1st Task: CFD Analysis OfDifferent Values of Flow

Authors: Julen Arruti
Victor Navarrete
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Subject: Numerical Methods Of Heat And Mass Transfer
Professor: Ekaterina Kitanina

1. - Problem Definition

➢ Physical Description

We are going to simulate the flow of an air flow through analuminum pipe in a different range of velocities and consequently different types of flows (laminar and turbulent).

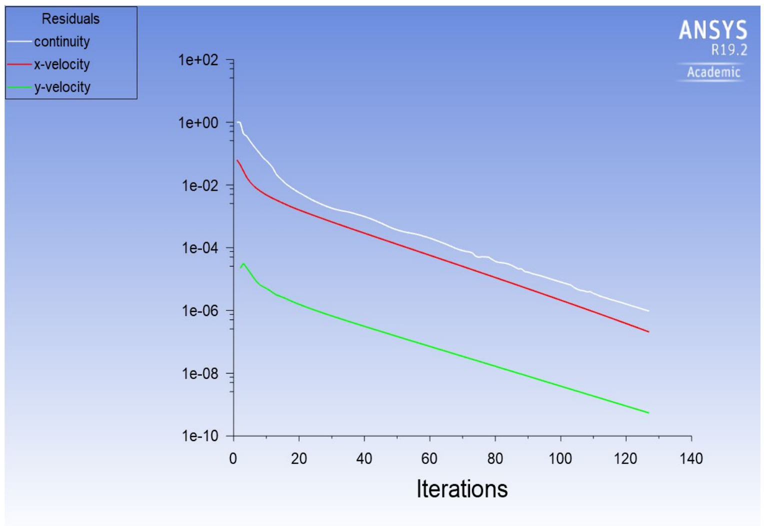
➢ Numerical Description

We are discretizing the pipes that we are analyzing into 10000 greeds and by the numerical methods we are going to calculate the different values of velocity vectors across the tube, the pressure drops from the inlet to the outlet due to the friction of the pipe walls.

2. - Results of the simulation:

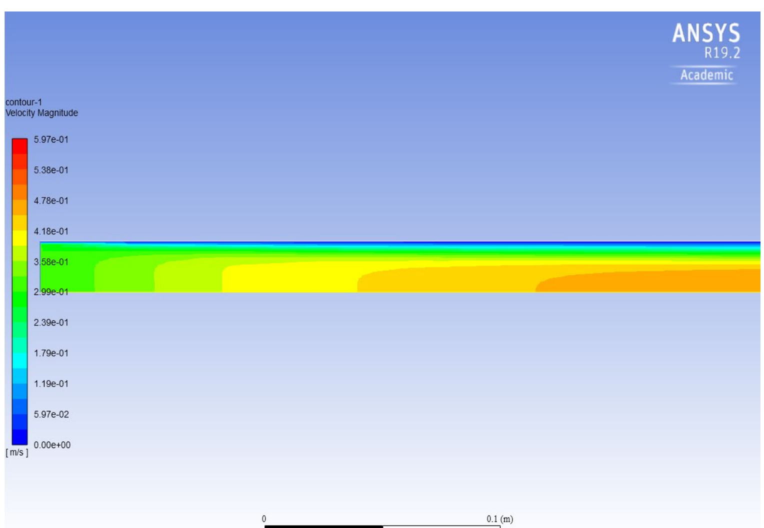
1stSimulation:

Figure 1.1 *Residual Results.*



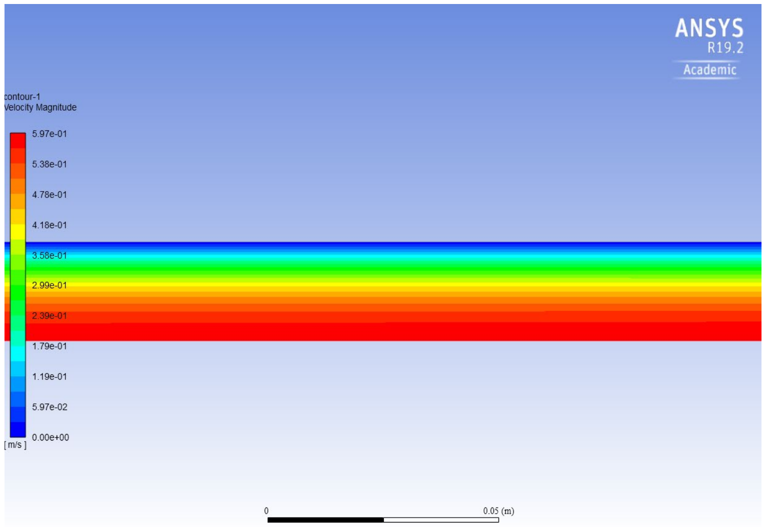
Source: Ansys simulations solutions (2018)

Figure 1.2 Contours Inlet Velocity in the pipe.



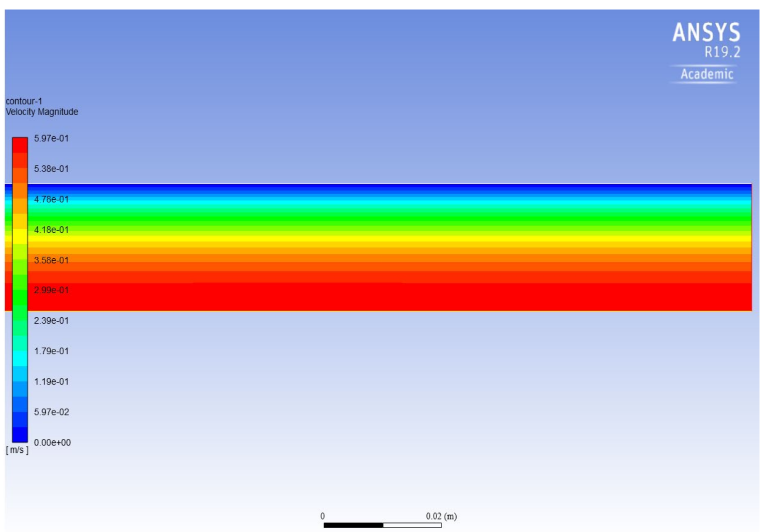
Source: Ansys simulations solutions (2018)

Figure 1.3 Contours Velocity in the middle of the pipe.



