A REPORT

ON

DEM Simulation of Two Different Particle Mixing in a Y-section (MESH FREE CFD SIMULATIONS)

BY

K. BADARI VISHAL 2018A4PS0807G

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DHIO Research & Engineering Pvt. Limited-Bangalore, Karnataka

A Practice School-1 station of

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May-June, 2020

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K.BADARI VISHAL 2018A4PS0807G B.E. (Hons.) MECHANICAL

Prepared in Partial fulfillment of the

Practice School-1

Course No. BITS F221

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Acknowledgement

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Title of the Project: DEM Simulation of Two Different particle mixing in a Y-Section

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Name of PS Faculty: Prof. Pardha Saradhi Gurugubelli Venkata

Keywords: Discrete Element Method (DEM), CFD, Three Particle/CAE, Mesh free 3D Simulations, Granular particles

Abstract: This report is based on the strategy utilized and simulations done for a two particle mixing in a Y-section using Three Particle/CAE software which is based on Discrete Element Method (DEM) and its applications across various engineering and research fields.

Signature of Student **Signature of PS faculty**

Date: **Date:**

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Introduction

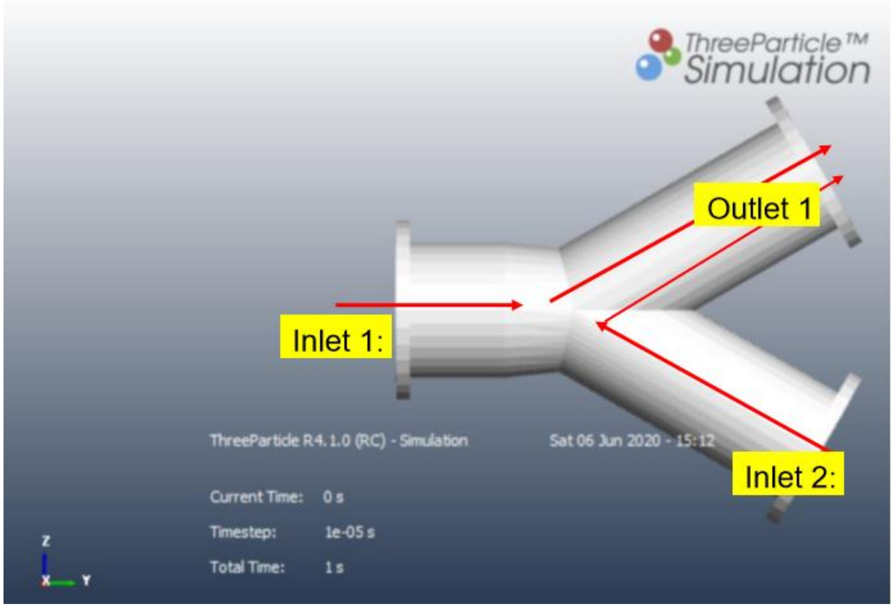
Discrete element method (DEM), also called ‘Distinct element method’ is a numerical method for computing and simulating the behavior and motion of small particles. It uses the strategy of particle based approach. It considers the collective interactions of all particles leading to the bulk behavior.

Simply put, it considers the interactions between the particles and the movements of particles individually. DEM’s applications include granular flows, powder mechanics, rock mechanics etc.

Three Particle/CAE is a multi-physics simulation software working on the principles of DEM. It helps in simulating complex engineering problems wherein there are no restrictions on the type of materials and particle shapes. Its principles extend in combining with Soothed Particle Hydrodynamics (SPH), Finite element analysis (FEA), Wear analysis.

The project assigned, i.e. DEM simulations of two particle mixing in a Y-section involves the simulations of granular particle flows entering the Y-sectioned pipe at two inlets and abiding by the objective. The objective was to limit the particles entering through inlet-2 from going out through inlet-1.

The Particle sizes and their velocities are varied accordingly until the velocities of the particles were stable enough to achieve the objective. Software used for achieving this strategy is ‘Three Particle’.



Discrete Element Method (DEM)

DEM involves a particle based approach, unlike FEA which utilizes an element based approach wherein a complex system is divided into simpler parts which further are termed elements. Simply put, it narrows down the study of a system by analyzing the behavior and motions of particles individually. It treats each particle in the bulk as a discrete element. It calculates the motion of each particle which is in contrast to continuum method.

Three Particle/CAE

Principles & Considerations

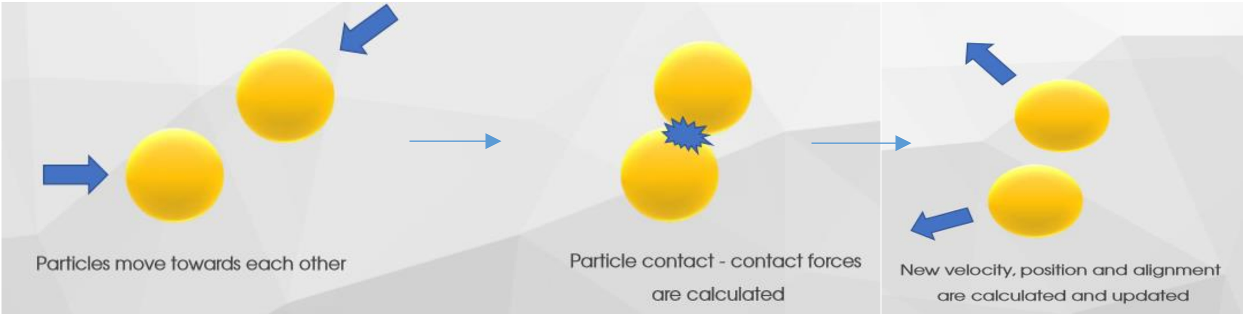
As introduced, the software uses the DEM strategy to compute simulations. It utilizes the particle based approach wherein it considers –

