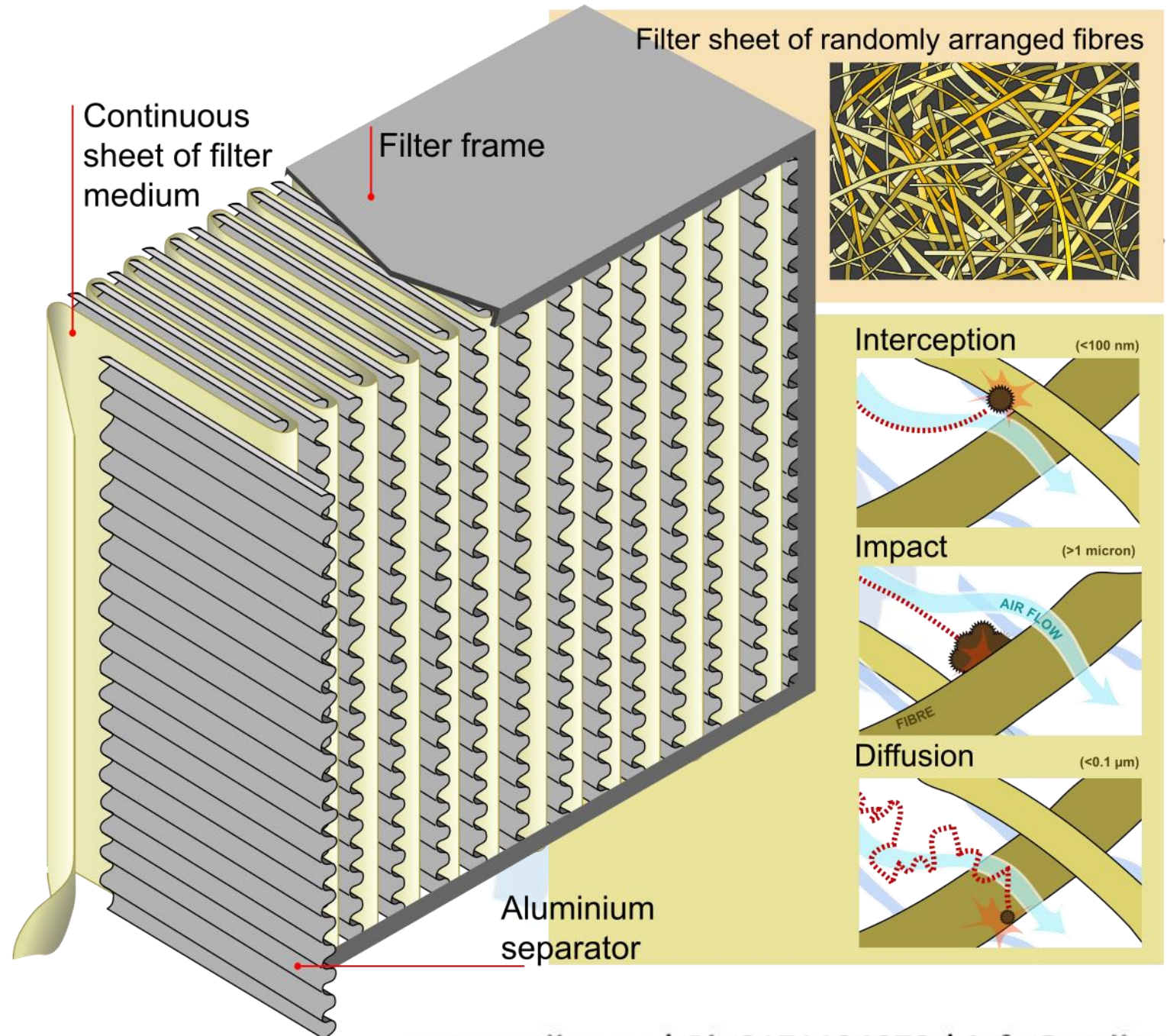




# Simulation Of Flow Through Filters Using The Porous Cell Zone In ANSYS Fluent

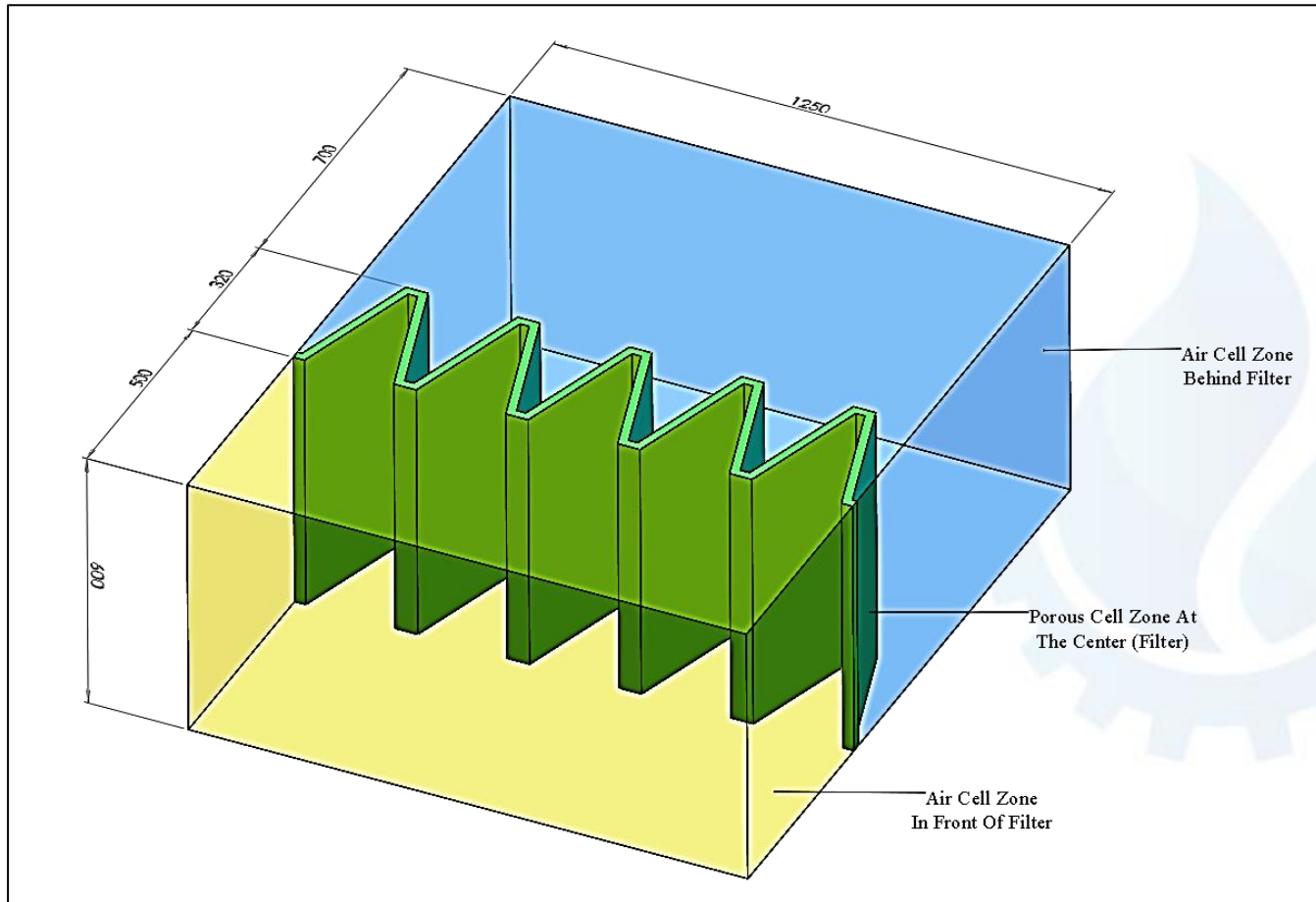
# Filters

- ❑ Filter is a device composed of fibrous or porous material useful to separate unwanted suspended solid particles from the gas or liquid flowing through it.
- ❑ The modeling as well as simulation of flow through such fine porous mediums are difficult using the computational resources we have in present.
- ❑ To overcome this difficulty, we can use porous cell zone conditions in ANSYS Fluent to simulate flow through filters.