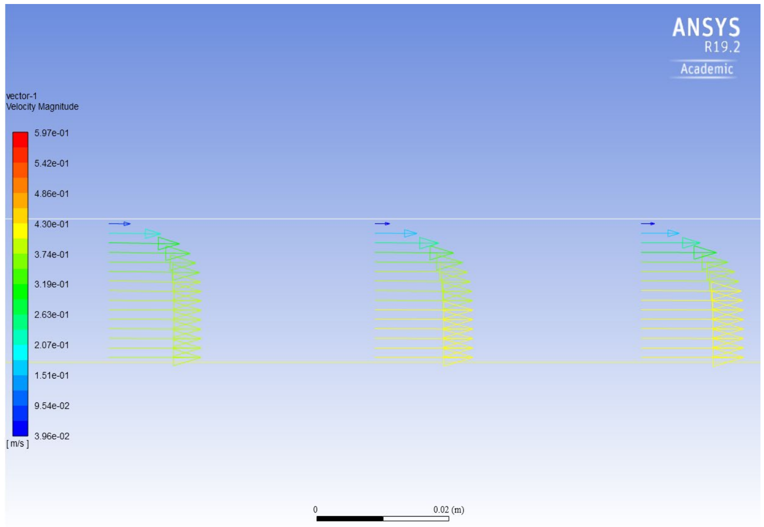
Source: Ansys simulations solutions (2018)

Figure 1.4 Contours Outlet Velocity in the pipe.



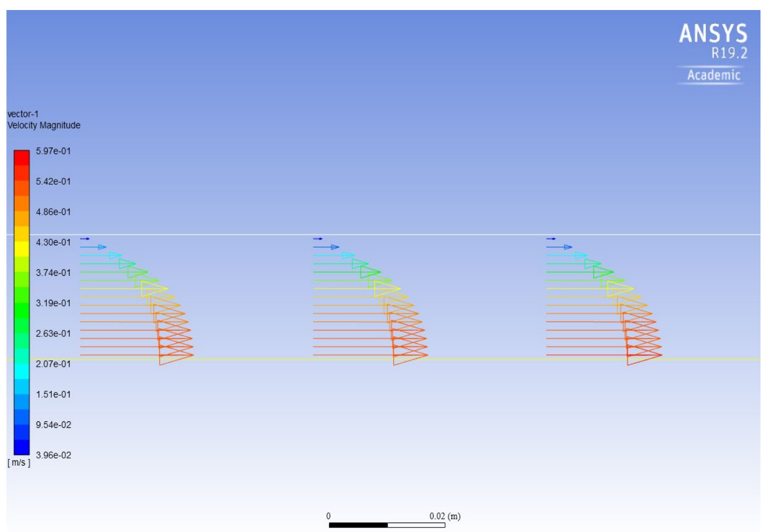
Source: Ansys simulations solutions (2018)

Figure 1.5 Vector Inlet Velocity in the pipe.



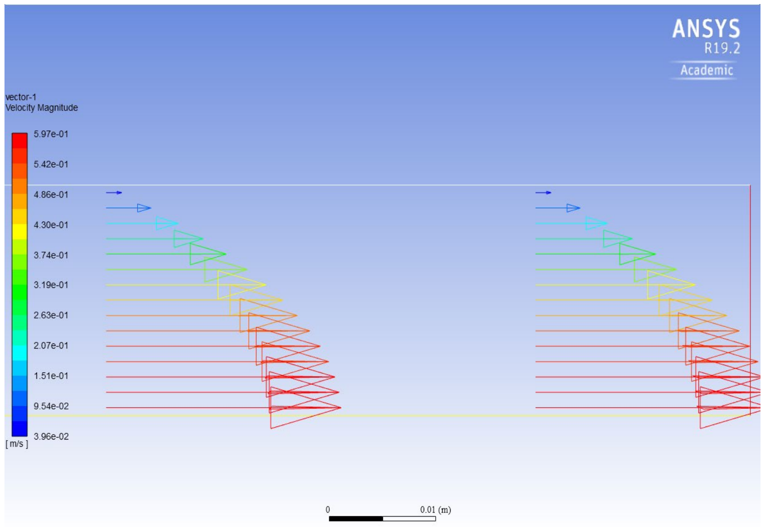
Source: Ansys simulations solutions (2018)

Figure 1.6 Velocity Vector in the middle of the pipe.



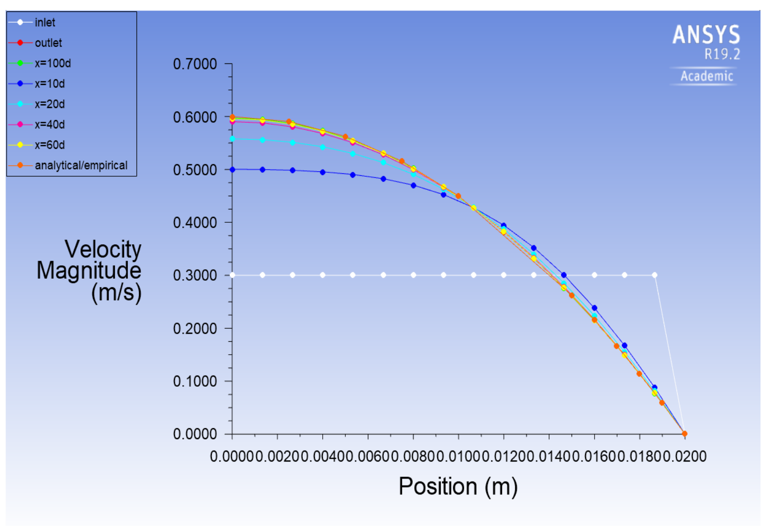
Source: Ansys simulations solutions (2018)

Figure 1.7 Vector Outlet Velocity in the pipe.



Source: Ansys simulations solutions (2018)

Figure 1.8 Empirical/Simulation



Source: Ansys simulations solutions (2018)