1. **Interaction of Particles** where the contact forces (like frictional, repulsive etc.), torques that are developed between the particles are taken into consideration.

2. **Movement of Particles** where the motion of each and every particle is considered individually.

3. **Type of interactions** where the interactions might be between granular particles themselves or with the particles of other equipment.

Here's a simple two particle system showing how the software simulates -



Project

Problem Statement

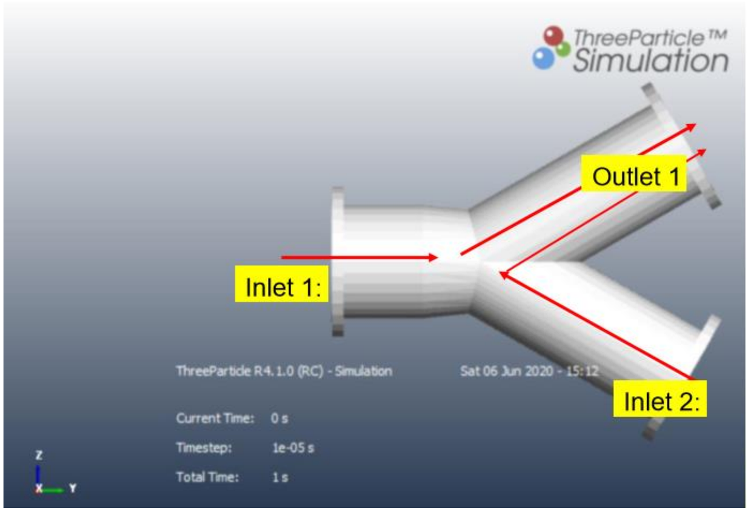
DEM Simulation of Two Different Particle mixing in a Y-Section

Objective

Given that particles enter through the Inlets (1 & 2) and exit through the Outlet. Objective is to stabilize the speed and volume of particles so that the particles entering from Inlet 2 don't go out of Inlet 1 – instead they go out from Outlet 1**.**

Theoretical Understanding

- Given is a Y-section structure involving a two different sized particle mixing.
- Generating streams of Particles (of sizes p1 & p2 (let)) from inlet-1 and inlet-2 respectively.
- Stabilizing the speed of particles so as to ensure that the particles coming inlet-2 won't flow out through inlet-1-instead they move out through outlet-1.
- Since we are given with only the size of particles, we approach the method using trial & errors until we find a suitable co-ordination of velocities for satisfying the given condition.



Methodology

Design – Setting up the model

- Setting up of parameters & Working directory
- Defining the materials and the interactions between the materials
- Defining Parts & Geometries
- Defining Geometry motions if any
- Defining the Bulk Particles & Particle Generation
- Defining Calculation Domain
- Defining Field forces/Torques if any
- Defining Loads (Gravity etc.)

Simulations

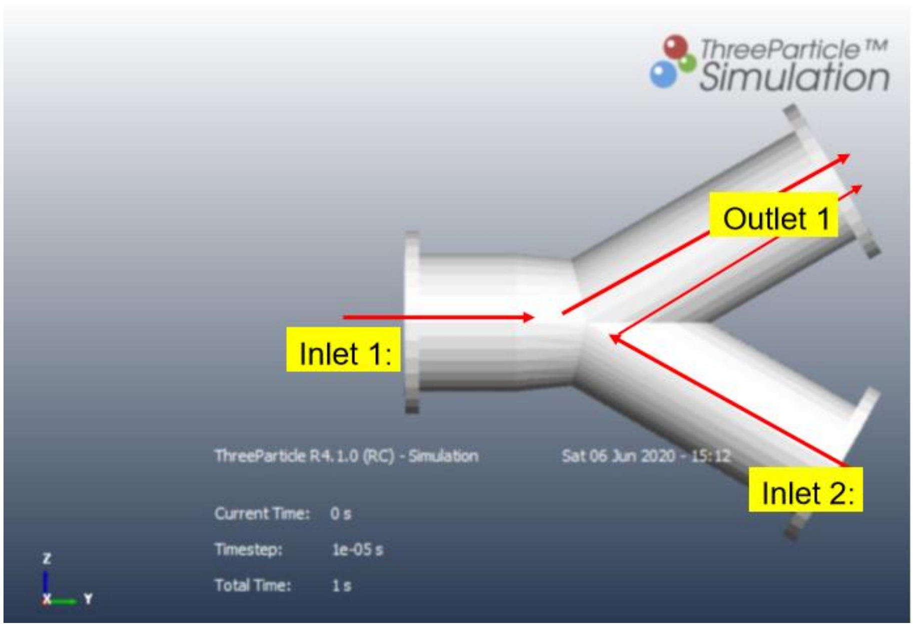
- Defining simulation & properties
- Defining Total time and time step
- Storing Data Points
- Running Simulations