- ❑ The viscous resistance ( $1/m^2$ ) and inertial resistance ( $1/m$ ) in three directions (X, Y and Z) can be provided for such cell zones representing the filter to simulate filters.

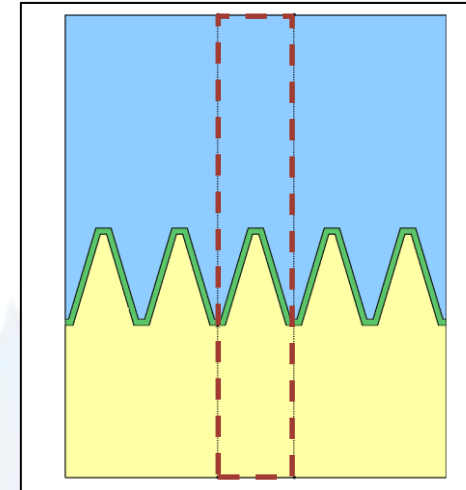


# Example – Simulating Filter

- ❑ Consider a case in which air flow is to be simulated through a filter of given dimensions to check the velocity and pressure contours in the given domain.
- ❑ To calculate the porous coefficients, experimental data is given for the filter in the form of pressure drop against the set of velocities.

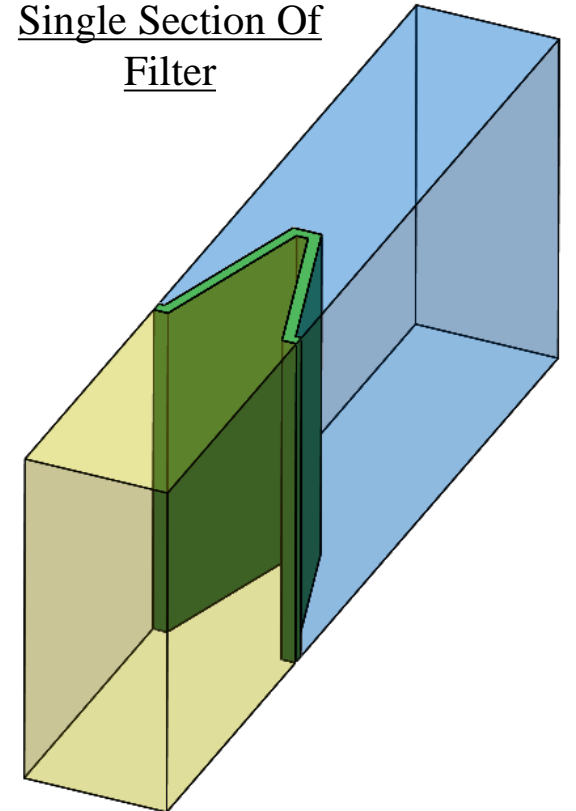


## Symmetry In The Fluid Domain



Taking the advantage of symmetry in the model, only a single section of the filter was considered for the fluid flow simulation.

