Fluid dynamics simulation 2021-2022

Homework N° 1 & 2

Biasi Alberto 2039791

Modeling Flow Through Porous Media

Description: The objective of the simulation is to describe the velocity profile and the pressure drop in a catalytic converter. The problem is modeled using only nitrogen to represent off gases from the engine, because this is the main component in the stream and it isn't involved in any reaction in the catalyst surface, the converter is divided in 3 main areas, two turbulent areas at the inlet and outlet and a region in between described as laminar, the latter is composed of a monolith catalyst, made of a ceramic support with the Pd/Pt catalyst on it.

The monolith is obtained with extrusion of a ceramic mass, and it is composed of many parallel channels, because of its shape the catalytic region could be described as laminar.

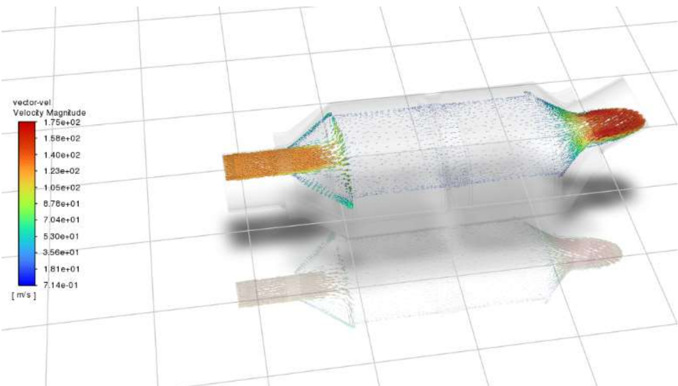
The initial conditions of the inlet stream are 800K and 125 m/s.

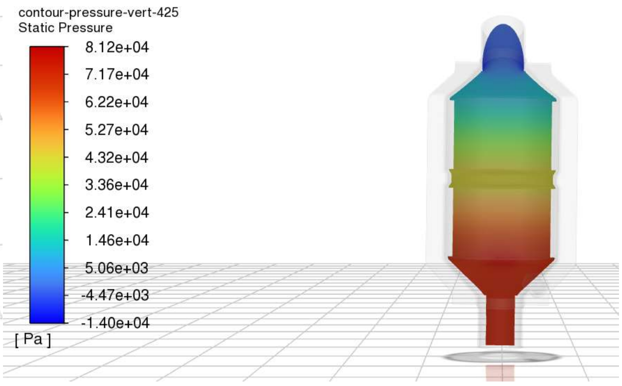
Grid size and quality: The mesh is unstructured hybrid with polyhedral, and it is composed of 367167 cells, the area around the sensor is obtained using a local sizing instead in the rest of the volume it is coarser, with minimum orthogonal quality of 1.10430e-01 and Maximum aspect ratio of 8.00810e+01.

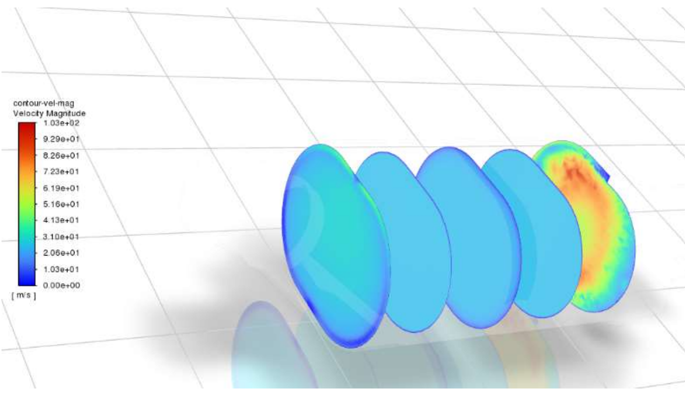
Results: The simulation was performed using the K-omega method, in 150 iterations (4 min).

The velocity profile obtained in the simulation is represented in Figure 1, looking at the velocity vector's directions can be noticed that in the converter there is a strong recirculation at the inlet in the turbulent area, in the porous media the velocity is more uniform and in the same direction, because of the parallel channel shape that avoid permeability in any direction different from the longitudinal one of the pipes, but at the end of the catalyst we can see two others small recirculation on the sides, due to the section change. The velocity varies a lot also in the inlet and outlet pipes, the stream velocity decreases outside the pipes due to the section increase and decrease respectively (Figure 2).

