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CFD Modeling of Lapple Cyclone for Gas-Solid Separation

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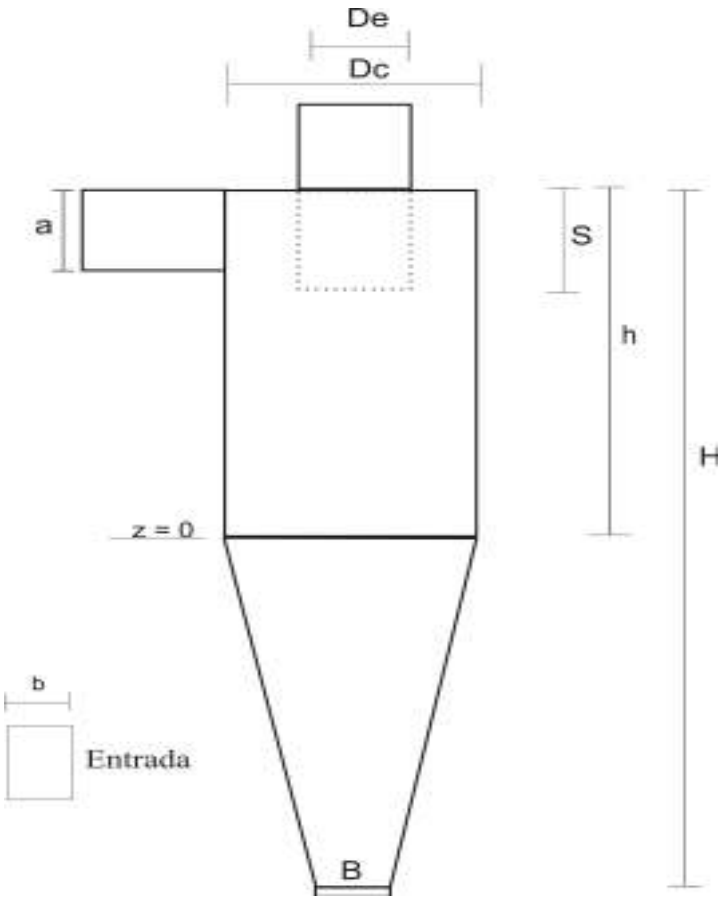
Introduction

- **Cyclones**
  - Devices that employ centrifugal force generated by spinning gas stream to separate particles from the carrier gas.
  - Simulation and optimization on the cyclone's operation are a current need.
  - Lapple type is one of the most known.

Introduction

- Dimensions of the cyclone Lapple for this study:

  - Dc = 0,254 and 0,127 m;
  - De/Dc = 0,500;
  - a/Dc = 0,500;
  - b/Dc = 0,250;
  - S/Dc = 0,625;
  - h/Dc = 2,000;
  - (H-h)/Dc = 2,000;
  - B/Dc = 0,205.



Mathematical Modeling

- Finite Volume Method
- Multi-phase Fluid Dynamic Model (Meier,1998)
- RSM-LRR Turbulence Model
- Upwind Approximation Scheme
- Size-cut (Lapple, 1951): $$dpc = \left(\frac{9\,\mu b}{2\pi Ne v (\rho_s - \rho_g)} \right)^{\frac{1}{2}}$$