## Single Section Of Filter

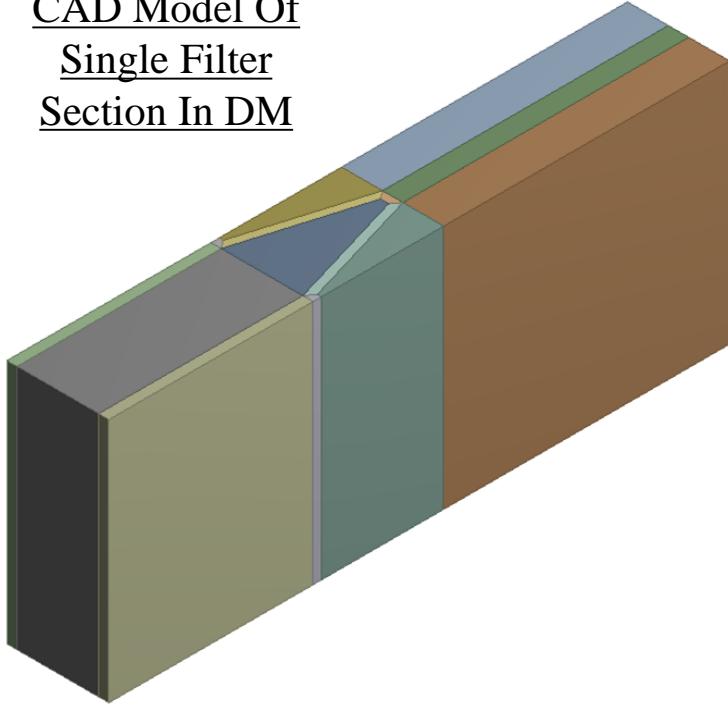




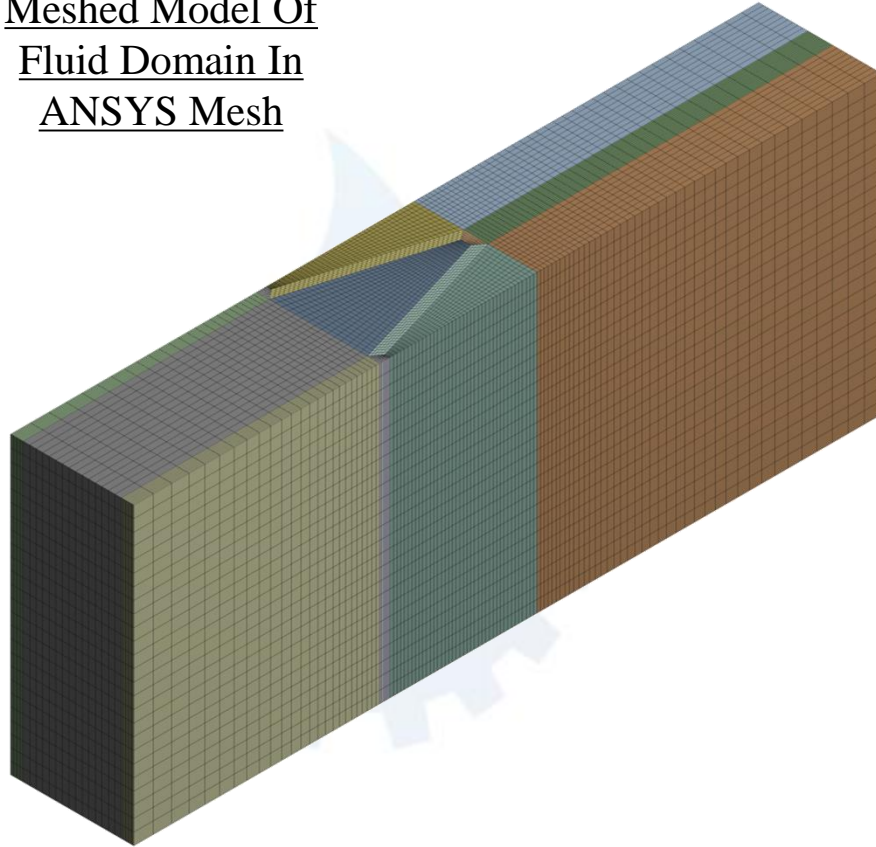
# Geometry And Mesh

- ❑ The CAD model representing the fluid domain was created in Design Modeler.
- ❑ The model was sliced into multiple bodies so that structured grid can be obtained using ANSYS Mesh.
- ❑ The structured grid was obtained in the ANSYS Mesh using the sweep method and edge sizing for the parallel corresponding edges. The fluid domain was divided into 1,06,250 hexahedral cells.

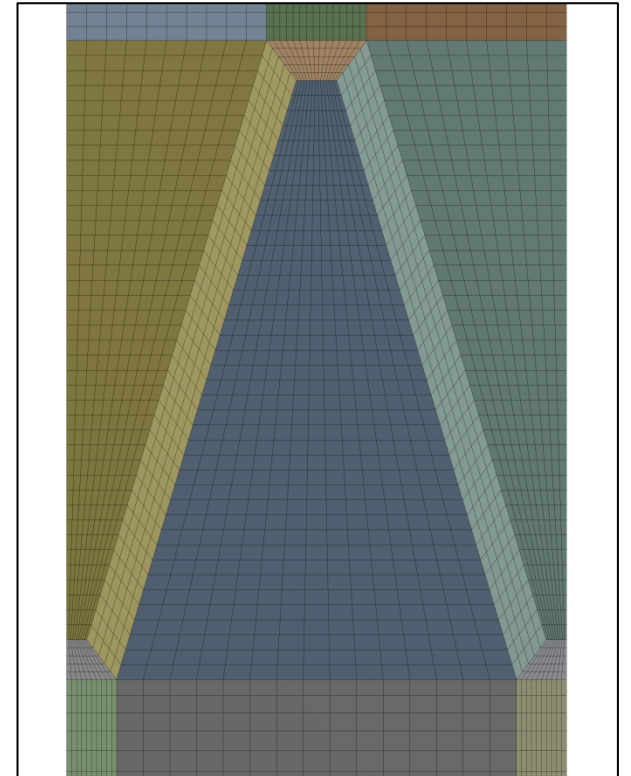
CAD Model Of  
Single Filter  
Section In DM