$$v = v_{max} \cdot (1 - \frac{r^2}{{r_0}^2})$$

$$v_{max} = 2 \cdot 0{,}3 = \boxed{0{,}6\ \frac{m}{s}}$$

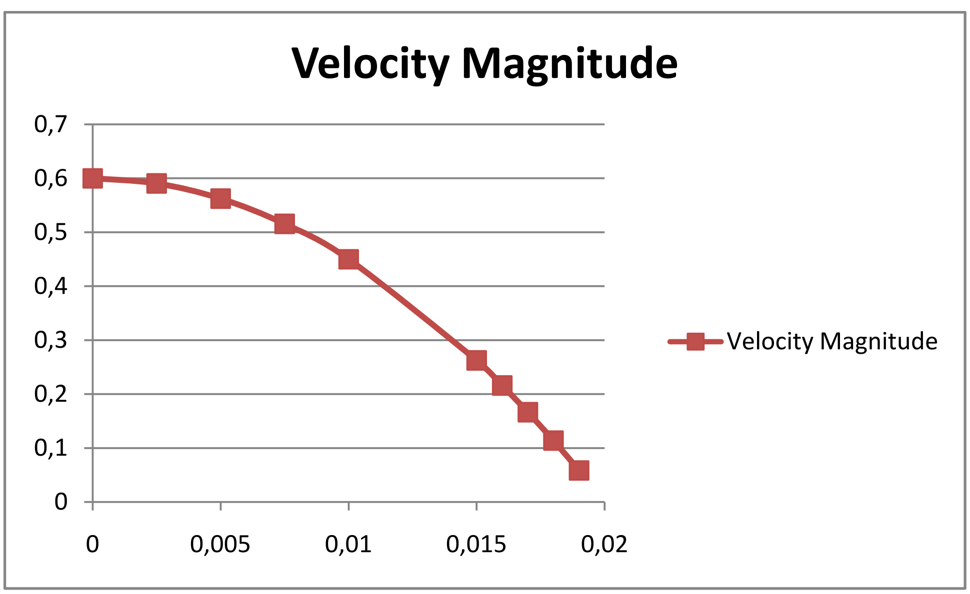
$$v = 2 \cdot v_{inlet} \cdot \left(1 - \frac{r^2}{{r_0}^2}\right)$$

Figure 1.9 Empirical Velocities.

XY	Velocity Magnitude
0	0,6
0,0025	0,590625
0,005	0,5625
0,0075	0,515625
0,01	0,45
0,015	0,2625
0,016	0,216
0,017	0,1665
0,018	0,114
0,019	0,0585
0,02	0
0,02	0

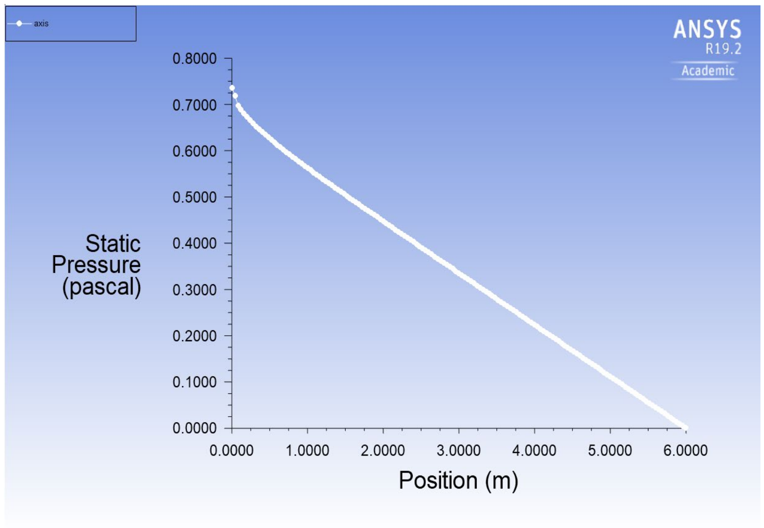
Source: Empirical results (2018)

Figure 1.10 Empirical Velocities



Source: Empirical results (2018)

Figure 1.11 Pressure Drop.



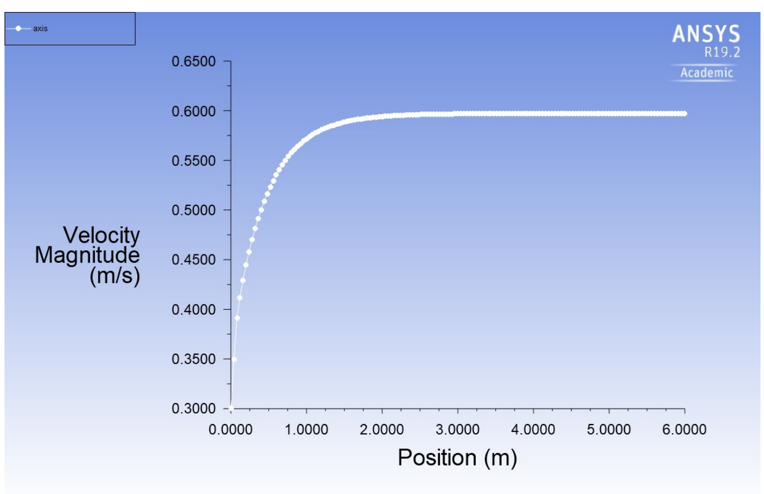
Source: Ansys simulations solutions (2018)

$$Re = \frac{\rho \cdot v \cdot d}{\mu} = \frac{1{,}17 \cdot 0{,}3 \cdot 0{,}04}{1{,}872 \cdot 10^{-5}} = \boxed{750}$$

$$\lambda = \frac{64}{Re} = \frac{64}{750} = \boxed{0{,}0853}$$

$$L_{entrance} \cong 0{,}06 \cdot Re \cdot d$$
$$0{,}06 \cdot 750 \cdot 0{,}04 = \boxed{1{,}8}$$

Figure 1.12 Axis Velocity along the pipe.



Source: Ansys simulations solutions (2018)

As we can see in the figure 1,12 the velocity stabilized it after the 2ndmeter and comparing with the calculi of $L_{entrance}$ it suppose to be at 1.8 mt.

$$\Delta p = \lambda \cdot \frac{L}{D} \cdot \frac{\rho V^2}{2}$$

$$\Delta p = 0{,}0853 \cdot \frac{6}{0{,}04} \cdot \frac{1{,}17 \cdot 0{,}3^2}{2} = \boxed{0{,}673}$$

Figure 1.13 Empirical Pressure/Simulate Ansys

X	Empirical	Ansys
0	0,6739	0,736643
0,2	0,6515	0,67319
0,4	0,6290	0,640666
0,6	0,6065	0,612891
0,8	0,5841	0,587267
1	0,5616	0,562848
1,2	0,5391	0,539164
1,4	0,5167	0,515943
1,6	0,4942	0,493022
1,8	0,4717	0,470293
2	0,4493	0,447691
3	0,3370	0,335472
4	0,2246	0,223601
5	0,1123	0,111771
5,8	0,0112	0,0223064

