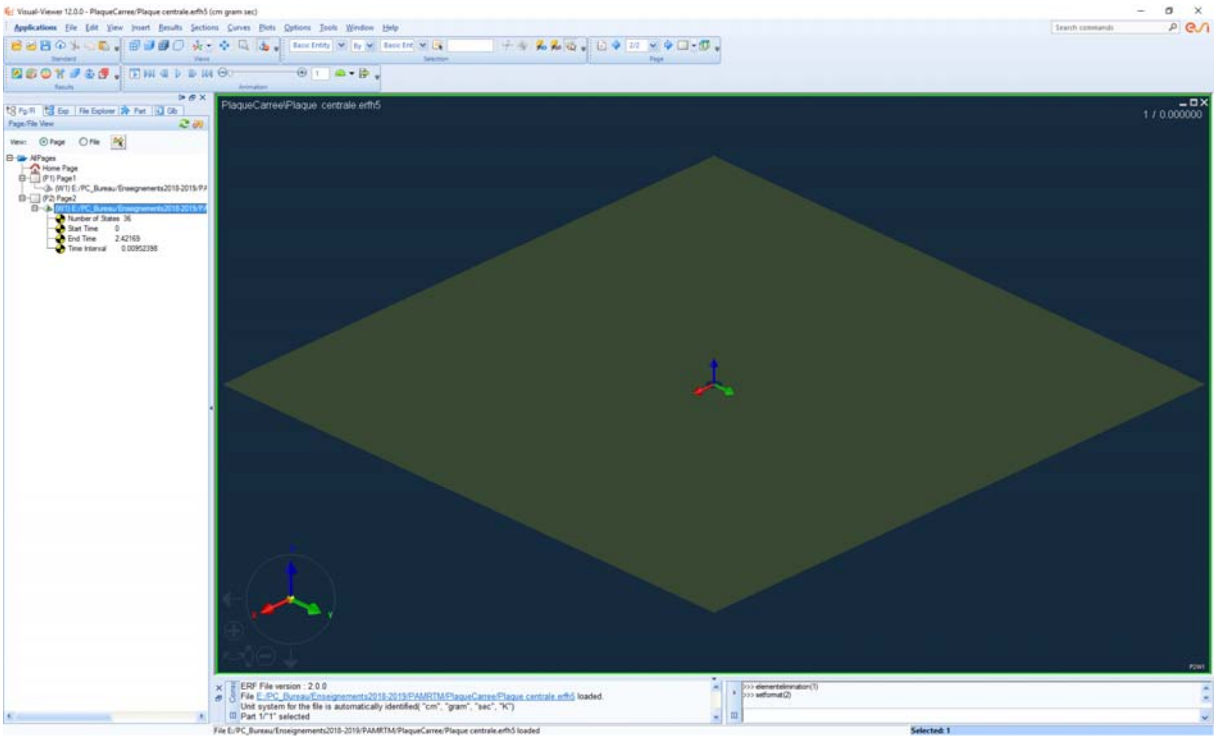
2 possibilities :

You can either click on “load results”

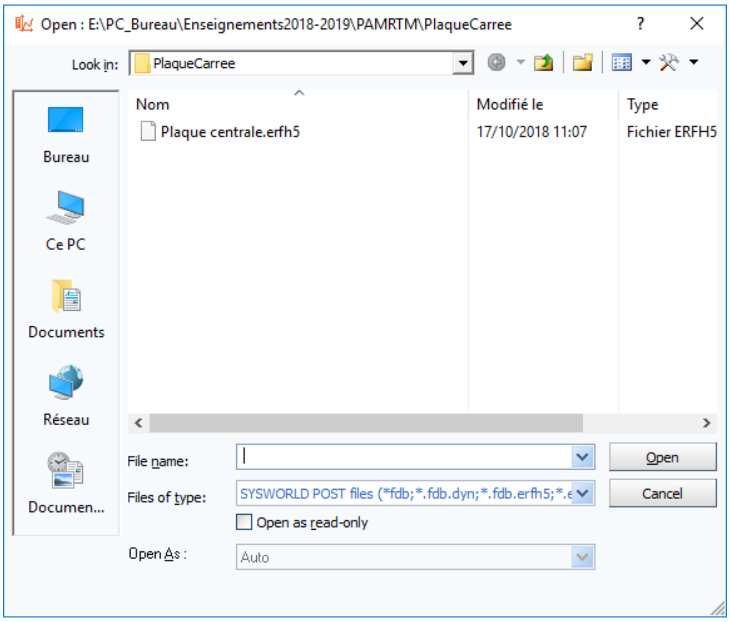
Or you can:

→ Open the Viewer

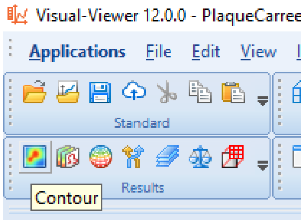


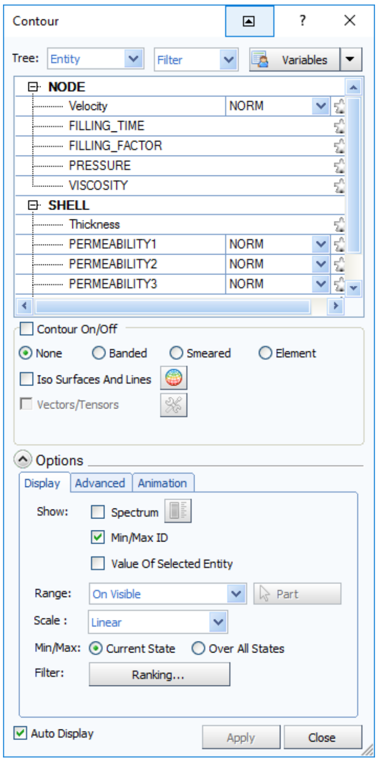


→Load you result file: its extension is *.erfh5*



→Then click on the *contour* button and visualize the different fields.





Post-processing files

In your work directory open with Excel (or any spreadsheet software) the two files:

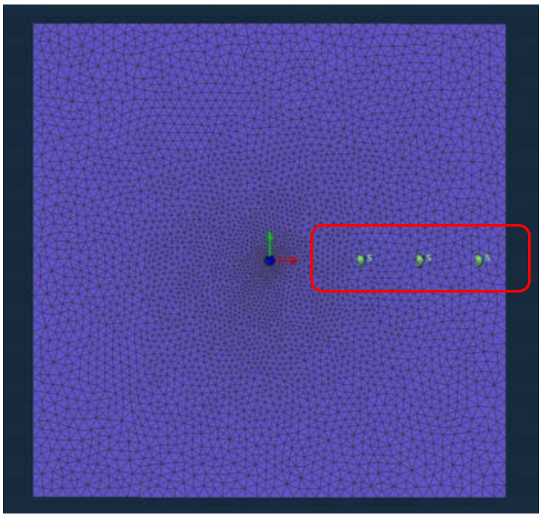
*filename*_BC1.out and *filename*_BC1.out

These files gather information on the boundary conditions of your simulation.

Work to do

1. Perform injection at constant pressure and observe the filling fronts, the pressure field, the total filling time, for opened and closed vents for the isotropic reinforcement.
2. Use the information in the "Boundary Conditions" files

    - For the injection simulation on isotropic reinforcement at constant pressure and open vents, plot on Excel for the injection zone and for the vents:
        - The change in pressure, the change in flow, the change in net volume.
        - Do the same with the vents closed.
        - Conclusion.
    - Carry out the same simulation with a constant flow rate (1L/min) at the injection zone and plot the same graphs.
3. Position 3 sensors.



In the case of constant pressure injection, plot the evolution of the pressure as a function of time for the 3 sensors then:

- Determine the passage time of the front on each sensor.
- Compare this time with the theoretical value given by Darcy's law.
- Repeat the same comparison for a constant start injection.

4. Proceed in the same way for an anisotropic reinforcement