Meshed Model Of  
Fluid Domain In  
ANSYS Mesh



Top View Of Meshed Model



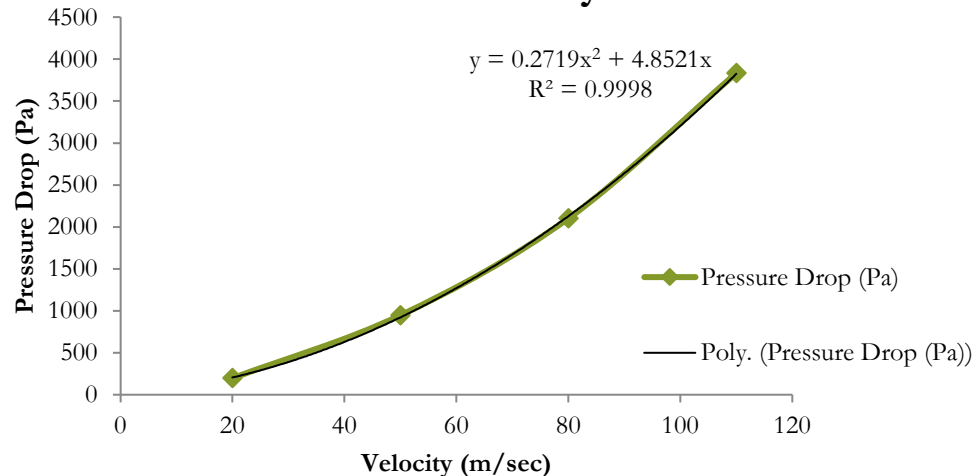
# Calculation Of Porous Coefficients From Experimental Inputs

- ❑ The viscous and the inertial resistance coefficients are calculated using the experimental inputs for pressure drops against given velocities.
- ❑ These values are required to define the porous cell zone in ANSYS Fluent.

## Given Inputs To Calculate Coefficients

Experimental Input	
Velocity (m/sec)	Pressure Drop (Pa)
20	197.8
50	948.1
80	2102.5
110	3832.9

## Chart For Pressure Drop Against Velocity



## Coefficient Calculation Step 1

Plot a chart in excel for given input and create a trend line through these points to get the polynomial equation as shown:  $\Delta P = 0.2719v^2 + 4.8521v$

## Coefficient Calculation Step 2

The f1 (0.2719) and the f2 (4.8521) coefficients in the above equations can be used to calculate the inertial and viscous resistance respectively using the following equations:

$f1 = C_2 \frac{1}{2} \rho \Delta n$  ( $C_2$  is inertial resistance coefficient) and

$f2 = C_1 \mu \Delta n$  ( $C_1$  is viscous resistance coefficient)

$\Delta n$  = filter thickness

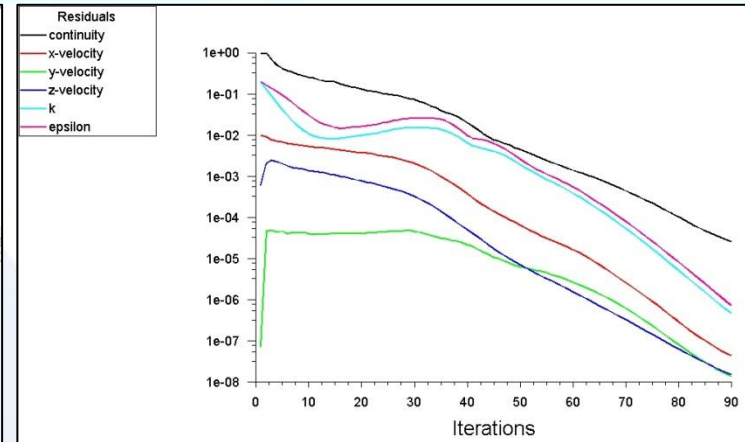
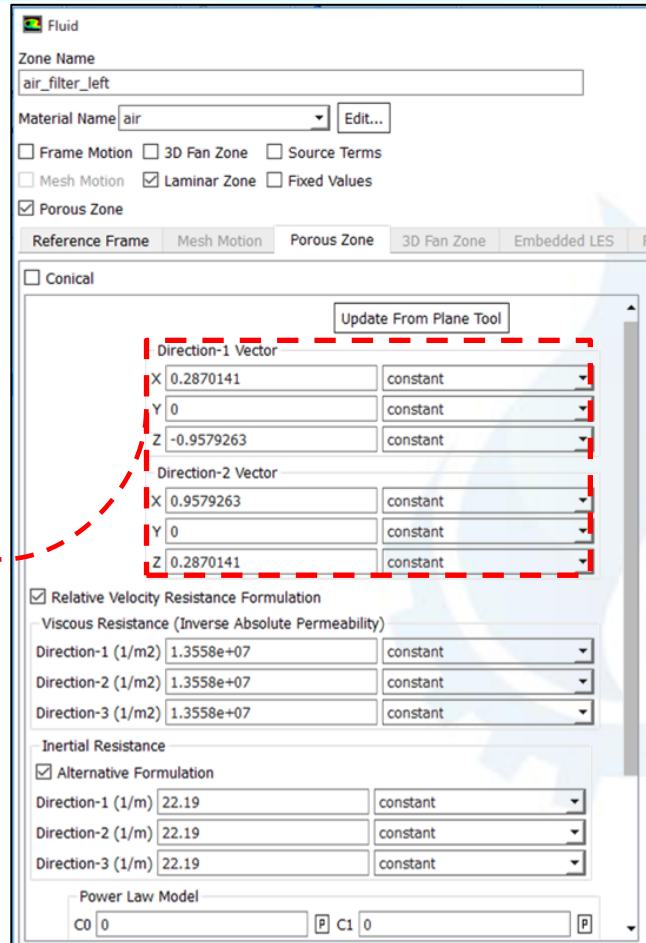
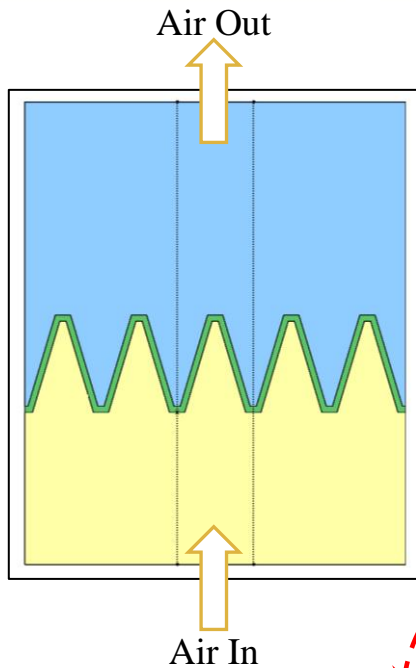
$\rho$  = fluid's density