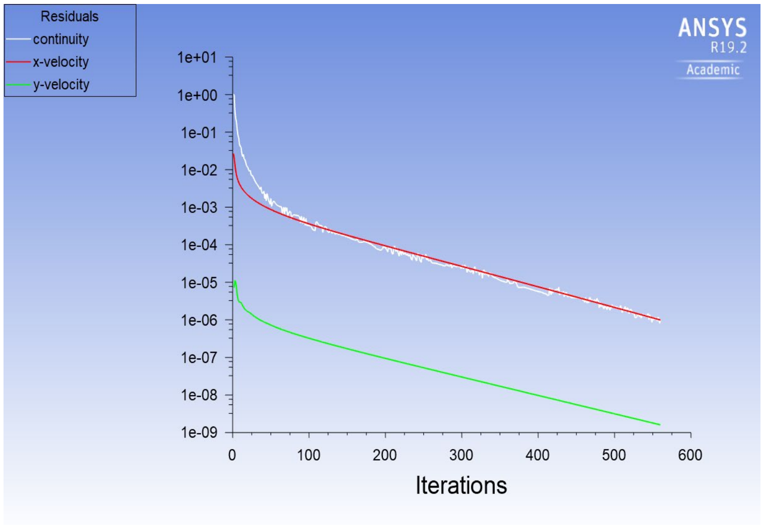
Source: Empirical results (2018)

Figure 1.14 Empirical Pressure/Simulate Ansys

Source: Empirical results (2018)

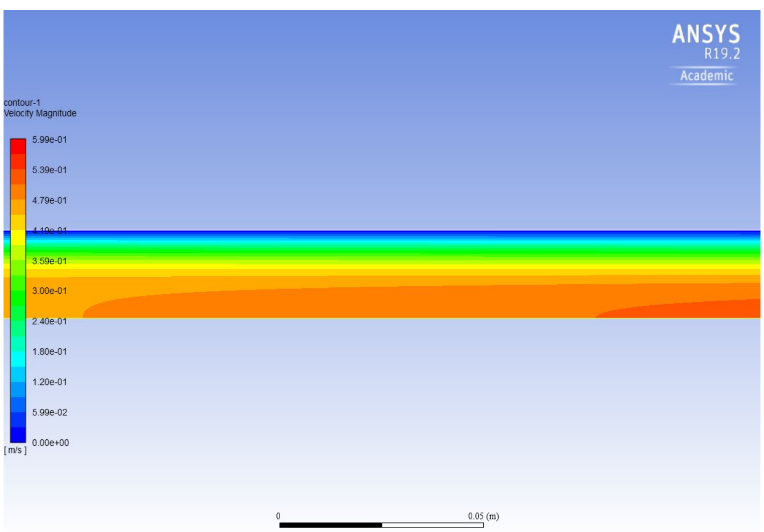
2ndSimulation

Figure 2.1 Residual Results.



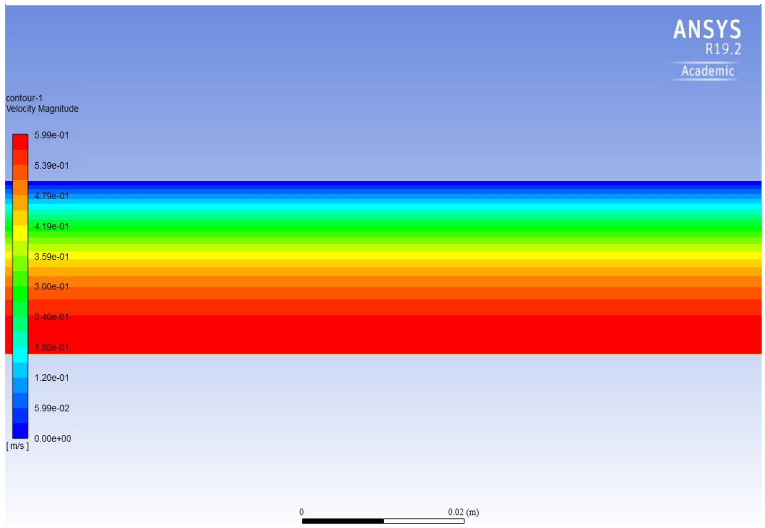
Source: Ansys simulations solutions (2018)

Figure 1.2 Contours Inlet Velocity in the pipe.



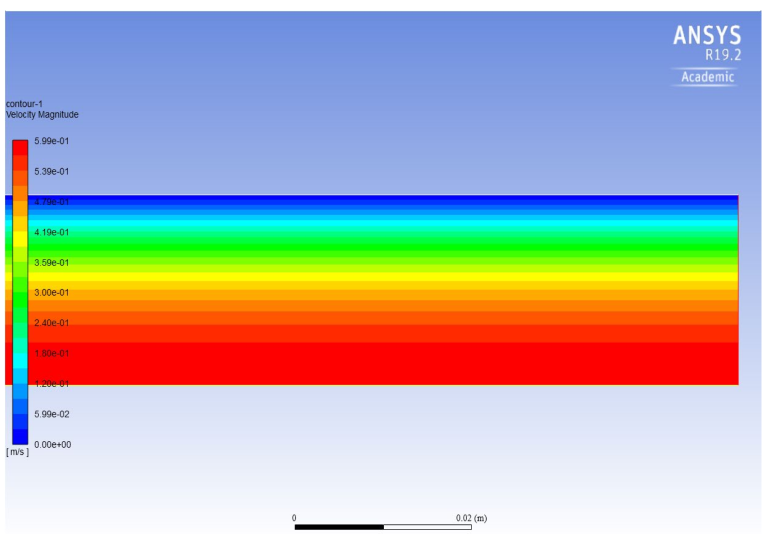
Source: Ansys simulations solutions (2018)

Figure 2.3 Contours Velocity in the middle of the pipe.



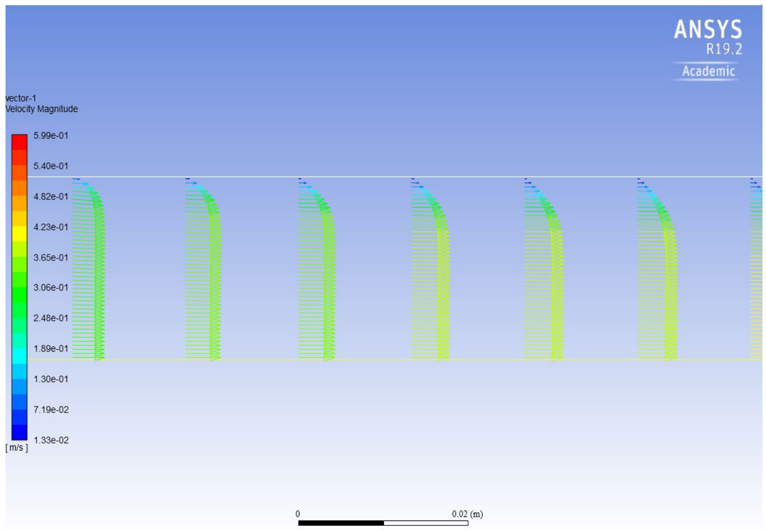
Source: Ansys simulations solutions (2018)

Figure 2.4 Contours Outlet Velocity in the pipe.