Analysis

- Setting Attributes
- Coloring by attributes
- Creating Videos, Images
- Generating plot(s)
- Generating a CSV file /Excel file based on data plotted and analyzed

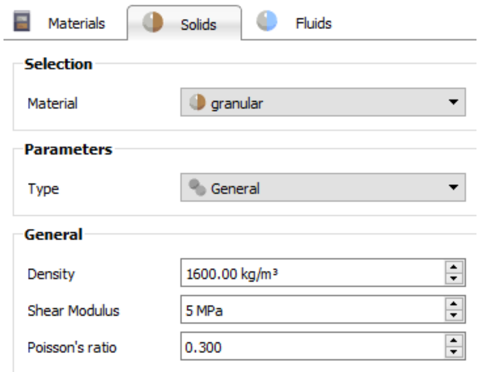
CAD Model Details

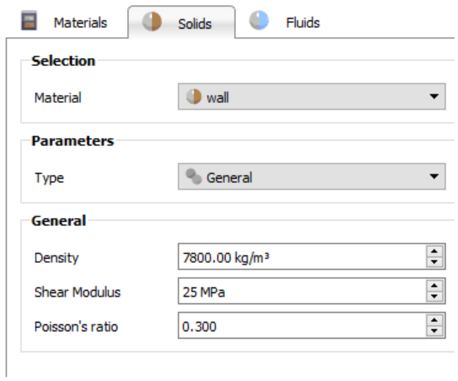
- Given a Y-Section
- Assuming its material same as the material of a wall
- Two Inlets: Inlet-1 & Inlet-2
- One Outlet: Outlet-1
- The two arms i.e. Sections of Inlet-2 and Outlet-1 are inclined at an angle of 30^0 with respect to the axis of inlet-1
- Inner Radius of section Inlet-1 is 95mm
- Inner Radii of Sections Inlet-2 and Outlet-1 are 85mm and 85mm respectfully.



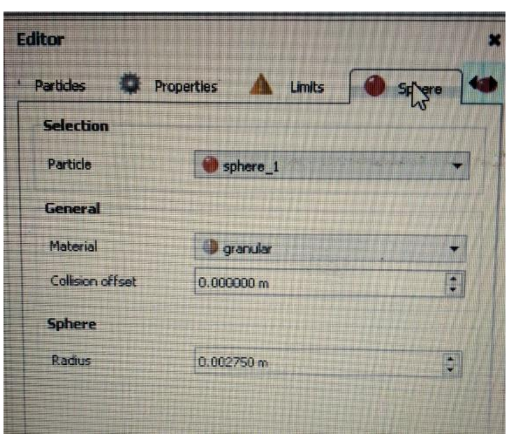
Material Details

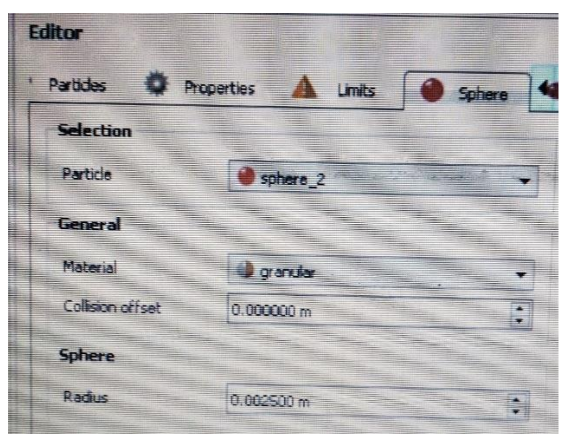
- We define two material types namely: ‘granular’ (for the particles) & ‘wall’ (for the Y-section) with the following properties –





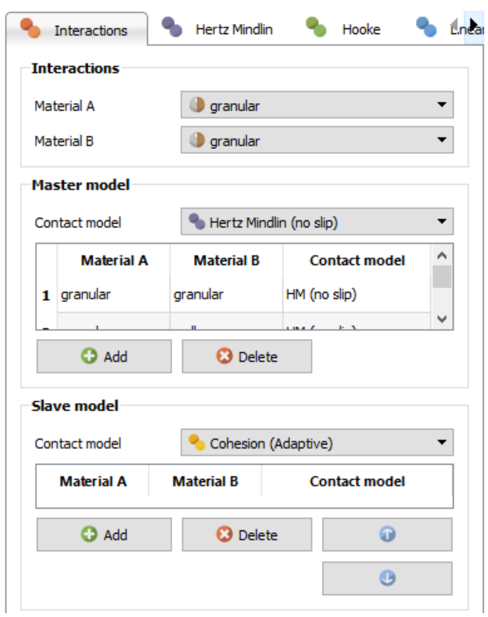
- We also define the particles (sphere_1 & sphere_2), their material properties and their size-
- Radius of sphere_1 = 0.002750 m
- Radius of sphere_2 = 0.002500 m