$\mu$  = fluid's viscosity

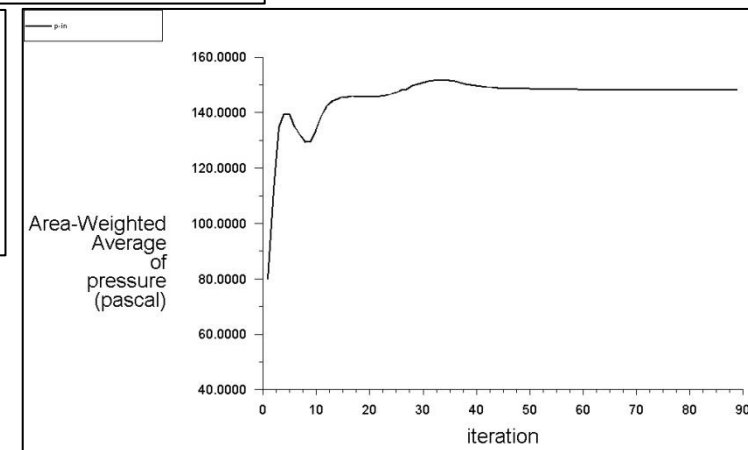
For the given input data, the  $C1$  and  $C2$  are calculated as  $1.36E+07$  and  $22.19$ . ( $\Delta n = 0.02m$ )

# Case 1-Filter With Same Porosity In All Directions

- ❑ In this case, it was assumed that the porous zone (filter) offers same porosity in all directions.
- ❑ The values calculated for inertial and viscous resistance coefficients were provided same in all directions.
- ❑ The air was given an inlet velocity of 10m/sec and the outlet was set at 0 Pa gauge pressure.