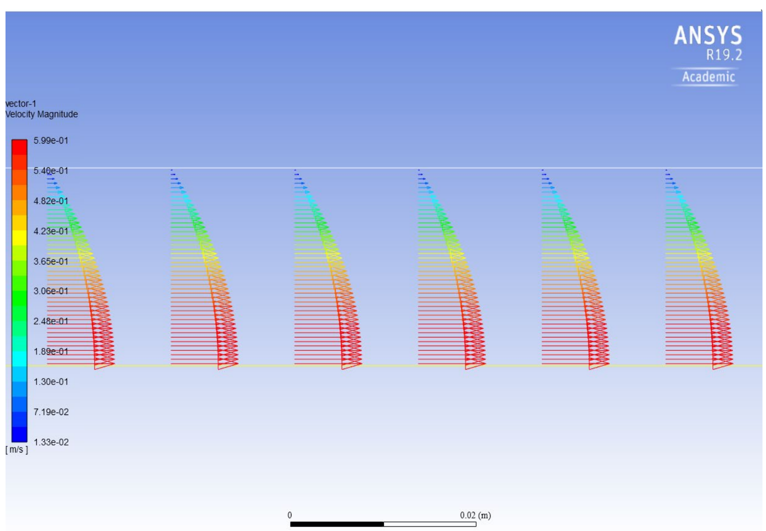
Source: Ansys simulations solutions (2018)

Figure 2.5 Vector Inlet Velocity in the pipe.



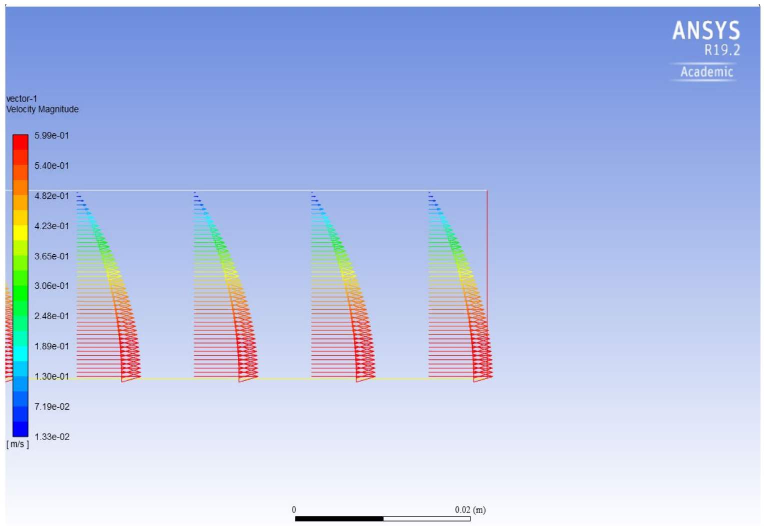
Source: Ansys simulations solutions (2018)

Figure 2.6 Velocity Vector in the middle of the pipe.



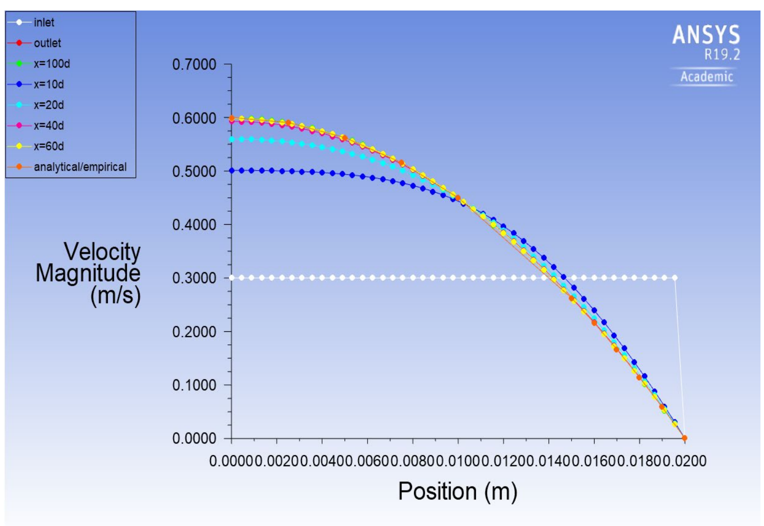
Source: Ansys simulations solutions (2018)

Figure 2.7 Vector Outlet Velocity in the pipe.



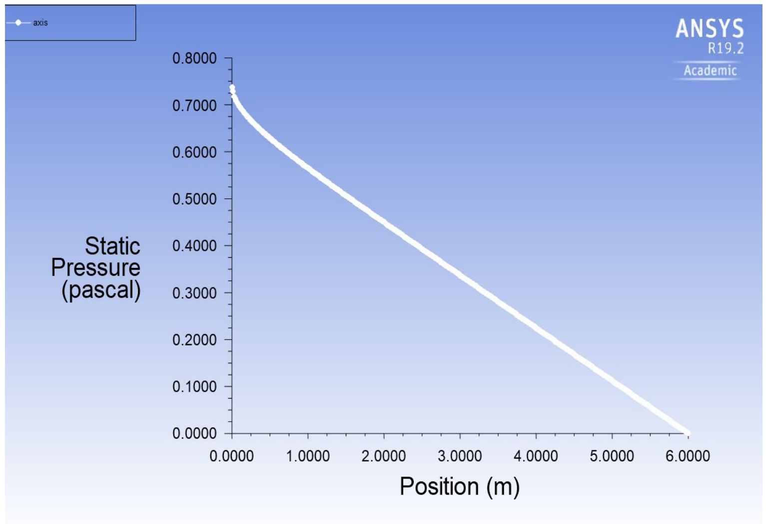
Source: Ansys simulations solutions (2018)

Figure 2.8 Empirical/Simulation



Source: Ansys simulations solutions (2018)

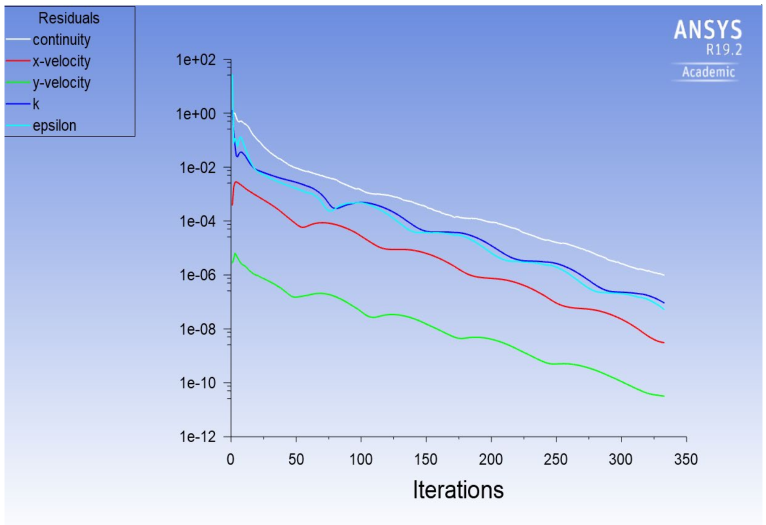
Figure 2.9 Pressure Drop.