  $with\ \ \mu = gas\ \ viscosity;$

  $b = entrance's\ width;$

  $Ne = number\ of\ the\ returns\ of\ the\ gas\ (5);$

  $v = feeding's\ velocity\ (15{,}2\,m/s);$

  $\rho_s = density\ of\ \ solid\ (1550\,Kg/m^3);$

  $\rho_g = density\ of\ \ gas.$

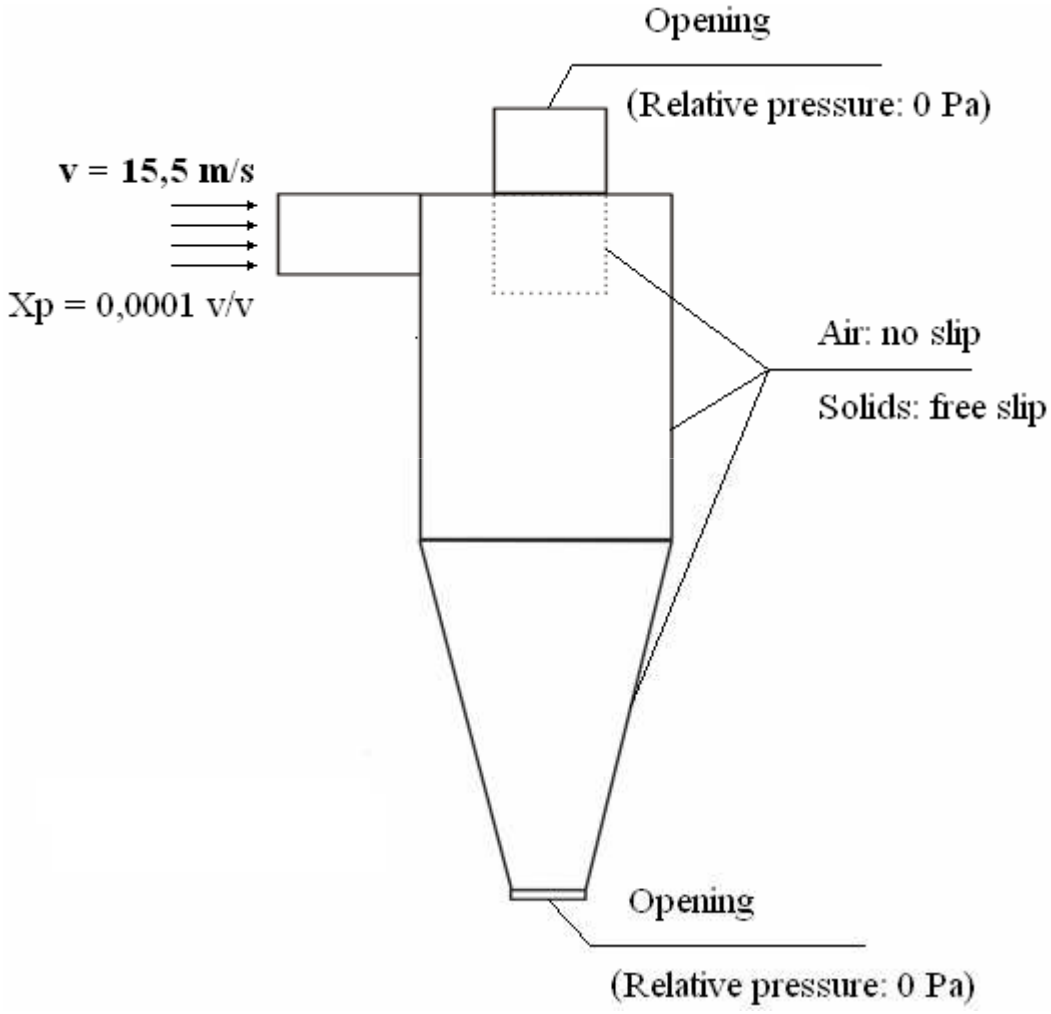
  Air: Standart conditions (0ºC and 1 atm)

  Feed solids: 0,0001 v/v

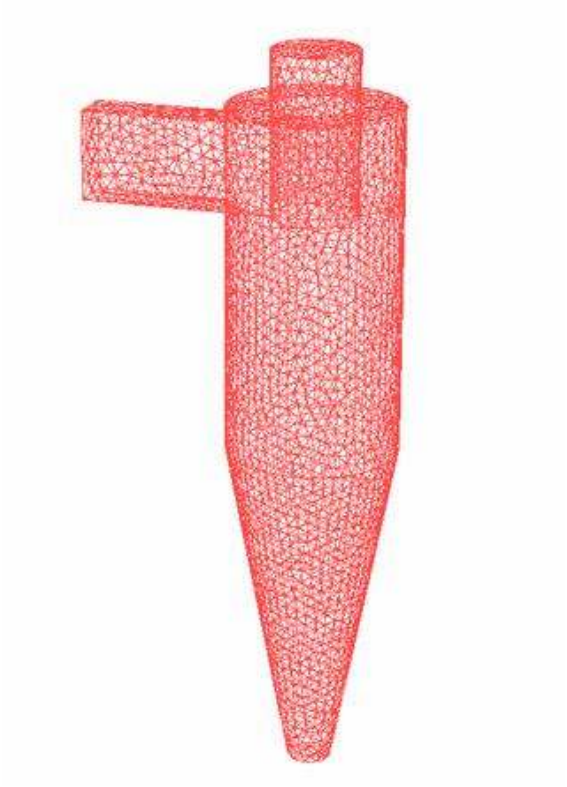
- Efficiency (η): $$\eta = \frac{\dot{m}_s}{\dot{m}_e} \quad with \quad \dot{m}_s = mass\ flow\ rate\ in\ entrance$$