The pressure profile obtained in the simulation is represented in Figure 3, the porous media is the region in with the major pressure drop is concentrated, this is due to the viscous and inertial forces in the laminar flow inside the catalyst.







Net mass flowrate [kg/s]: -2.1321469e-07

Net energy flowrate [kg/s]: -0.1619765

Modeling Flow using VOF Model

Description: The objective of the simulation is to describe a transient system composed of 2 phases, in a printer head nozzle. The two phases on exam are air and ink, the latter is considered as liquid water.

The system in composed of two parts: the nozzle filled with ink, at the beginning, on top, characterized by a wettable surface, and a section below filled of air with not wettable walls.

The system is simulated for 30 µs, during the first 10 µs an impulse described by a specific cosine function determine the inlet velocity of the ink and for the duration of the simulation gravity is not considered.

Grid size and quality: The mesh is two dimensional, structured, composed of quadrilaterals and it is made of 24600 cells, with minimum orthogonal quality of 9.93025e-01 and Maximum aspect ratio of3.65205e+00.

The system is described as 2D because of the symmetry of the nozzle respect to the central axis.

Results: The simulation was performed using the Laminar model (3000 iteration, 12 min), and the multiphase system was described using the Volume of Fluid homogeneous model, to define the phase interaction was used the surface tension between air and water(ink). To define the impulse on the ink was used a transient boundary condition in the ink inlet.

The results of the simulation are reported in the figures below, Figure 1 represents the phase of the initial impulse, in which the droplet is formed, when this starts to fall free, we can notice that the interface in the nozzle present a curved shape because of the wettability constraint.

In figure 3 the 2 droplets are represented, according to the VOF model at the boundaries is defined a region in which the two phases mix, in fact in this region the Volume fraction changes between 0 and 1 when passing through the interface.

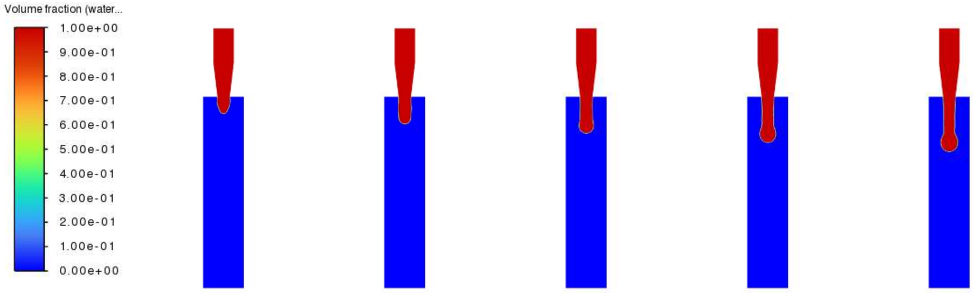


Figure 1: Multiphase Volume Fraction(1-Ink,0-Air): 2 µs, 4 µs, 6 µs, 8 µs and 10 µs.

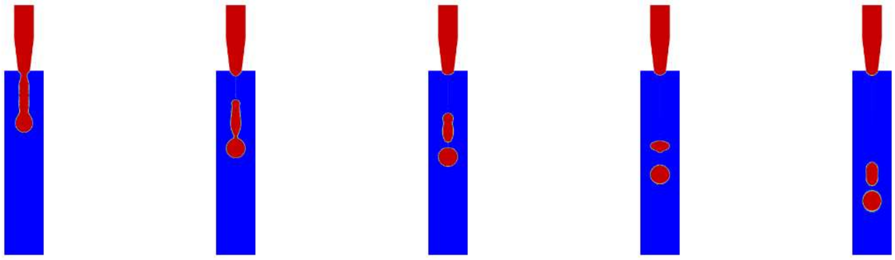


Figure 2: Multiphase Volume Fraction(1-Ink,0-Air): 12 µs, 18 µs, 20 µs, 24 µs and 30 µs.

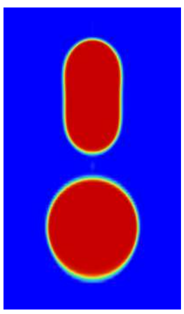


Figure 3: Detail of the interface in the droplets.