Source: Ansys simulations solutions (2018)

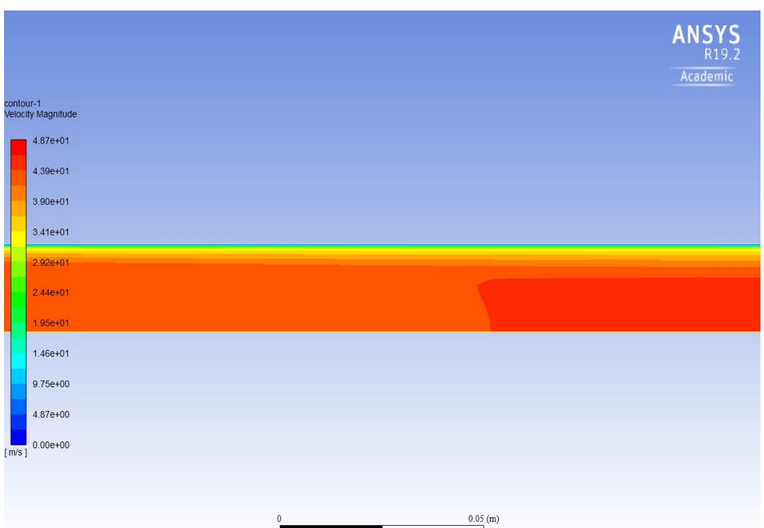
3rdSimulationTurbulence

Figure 3.1 Residual Results.



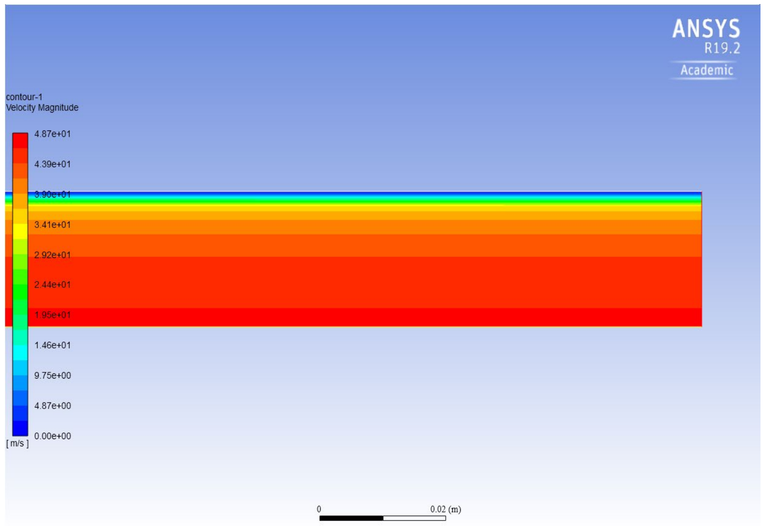
Source: Ansys simulations solutions (2018)

Figure 3.2 Contours Inlet Velocity in the pipe.



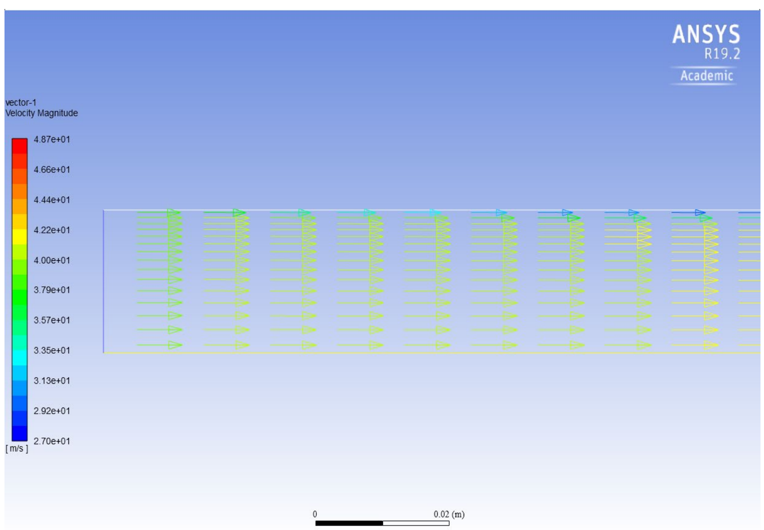
Source: Ansys simulations solutions (2018)

Figure 3.3 Contours Outlet Velocity in the pipe.



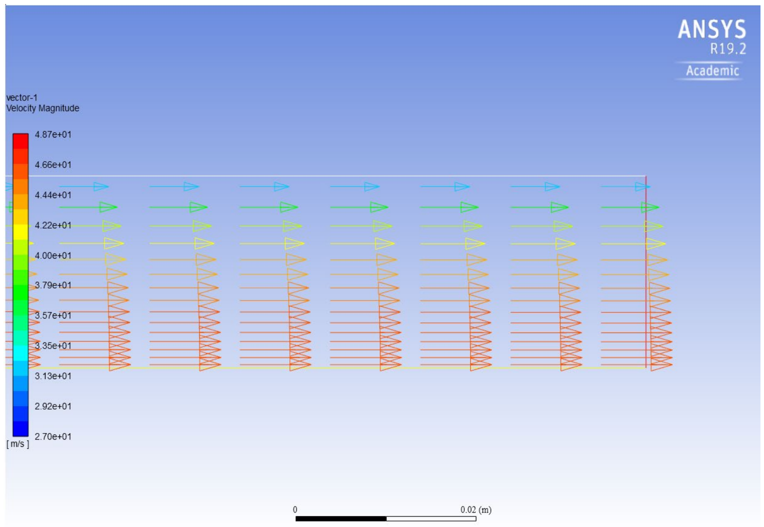
Source: Ansys simulations solutions (2018)

Figure 3.4 Vector Inlet Velocity in the pipe.