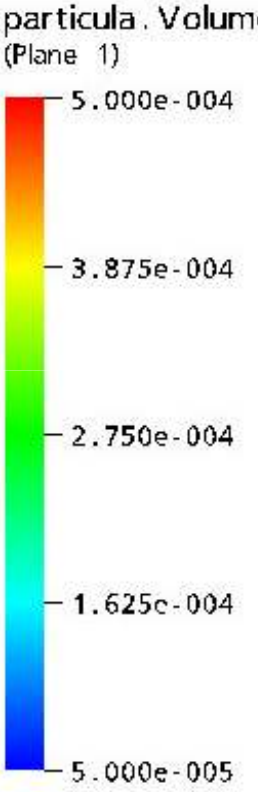
  $$and \quad \dot{m}_e = mass\ \ flow\ rate\ in\ exit.$$

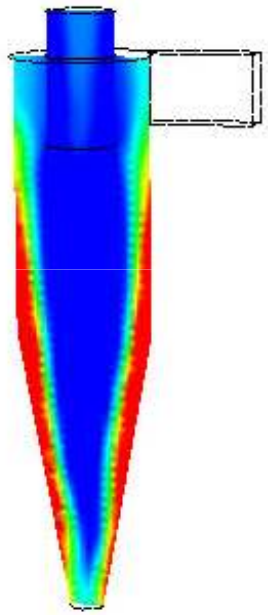
Boundary Conditions



Simulation Dc = 0,254 m







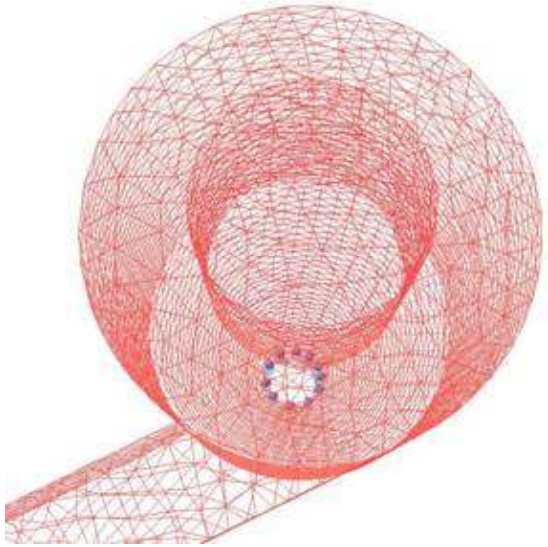
Mesh: 70439 tetrahedral elements

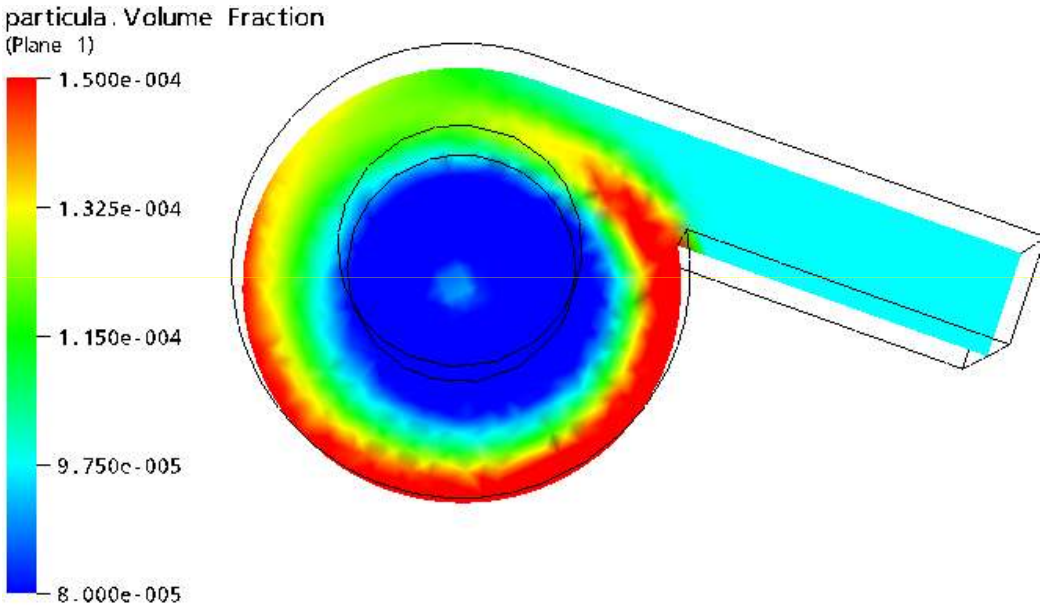
Dp = 3,70 μm (size-cut)