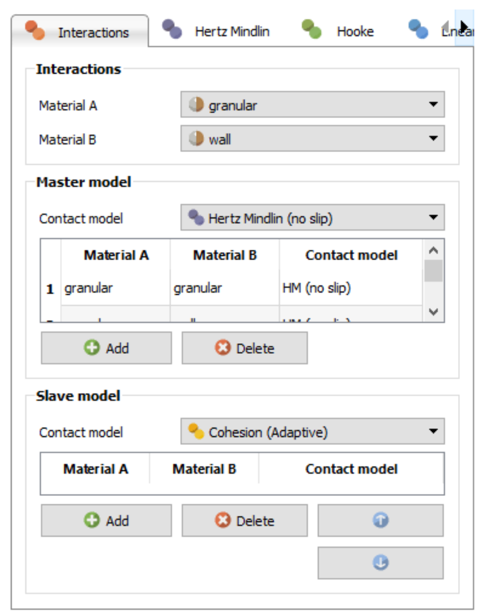




Input Conditions

- Input conditions involve setting up of Interactions between the models.
- Two set of interactions in our case include: ‘granular-granular’ (particle-particle interactions) and ‘granular-wall’ (particle-wall/y-section interactions).
- We have assumed the Hertz-Mindlin (no slip) condition as we are considering incompressible particles for our case.

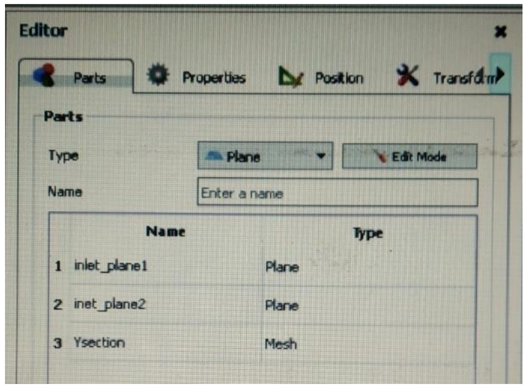




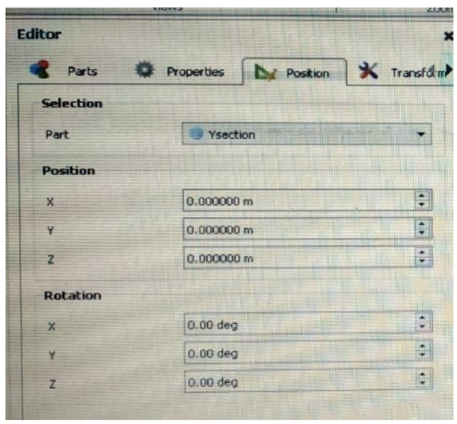
- Further parameters that are to be kept under input conditions which happen with the interactions between the materials are:
    - Method
    - Restitution
    - Friction

Boundary Conditions

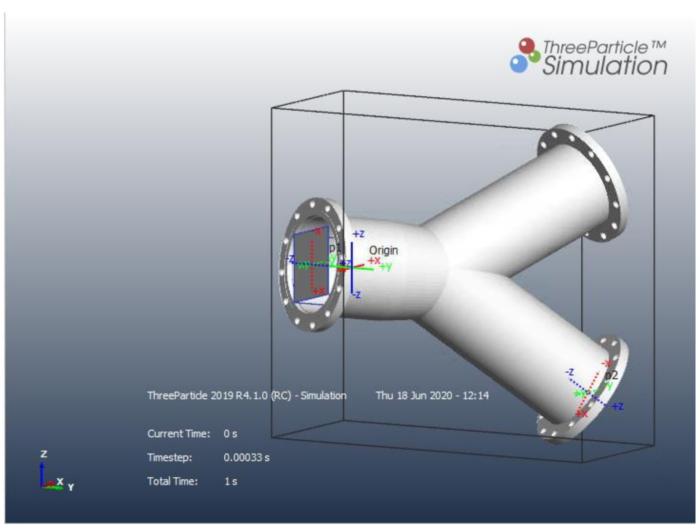
- The Y-section & Planes for particle generation are defined.



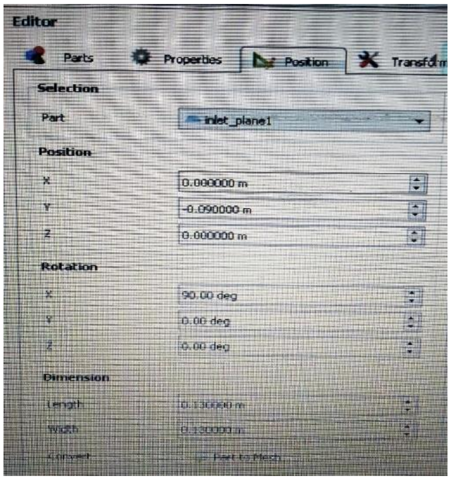
- The Y-section is fixed at its position (starting from origin).