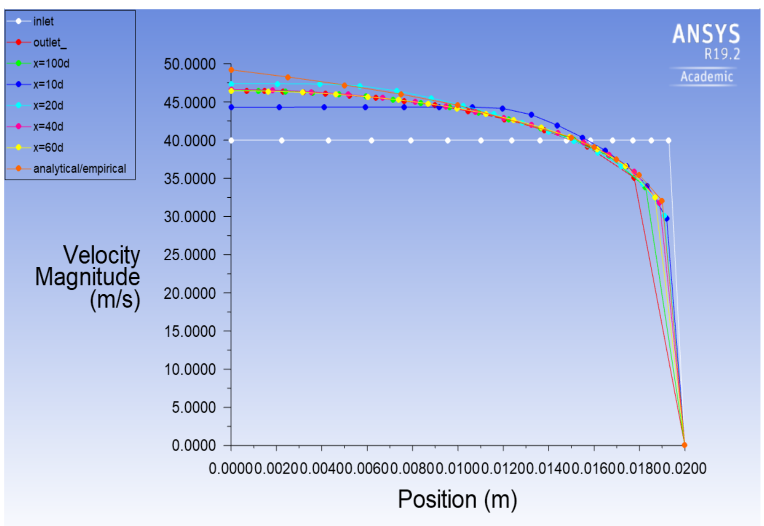
Source: Ansys simulations solutions (2018)

Figure 3.5 Vector Outlet Velocity in the pipe.



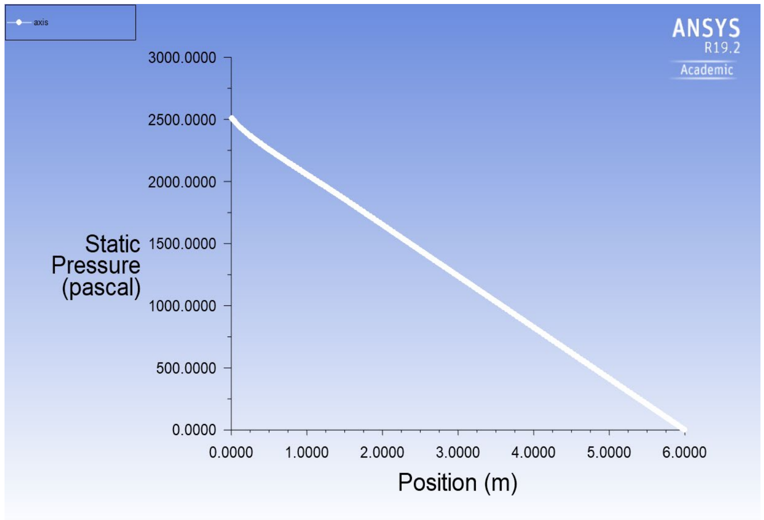
Source: Ansys simulations solutions (2018)

Figure 3.6 Empirical/Simulation



Source: Ansys simulations solutions (2018)

Figure 3.7 Pressure Drop.



Source: Ansys simulations solutions (2018)

$$v = v_{max} \cdot (1 - \frac{r^2}{{r_0}^2})$$

$$v_{max} = 1{,}23 \cdot 0{,}3 = \boxed{0{,}369\ \frac{m}{s}}$$

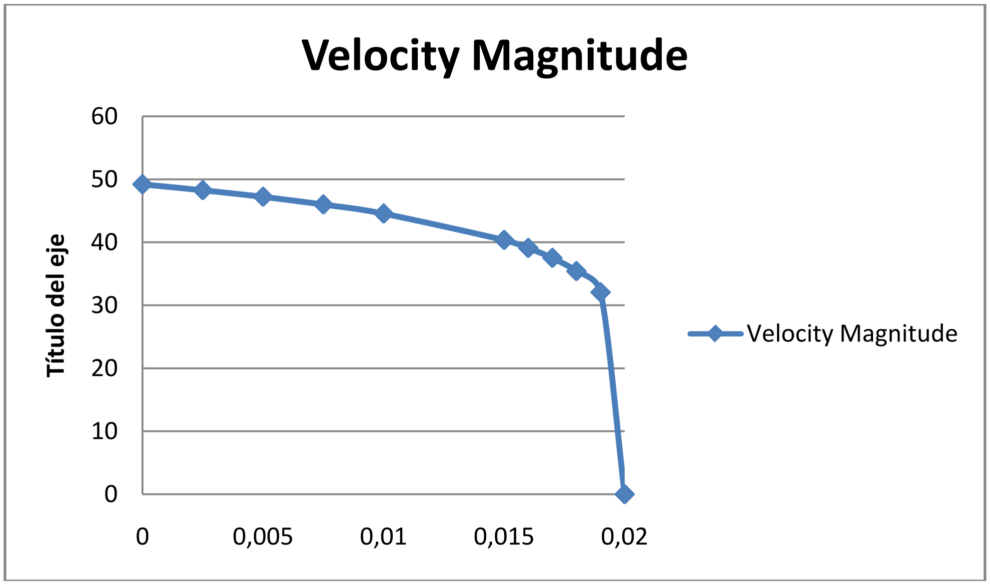
$$v = 1{,}23 \cdot v_{inlet} \cdot \left(1 - \frac{r^2}{{r_0}^2}\right)$$

Figure 3.8 Empirical Velocities.

XY	Velocity Magnitude
0	49,2
0,0025	48,27
0,005	47,22
0,0075	46,01
0,01	44,56
0,015	40,36
0,016	39,09
0,017	37,52
0,018	35,41
0,019	32,07
0,02	0

Source: Empirical results (2018)

Figure 3.9 Empirical Velocities.



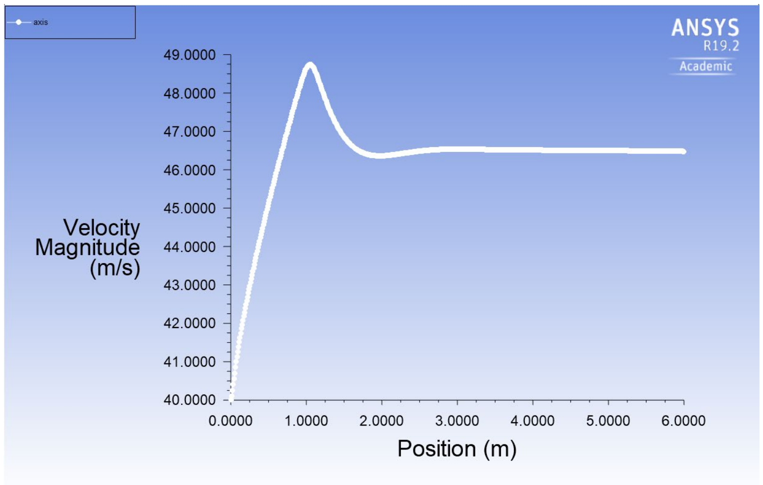
Source: Empirical results (2018)