Solids volume fraction

Simulation Dc = 0,254 m

Superior view



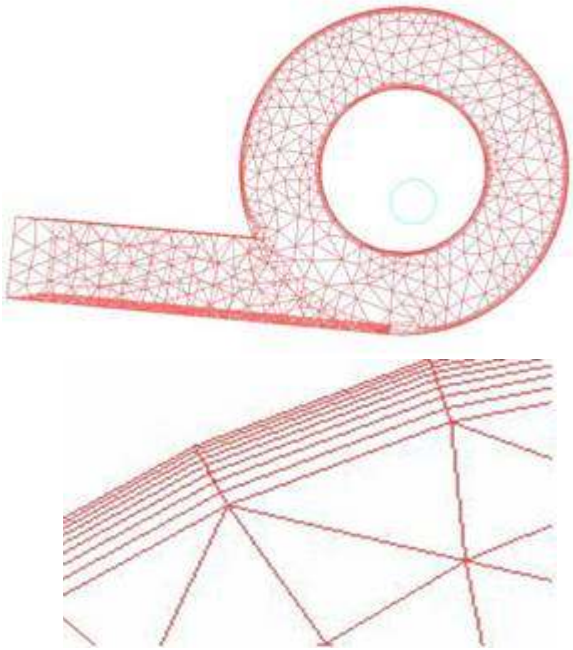


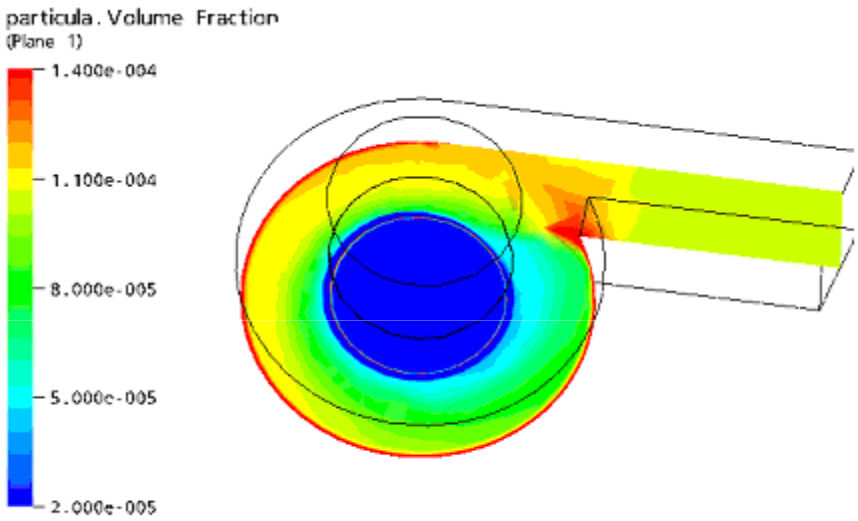
Tetrahedral mesh

Solids volume fraction for z = 0,45 m

Simulation Dc = 0,254 m

Mesh Refinement:





Solids volume fraction for z = 0,45 m

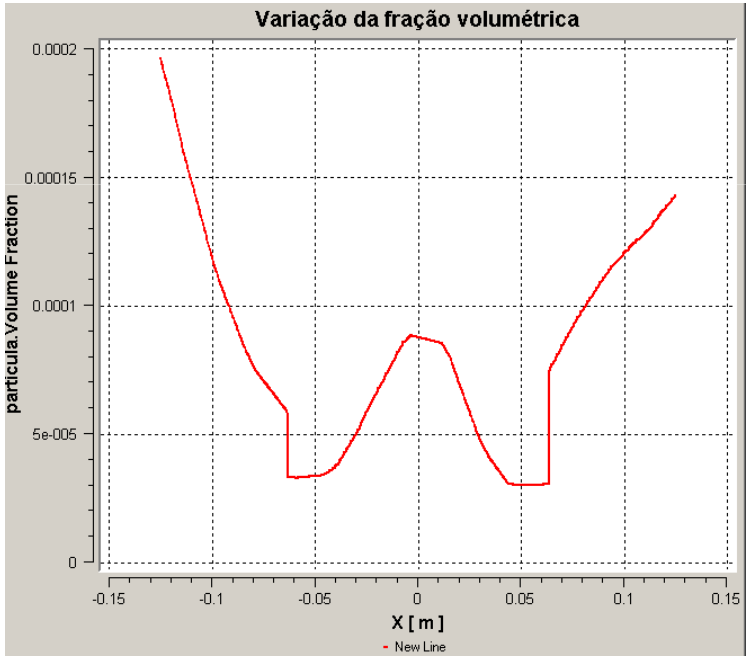
Mesh: 114074 tetrahedral elements including 6 hexahedral layers next to finder and on internal wall of the cyclone

Dp = 3,70 μm (size-cut)

Results and Discussion

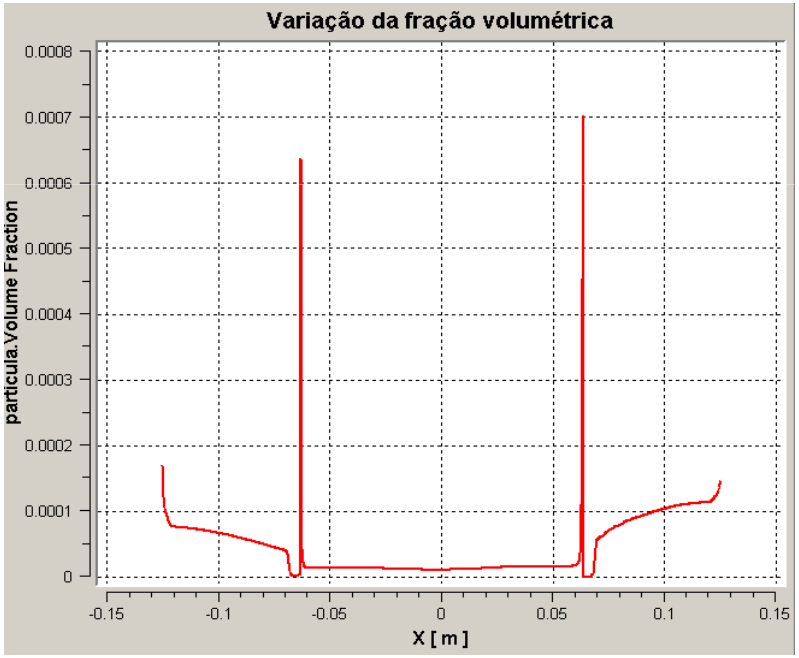
Variation of the volumetric fraction of solids throughout coordinate “x” in the height of finder

Without mesh refinement



Mesh tetrahedral with 70439 elements

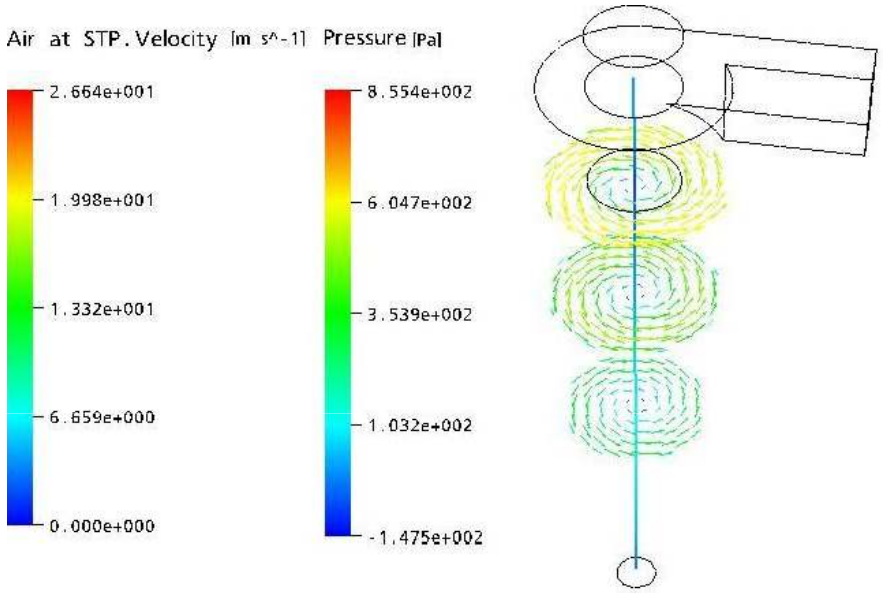
With mesh refinement



Mesh tetrahedral including 6 hexahedral layers on the internal walls totalizing 114074 elements