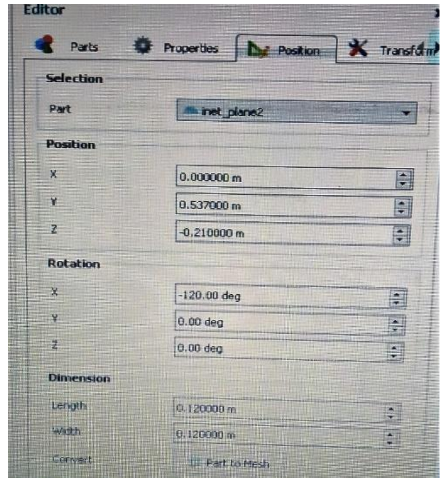


- Two planes are defined: One at inlet-1 and another at inlet-2. Particles are generated from planes **inlet1 & inlet2**.

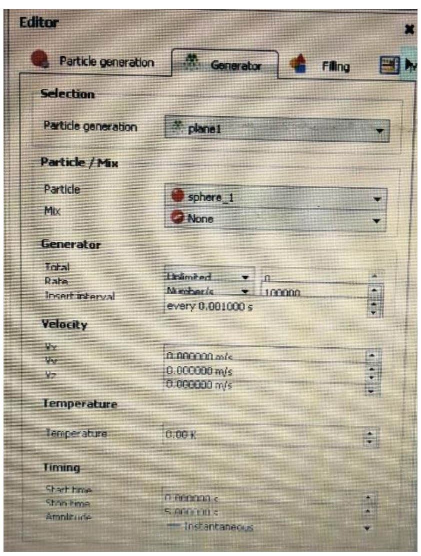


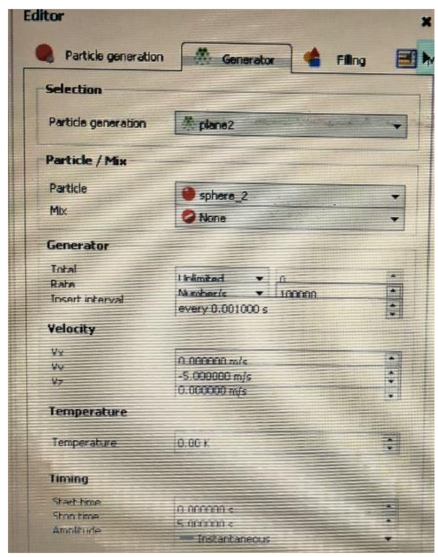
- Positions of the planes are defined.





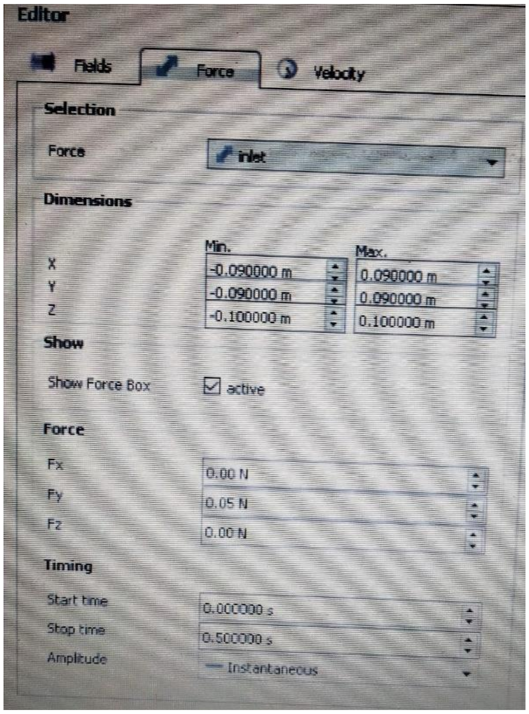
- Particle Generators are defined at both the planes.
- Parameters like Number of Particles generated per second, velocity, and timing are set based on trial and error approach until a stable condition which satisfies the objective is achieved.



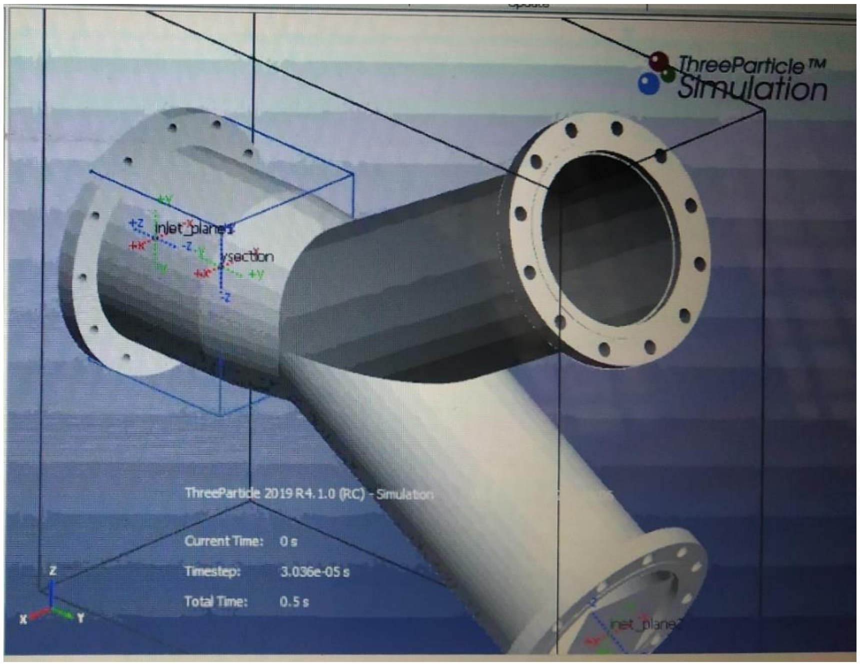


- A Force field at inlet-1 is presented throughout the running time of simulation.
- This force field acts as an external force throughout the simulation time.