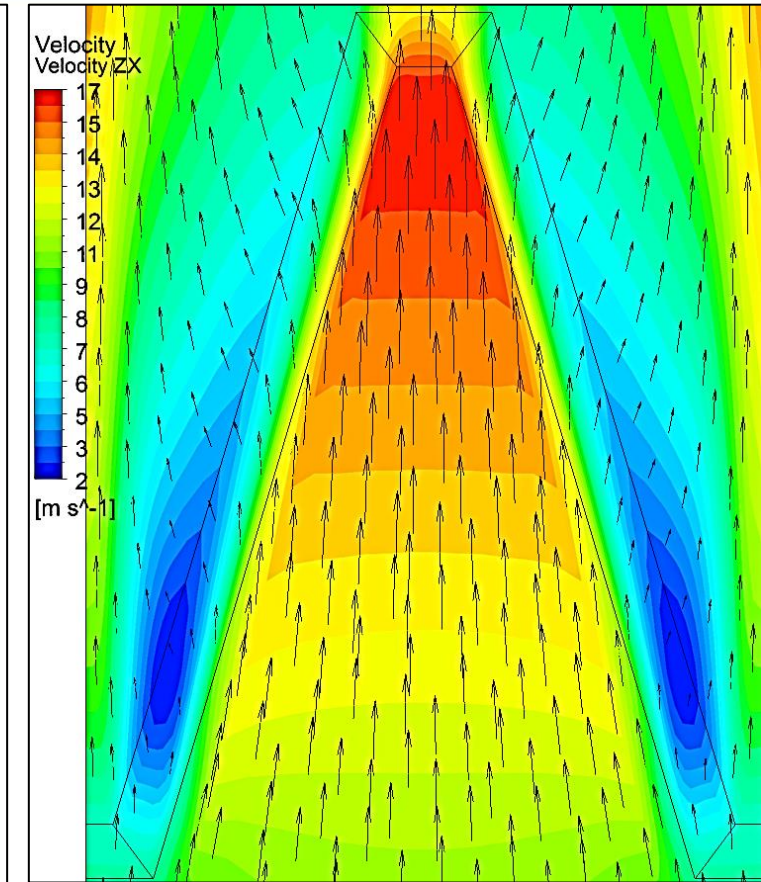
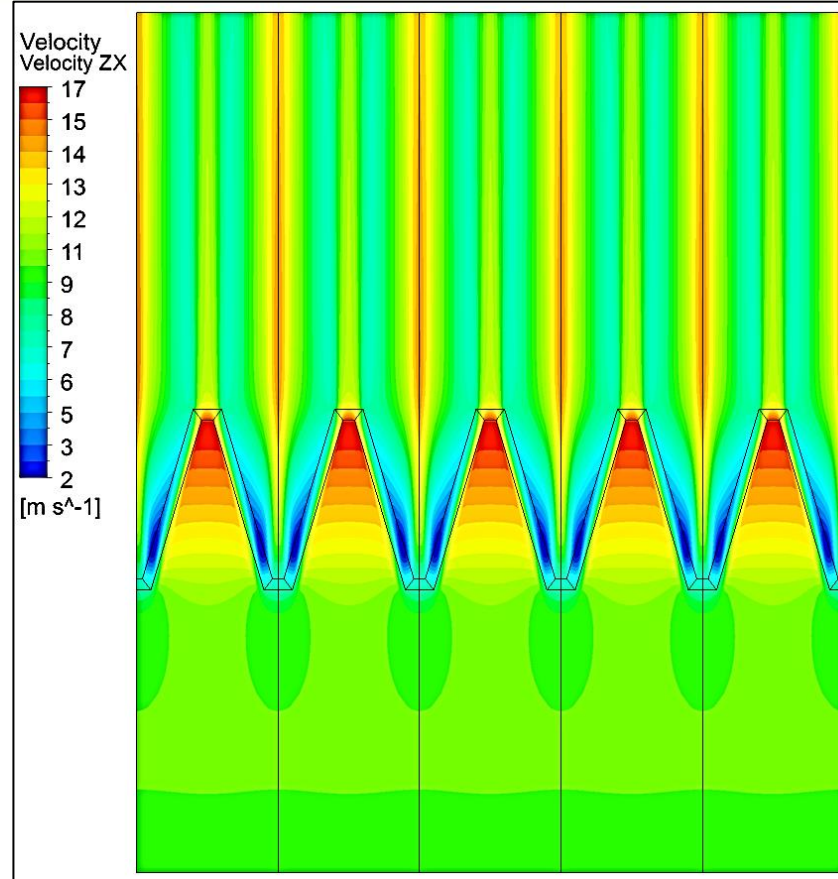
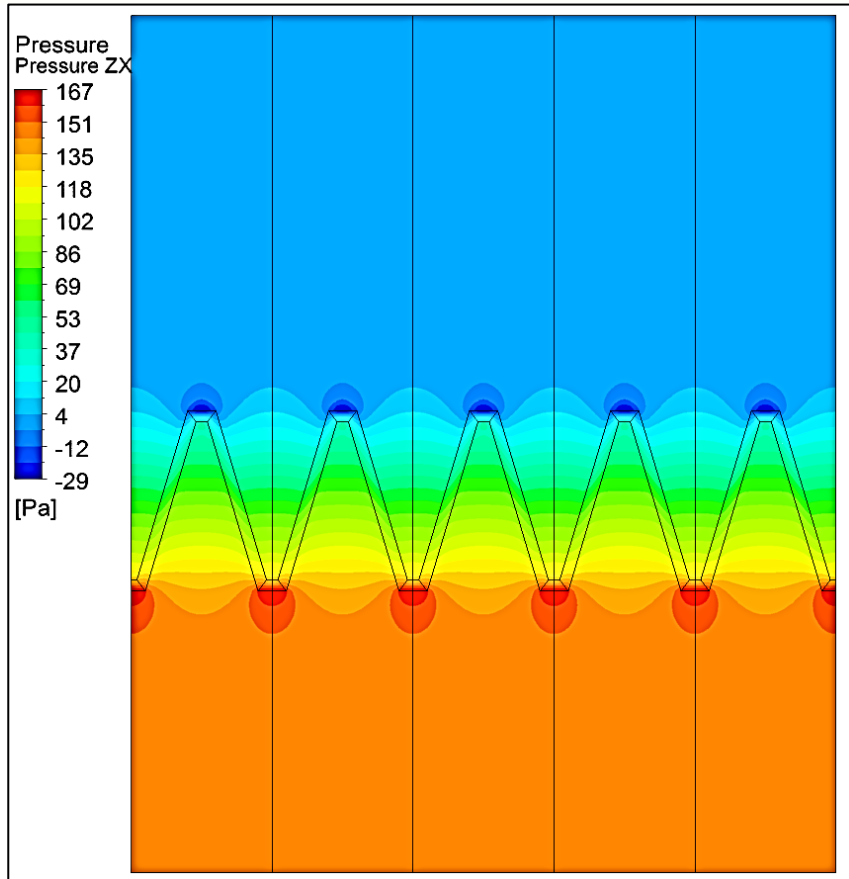


The inlet pressure was also monitored along with the residuals of the flow equations to confirm the convergence of results.



# Case 1-CFD Results

- ❑ The contours for pressure and velocity are shown below along with the velocity vectors.
- ❑ Pressure drop across the filter was computed as 148.5 Pa by CFD simulation.
- ❑ In the velocity vector, it can be seen that the air is free to move in any direction inside the filter as the resistance offered in all direction is same by the porous media.