$$Re = \frac{\rho \cdot v \cdot d}{\mu} = \frac{1{,}17 \cdot 0{,}3 \cdot 0{,}04}{1{,}872 \ \cdot 10^{-5}} = \boxed{100.000}$$

$$\frac{1}{\sqrt{f}} = -0{,}86 \cdot ln\left(\frac{\varepsilon}{3{,}7 \cdot d}\right) = \ -0{,}86 \ \cdot ln\left(\frac{2{,}5 \cdot 10^{-5}}{3{,}7 \cdot 0{,}04}\right) = \boxed{0{,}0179}$$

$$L_{entrance} \ \cong 4{,}4 \cdot Re^{\frac{1}{6}} \cdot d$$
$$\cong 4{,}4 \cdot 100.000^{\frac{1}{6}} \cdot 0{,}04 = \boxed{1{,}199}$$

Figure 3.10 Axis Velocity along the pipe.



Source: Ansys simulations solutions (2018)

$$\Delta p = \lambda \cdot \frac{L}{D} \cdot \frac{\rho V^2}{2}$$

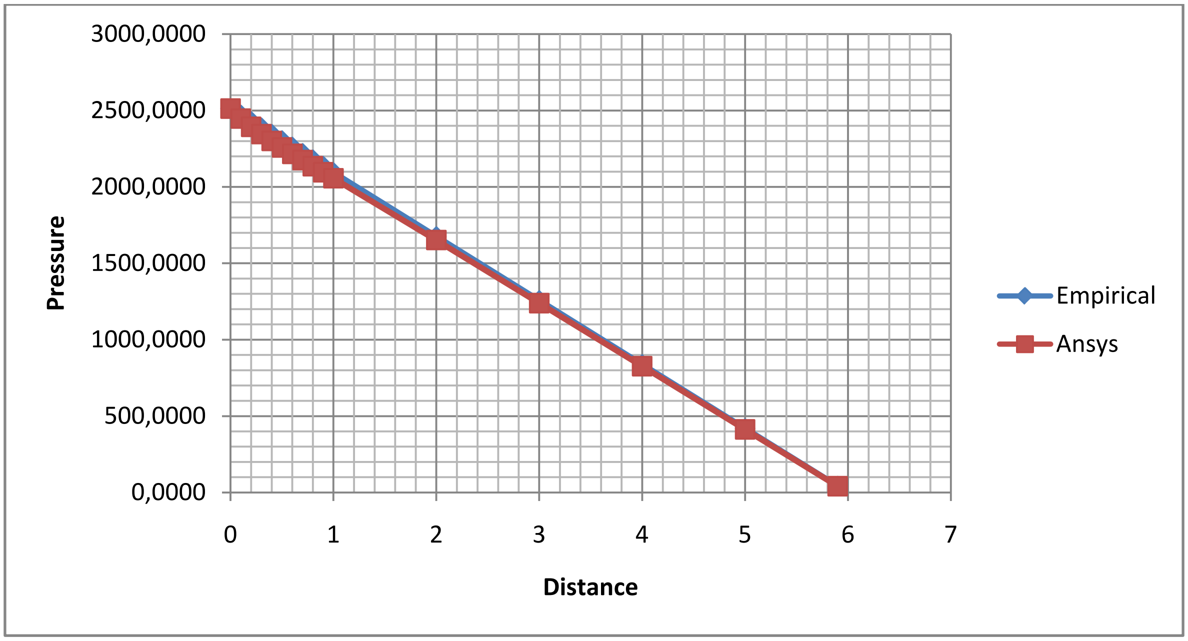
$$\Delta p = 0{,}0179 \cdot \frac{6}{0{,}04} \cdot \frac{1{,}17 \cdot 40^2}{2} = \boxed{2513{,}16}$$

Figure 3.11 Empirical Pressure/Simulate Ansys

X	Empirical	Ansys
0	2513,16	2512,84
0,1	2471,274	2447,13
0,2	2429,388	2393,17
0,3	2387,502	2345,48
0,4	2345,616	2300,77
0,5	2303,73	2257,97
0,6	2261,844	2216,42
0,7	2219,958	2175,76
0,8	2178,072	2135,72
0,9	2136,186	2096,10
1	2094,3	2056,74
2	1675,44	1652,28
3	1256,58	1239,19
4	837,72	826,59
5	418,86	413,42
5,9	41,886	41,20

Source: Empirical results (2018)

Figure 3.12 Empirical Pressure/Simulate Ansys



Source: Empirical results (2018

3. - Analysis of the data:

- **Residual analysis:**

As we can see in the Figures 1.1, 2.1 and 3.1, the results of the simulations show that the results converge so we can consider that the simulations were successful and that we can trust the results obtained in them. We should also point out that as more complex the flow is more iterationsare required to get a converged result.

- **Analysis of the velocity:**

As we can see in the group of Figures 1.2, 1.5, 2.2, 2.5, 3.2 and 3.5 the velocity in the inlet of the three pipes is almost the same in every point, excepting the regions nearby the wall was the friction begins to slow down the speed of the particles.

In regard with the images related with the outlet velocity (1.4, 1.6, 2.4, 2.7, 3.3, 3.5) we can see the effect of the friction of the wall deforms the linear inlet distribution of the velocities turning it into a parabolic distribution where the maximum speed is located in the middle of the pipe, while in the nearby region of the wall is much lower.

As far as entrance length is concerned, we can regard the Figures 1.12 and 3.11 and confirm that the empirical and analytical results are quite similar, that the velocity in the axis stabilizes around the length that was predicted by the formulas we used and that the formulas used were trustful.

- **Comparison between the empirical and theoretical results**

Watching the chart of the Figures 1.8, 2.8 and 3.6 we can see that the theoretical results match with the results obtained in the middle region with if the data is collected near the inlet are not accurate. Anyway, we can reaffirm that the theoretical values are valid based on the simulated results.

- **Pressure drops**

Based on the charts of the pressure drop of the snaps 1.9, 2.9 and 3.7 we can observe that as the airflow travels through the pipe, the pressure drops because of thewall's friction. This lower drop is what makes, apart from the inlet mass flow, which makes the flow travel from the high-pressure side, in the inlet, to the low-pressure side in the outlet.

If we take into account the results obtained in the figures 1.13, 1.14, 3.11 and 3.12, we can assure that the empirically obtained data and the measures obtained in the simulation are almost the same, with only a small variation. That is why we can say that the simulation is correct, and the results are trustful.