Results and Discussion

The vectors of the Figure to the side indicate the direction and the intensity of the total velocity of the gas, whereas the axial line the variation of the pressure.

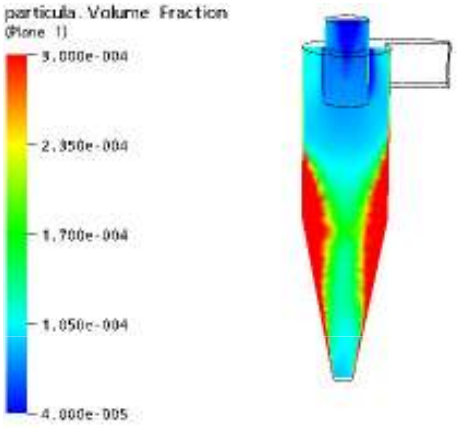


This behavior is waited and in agreement with the principle of the conservation of momentum for the simulated flow.

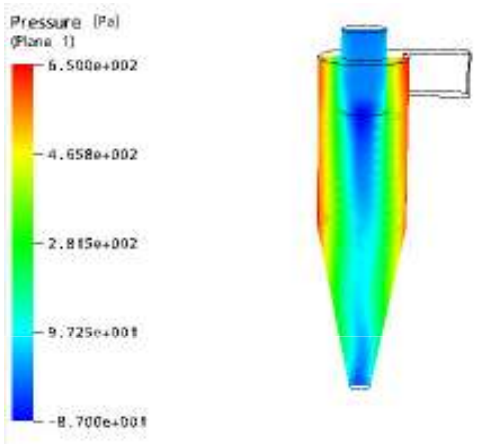
Simulation Dc = 0,127 m

Dp = 2,60 μm (size-cut)

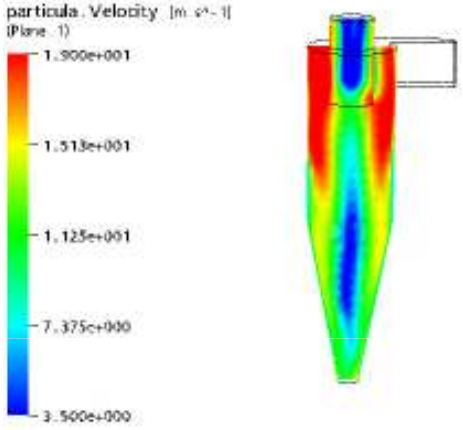
Mesh: 57135 tetra and hexahedral elements