- This force field is added keeping in mind the objective because this prevents the particles entering from inlet-2 to enter the gaps of plane1 and reach inlet-1.

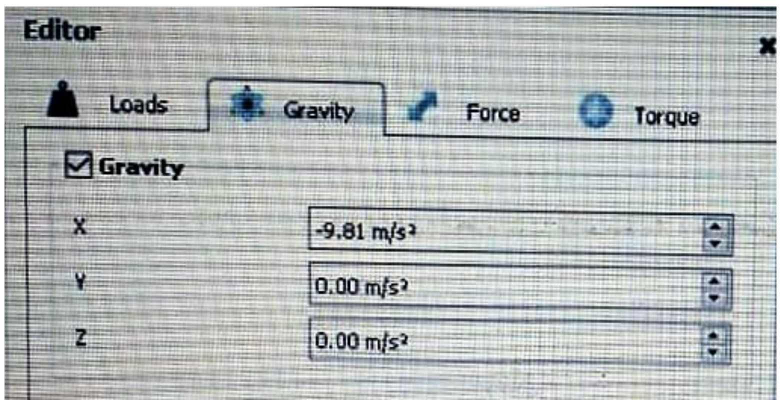


- The blue outline in the below figure is the force field.



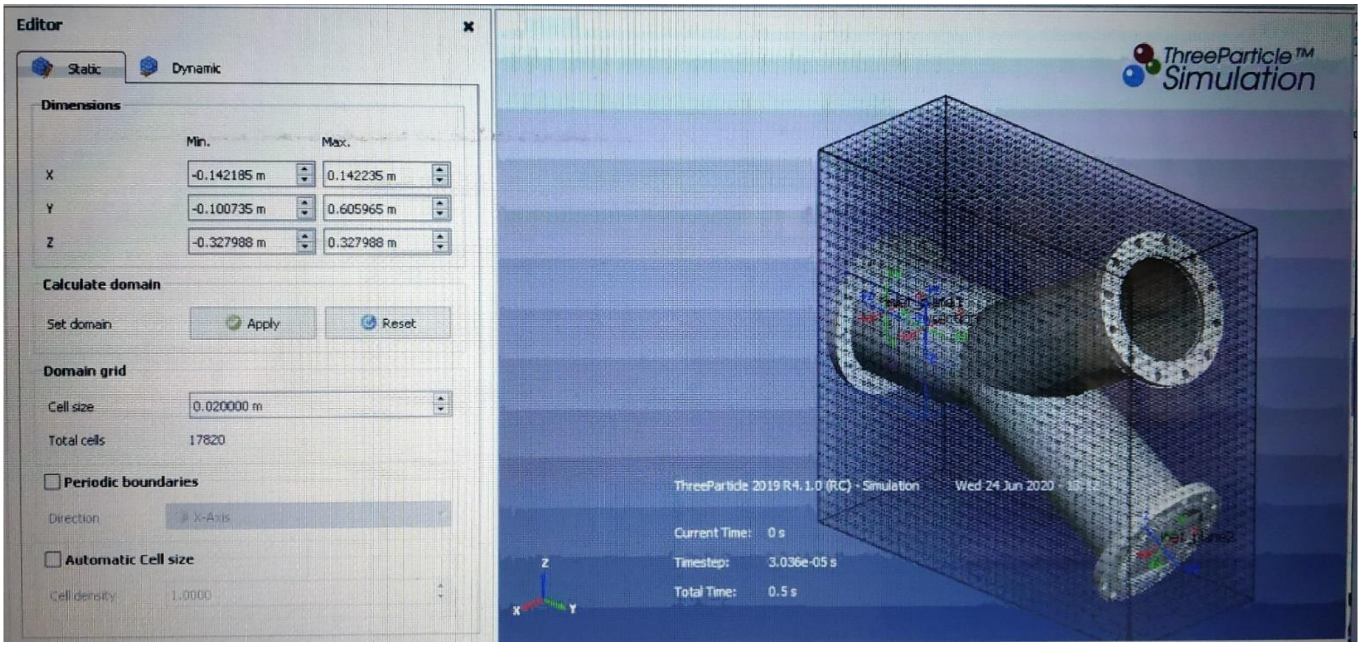
Loading Details

- The acceleration due to gravity (g) is the only load acting.
- All other loads have been disabled for the simulation.
- "g" is taken as $9.81 m/s^2$
- Given the orientation of the geometry, "g" is set in the direction of negative x-axis.