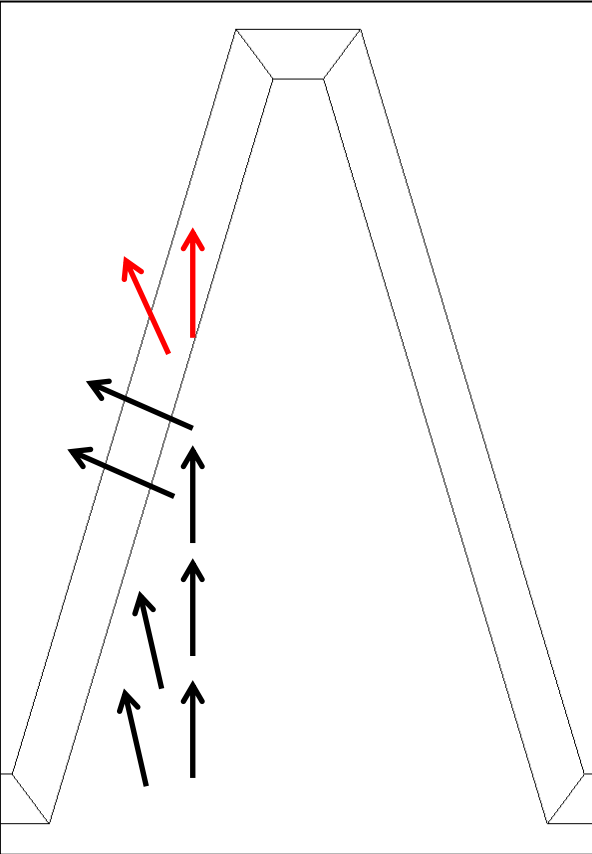




# Case 2-Filter With Different Porosity In Different Directions

- ❑ In this case, it was assumed that the flow can only pass through the direction along the thickness of filter. Otherwise it is restricted in any other direction.
- ❑ The values calculated for coefficients were provided to the direction along the filter thickness whereas the other flow directions were given higher coefficient values.

Flow inside the filter is only possible in the black colored arrows.



Fluid

Zone Name: air\_filter\_left

Material Name: air

☐ Frame Motion ☐ 3D Fan Zone ☐ Source Terms

☐ Mesh Motion ☒ Laminar Zone ☐ Fixed Values

☒ Porous Zone

Reference Frame Mesh Motion Porous Zone 3D Fan Zone Embedded LES Realizable

☐ Conical

Update From Plane Tool

Direction-1 Vector

X	0.2870141	constant
Y	0	constant
Z	-0.9579263	constant

Direction-2 Vector

X	0.9579263	constant
Y	0	constant
Z	0.2870141	constant

☒ Relative Velocity Resistance Formulation

Viscous Resistance (Inverse Absolute Permeability)

Direction-1 (1/m <sup>2</sup> )	1.3558e+07	constant
Direction-2 (1/m <sup>2</sup> )	1.3558e+10	constant
Direction-3 (1/m <sup>2</sup> )	1.3558e+10	constant

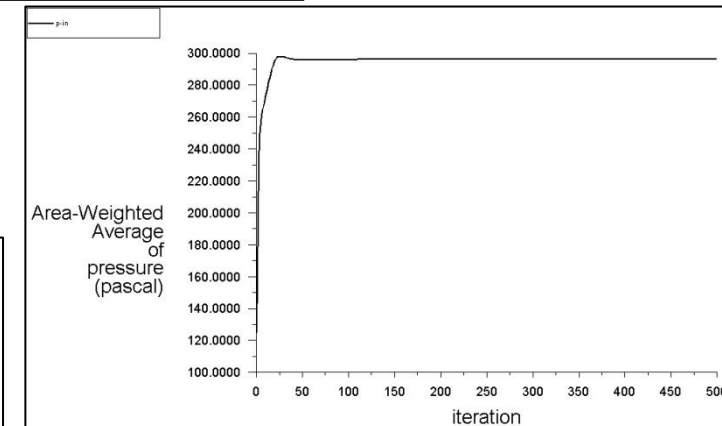
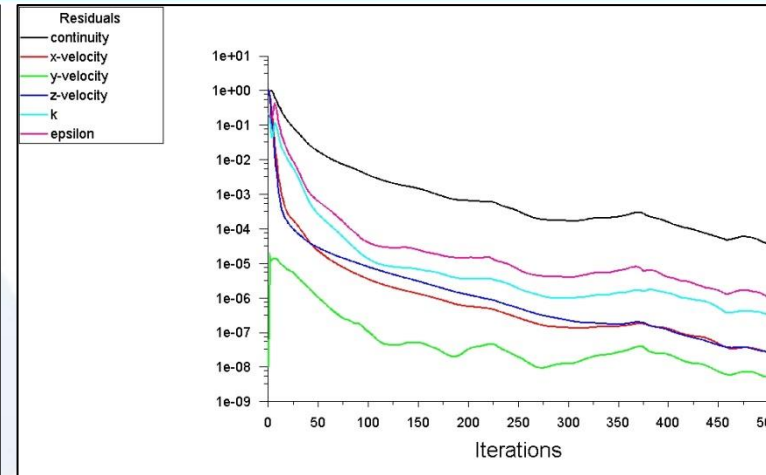
Inertial Resistance

☒ Alternative Formulation

Direction-1 (1/m)	22.19	constant
Direction-2 (1/m)	22190	constant
Direction-3 (1/m)	22190	constant