Volumetric fraction of solids



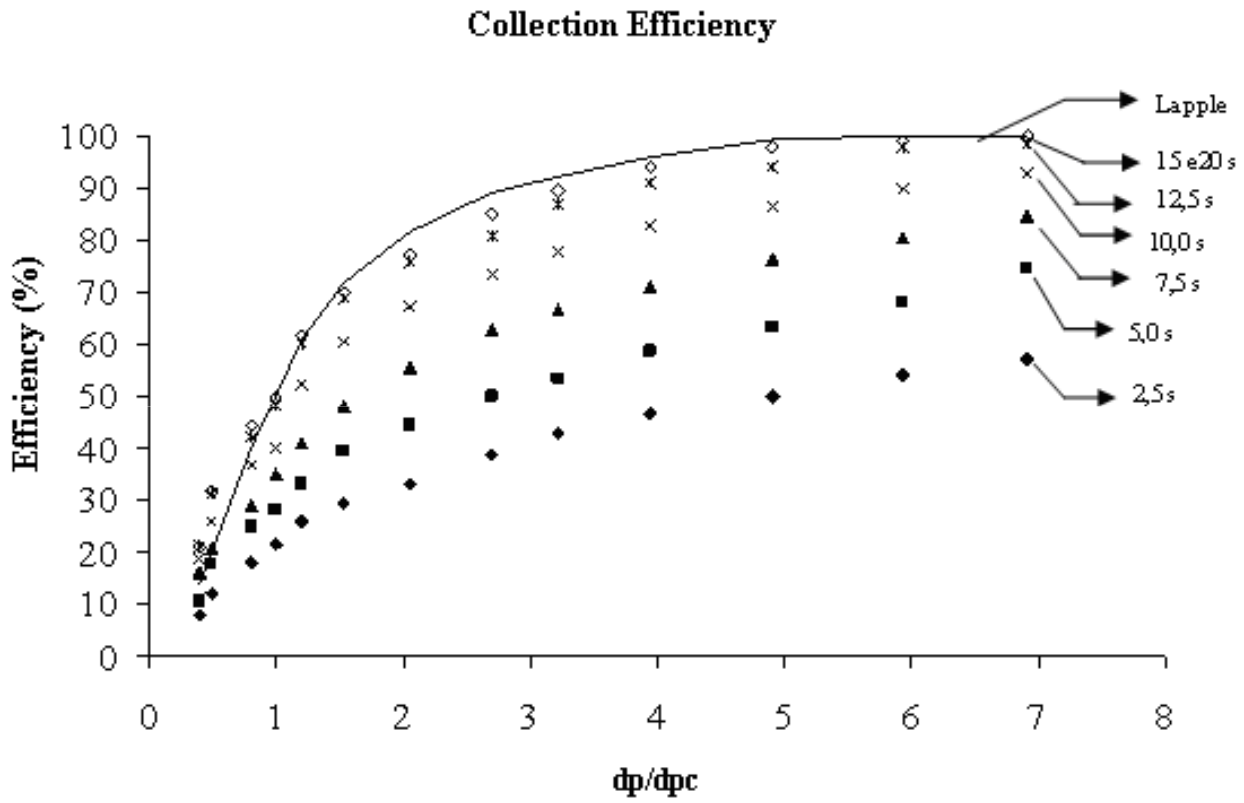
Pressure distribution



Resultant velocity distribution

Later, a cyclone with diameter of 0,127m was studied in order to reduce the required computational time for the simulations.

Results and Discussion



The simulations beyond correctly supplying the collection efficiencies for the stationary regimen, indicate the transient one according to the experimental expectation.

Conclusions

☞ The mesh refinement with 6 layers of prismatic elements on the walls of the cyclone and finder allowed to adequately describe the high gradients of concentration and velocity in these places, being improved the results;

☞ One evidenced that the model generates solutions that are in agreement with the data gotten for Lapple (1951) for all the simulated diameters of particles;

☞ The results presented referring to the profiles of velocity and of pressure, had been coherent with others of literature. In this way, it can be affirmed that the CFD model built is valid to describe the flow behavior in the cyclone, as well as foreseeing adequately its performance.

References

- BERNARDO, S., *Estudo dos Escoamentos Gasoso e Gás-Sólido em Ciclones pela Aplicação de Técnicas de Fluidodinâmica Computacional (CFD)*. Tese (Doutorado), FEQ/UNICAMP, Campinas, 266p, 2005.

- CORRÊA, J. L., GRAMINHO, D. R., SILVA, M. A., NEBRA, S. A., *The Cyclone Dryer-A Numerical and Experimental Analysis of the Influence of Geometry on Average Particle Residence Time*. Brazilian Journal of Chemical Engineering, vol. 21, no 01, pg. 103-112, 2004.

- DERKSEN, J. J., *Separation Performance Predictions of a Stairmand High-Efficiency Cyclone*. AIChE Journal, vol. 49 no 06 pg. 1359-1371, 2003.

- LAPPLE, C. E., *Process Use Many Collector Types*. Chemical Engineering vol. 58, pg 144-151, 1951.

- MEIER, H. F., MORI, M., *Gas-solid Flow in Cyclones: The Eulerian-eulerian Approach*. Computers Chemical Engineering, vol. 22, pg. S641-S644, 1998.

- MEIER, H. F., MORI, M., *Anisotropic Behavior of the Reynolds Stress in Gas and Gas-Solid Flows in cyclones*. Powder Technology, vol. 101, pg. 108-119, 1999.

Thanks for your attention!