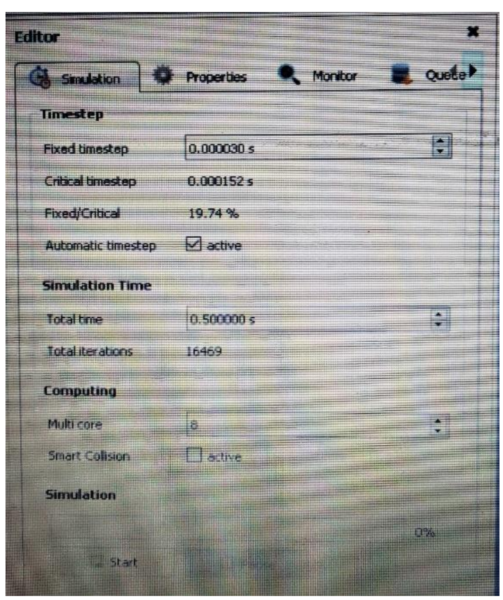
Meshing Details

- In DEM we define a calculation domain, inside which we calculate the required quantities.
- The Dimensions are based upon the dimensions of the geometry.
- The Cell size must be less than 5 times the radius of the smallest particle to ensure convergence.

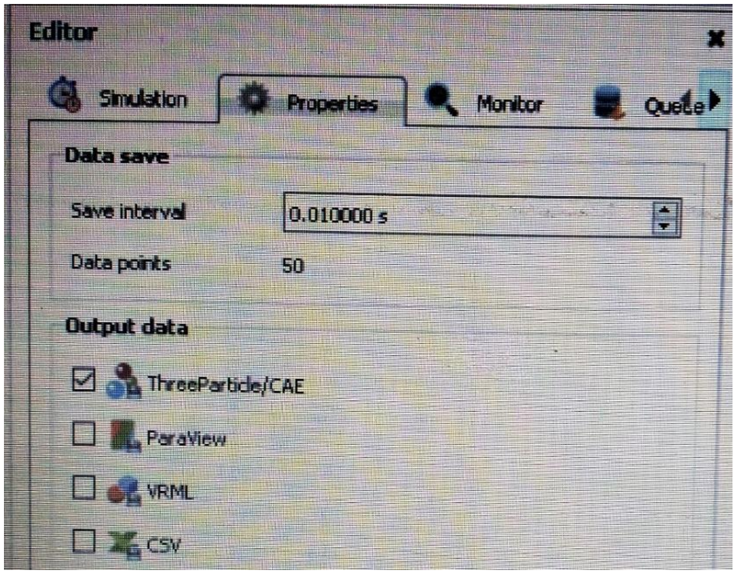


Simulation setup

- Fixed time step is set according to critical time step such that their ratio is in the range 10-20%.
- The simulation time is the run time of the simulation.
- The simulation time is set according to the problem statement so that the analysis part would be clear and thorough.

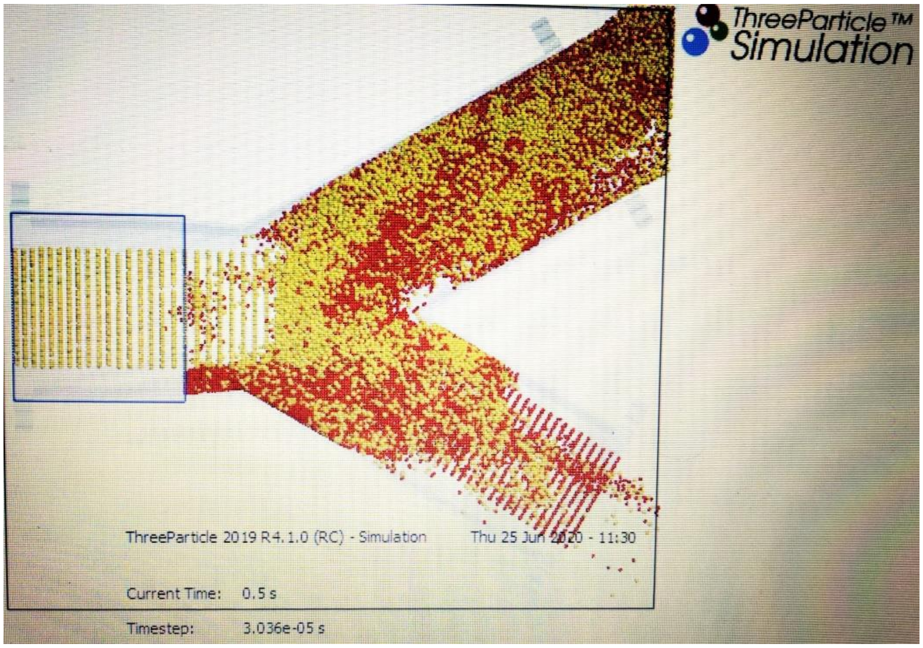


- Intervals for saving Data after regular periods are defined which are helpful for the post-processing part or the later analysis part.