Power Law Model

C0	0	P	C1	0	P
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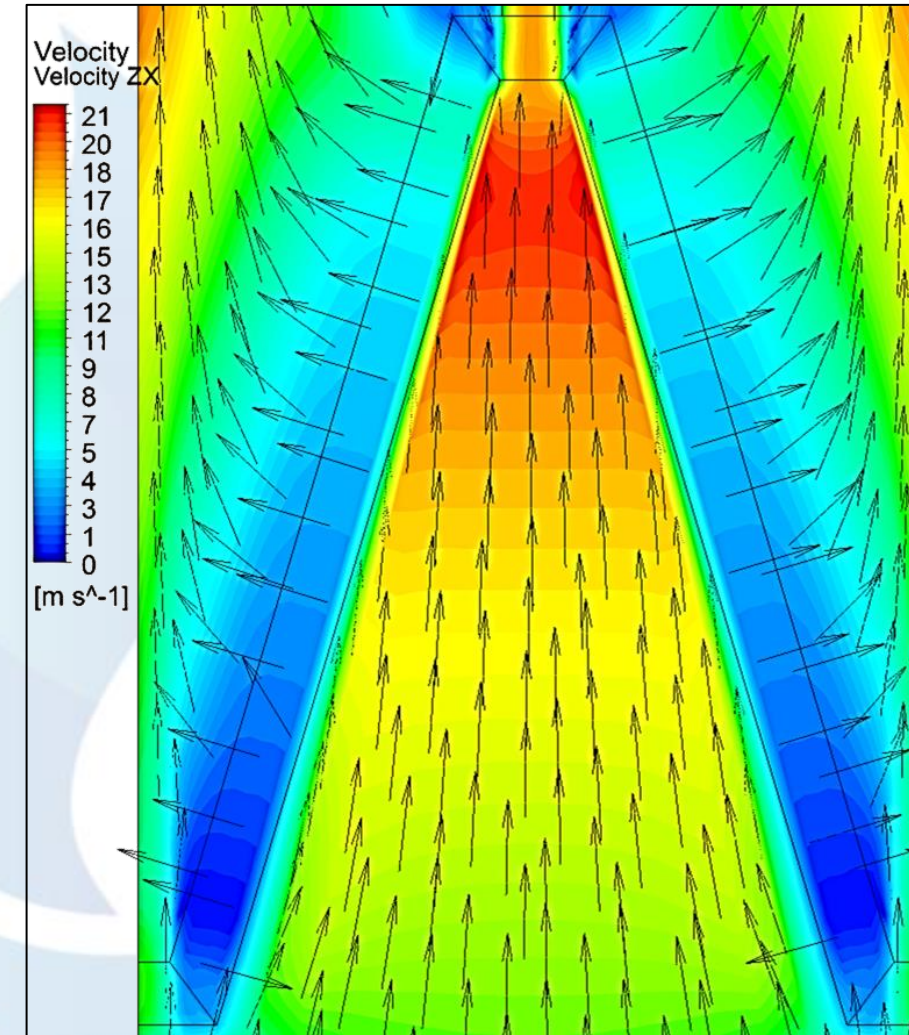
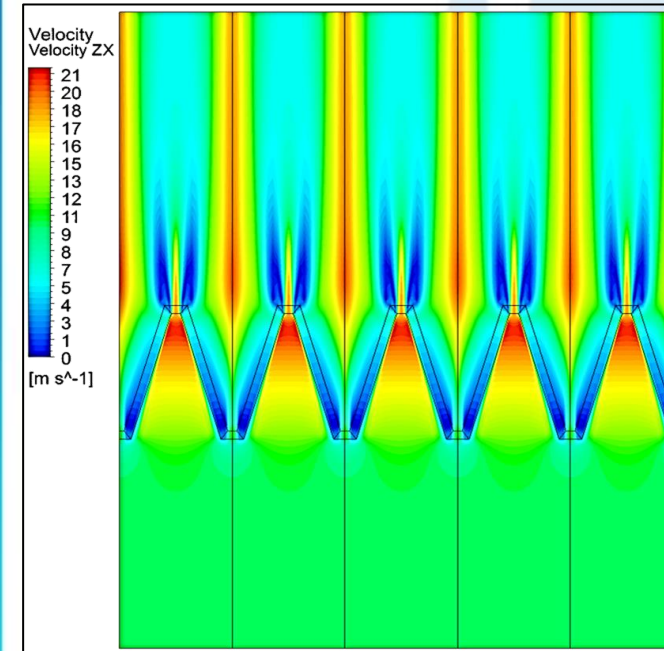
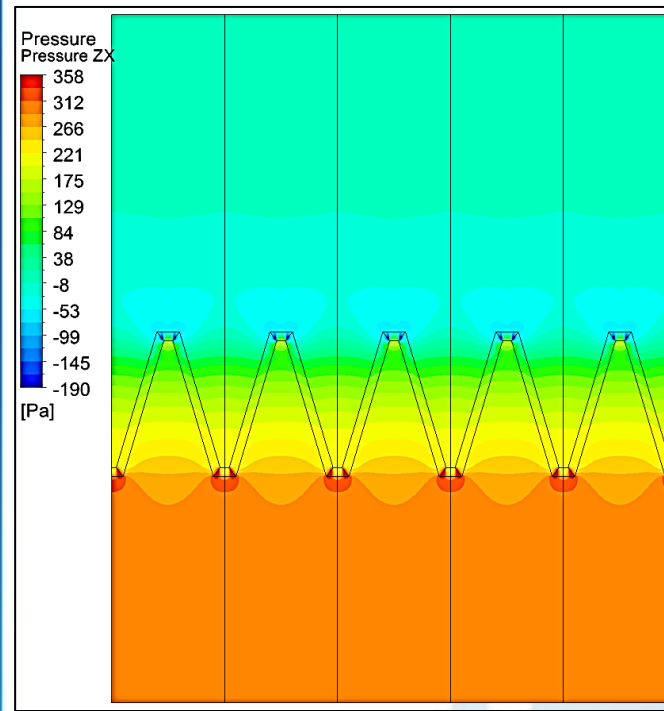


Higher coefficients were provided for direction-2 and direction-3 to restrict the flow in those directions.



# Case 2-CFD Results

- ❑ Pressure drop across the filter was computed as 296.6 Pa by CFD simulation.
- ❑ In the velocity vector, it can be seen that the air is only free to move in direction along the filter's thickness due to very high resistances offered in other directions.
- ❑ As there is more restriction to air flow inside the filter therefore pressure drop has increased in this case.



# Conclusion

- ❑ Fluid flow through a porous medium (Filter) was discussed and simulated using ANSYS Fluent in this case study.
- ❑ The porous media coefficients can be calculated using the experimental inputs for pressure drop against given velocity.
- ❑ Different porous coefficients (inertial as well as viscous resistance) can be provided for three different directions in the porous cell zone conditions.
- ❑ Higher value of resistance coefficients (in order of 1000) can be provided for a particular direction to restrict flow in that direction.