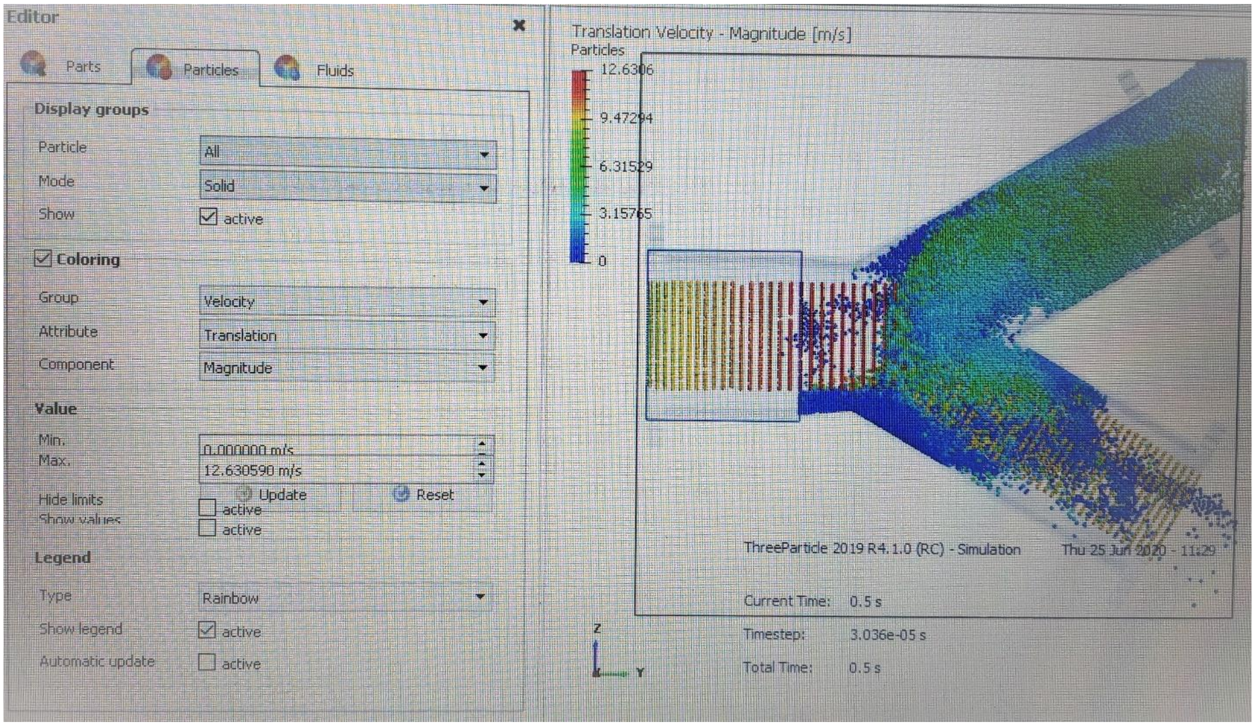
Results

- Here is a snapshot of the simulation at the end of 0.5 seconds.



- As seen from the above snapshot, it is clear that the red particles (particles entering from inlet-2) were refrained from moving out through inlet-1.
- Rest all movements were possible and were not under constraints.
- As expected, the behavior of particles abide by the principles of mass and momentum relations under collision theory including factors like static friction, rolling friction and coefficient of restitution.
- Thus the given simulation & analysis meets the requirements of the objective of preventing the inlet-2 particles from moving out through inlet-1.

- Here is another snapshot showing the variations in velocities of the particles at the end of the simulation time of 0.5 seconds.



➢ Being a trial & error approach, 3 iterations were performed, simulated and analyzed by varying the inputs.

➢ All results of three iterations are as follows:

	INPUT			OUTPUT		
ITERATION	FIELD FORCE / EXTERNAL FORCE	PARAMETER	MAGNITUDE	VERDICT	PARAMETER	MAX VELOCITY MAGNITUDE
Iteration-1	0.05 N	Inlet-1 Particle's Velocity	0.00 m/s	Satisfied the given objective	Inlet-1 Particle's Velocity	14.67 m/s
		Inlet-2 Particle's Velocity	5.00 m/s		Inlet-2 Particle's Velocity	10.55 m/s
Iteration-2	0.03 N	Inlet-1 Particle's Velocity	0.00 m/s	Satisfied the given objective	Inlet-1 Particle's Velocity	12.63 m/s
		Inlet-2 Particle's Velocity	5.00 m/s		Inlet-2 Particle's Velocity	10.55 m/s
Iteration-3	0.008 N	Inlet-1 Particle's Velocity	0.00 m/s	Satisfied the given objective	Inlet-1 Particle's Velocity	9.32 m/s
		Inlet-2 Particle's Velocity	5.00 m/s		Inlet-2 Particle's Velocity	10.55 m/s

Conclusion

All the simulations performed satisfied the given objective. The addition of an external force/force field has been crucial to avoid the inlet-2 particles from entering the inlet-1 zone. As seen from the results, even though the inlet-1 particles were given o initial velocity, because of the presence of force field they could accelerate to a maximum velocity higher than what the inlet-2 particles could achieve.

Hence the simulations to satisfy the given objective were performed and turned successful. The results are summarized and can be used as a basis for further study.

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