A Hydrodynamic Study On Fluidised Bed Gasifier

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***Abstract:-* Fluidized beds are widely employed in industrial operation due to their excellent solid mixing, heat and mass transfer properties. The gas-solid flows in fluidized beds are heterogeneous and usually simulated with the Eulerian description of phases and this description requires the usage of fine meshes and small time steps for the proper prediction of its hydrodynamics. Such constraint on the mesh and time step size results in a large number of control volumes and long computational times which are unaffordable for simulations of large scale fluidized beds. The current trend in the computational fluid dynamics of gas-solid flow much relies on two factors: computational time and accuracy. Accurate simulations are computationally very expensive, and thus, not affordable in practice. On the other hand, a failure to include the effect of small scale flow structures on the fluid dynamics results in inaccuracy in the predicted flow phenomena. Thus, there is a need to find better modelling capabilities which can produce fast simulation results with reasonable accuracy. In the present work an approach for the computationally less expensive simulations of the gas-solid flow in fluidized beds are done. When the fluidization process began, a nice up flow of solids was seen. During the first few time steps of the simulation, the solids are moved as a block against the gravity. Mesoscale structure like bubbles can be eventually seen in the solids concentration profiles. Inhomogeneity is then seen in the contours due to fluctuations of solid volume fraction, and the contours no longer remained symmetrical. This non-homogeneous flow prediction is similar to the real fluidization characteristics in BFBs.**

Keywords: FBG, Hydrodynamics, Eulerian

I. INTRODUCTION:

Due to their excellent solid mixing, heat and mass transfer properties of fluidized beds, are employed in industrial operation in large scale. In fluid dynamics proper modelling is most required in understanding industrial multiphase flow. The gas-solid flows in fluidized beds are heterogeneous and usually simulated with the Eulerian description of phases and this description requires the usage of fine meshes and small time steps for the proper prediction of its hydrodynamics. Such constraint on the mesh and time step size results in a large number of control volumes and long computational times which are unaffordable for simulations of large scale fluidized beds. The current trend in the computational fluid dynamics of gas-solid flow much relies on two factors: computational time and accuracy. Accurate simulations are computationally very expensive, and thus, not affordable in practice. On the other hand, a failure to include the effect of small scale flow structures on the fluid dynamics results in inaccuracy in the predicted flow phenomena. Thus, there is a need to find better modelling capabilities which can produce fast simulation results with reasonable accuracy. In the present work an approach for the computationally less expensive simulations of the gas-solid flow in fluidized beds are done .Eulerian- Eulerian multiphase[**Athirah Mohd Tamidi et al[1]]** model coupled with kinetic granular theory can be employed for developing hydrodynamic model and to study the effect of particle size to the solid fluidization in fluidized bed. In this validating model the granular temperature of solid or fluctuation energy of solids particles calculated by neglecting the loss of energy due to convection and diffusion. Further as the particles have higher energy it moved more rapidly when gasified by air and this rapid movement resulted in the smaller bubbles to coalesce more rapidly and form larger bubbles. The instantaneously expended bed height for different solid particle size which was simulated showed the effect of particle diameter to the solid fluidization in the gasifier, which indicates that if the particles are small and lighter, easily it gets fluidized and the expended bed height will be highest which means that the voidage between the solid particles are too big which is not suitable for biomass gasification reaction as the interaction between the solid particles is almost nil and vice-versa.

Eulerian–Lagrangian [**Wenqi Zhong et al** [2]] three-dimensional numerical model approach, was simulated and the complex granular flow behaviours is addressed. The model has made use of Eulerian method for fluid phase and a discrete particle method for solid phase, by considering particle contact force. Air was used as the fluidizing agent and introduced into the reactor below the distributor and the system has silica sand, carbon and ash particles. It was observed that as gas moved up the distributor, large bubbles was formed. Further coalescence and eruption was difficult to identify because of the high gas velocity and gas-particle interactions caused the particles to gradually move up and solid volume fraction decreased along the reactor height.

The flow behaviour in biomass gasification reactor using a multiphase Eulerian model [**Britt Margrethe Halvorsena et al [3]]** approach describes the gas-solid fluidized bed consisting of two interpenetrating fluids. In order to consider the transient nature of a gas-solid bubbling fluidized bed system a non-steady state model was applied. Kinetic theory of granular flow has been applied and this theory has considered the conservation of solid fluctuation energy. The simulations are performed with 350 µm particles using air as fluidizing medium, it was understood that solids were relatively quiescent and the pressure fluctuations in the bed was negligible when fluidization velocity was below the minimum and the fluctuations was significant as the bed started fluidizing. The simulations are also performed with 500 µm particles with steam as fluidizing gas, the bubble size and frequencies deviated for the two cases as the gas velocities increased from minimum fluidization velocity.

The study [**Dimitrios Mertzis et al [5]]** on effect of the fluidization medium (air) velocity profile to the sand-bed fluidization behaviour enabled to understand that the fluidization is a highly time-dependent process, and the solution should progress for several seconds (>2) of flow time in order to receive a close to steady-state flow field.

Hydrodynamics of a two - dimensional gas –solid [**Pranati Sahoo et al[4]]** fluidized bed is studied for coarse and fine particles to observe the bed dynamics namely pressure drop across the bed, the minimum and maximum heights of the expanded bed which are attained during the fluidization process. The Eulerian granular multiphase model is used for modelling the transition nature of bubbling fluidized bed by treating gas and solid phases as continua interpenetrating and interacting with each other and everywhere in the computational domain. Assumptions such as, constant pressure gradient isothermal non-reactive, no lift force, no mass transfer between gas and solid phase and constant density of each phase has been considered for simulation.

The results obtained by the models could be utilised in interpreting the pressure drop profiles into visualisation of the flow field and the bed expansion which affects biomass reaction kinetics once when they are introduced into the model.

II. SIMULATION AND MODELS USED

Fluent V14 is used for running the simulations.2D segregated 1st order implicit unsteady solver is used (the segregated solver must be used for multiphase calculations).Gravity was enabled and a value of -9.81 m/s is specified for the gravitational acceleration in the Y direction. An Eulerian multiphase model for two phases approach is considered for analysis. Heat transfer was enabled by enabling the energy equation. Laminar viscous model is taken since the experiments have shown negligible three-dimensional effects in the flow field for the case modelled, indicating a very weak turbulent behaviour. Air constitutes the gas phase and Solid phase consists of sand particles of uniform diameter, 0.385mm in this case and sand particles is treated as granular phase. The model used for sand particles are tabulated in the Table 1

Table1. Shows the models used in simulation for sand particles

Property	Model
Radial Distribution	Lun- et-al
Granular Viscosity	syamlal-obrien
Granular Bulk Viscosity	Lun- et-al
Granular Temperature	Algebraic
Frictional Viscosity	Schaeffer
Packing limit	0.6

Further, the solid–gas phase interaction is defined by Syamal Oberien model for drag coefficient and Gunn for heat transfer coefficient.

III. BOUNDARY CONDITIONS

1. Velocity inlet Boundary Conditions (Air Inlet) : Air velocity was varied as 0.07 m/s, 0.7 m/s, 1.4 m/s
2. Pressure outlet boundary conditions (Gas Outlet): Mixture Gauge Pressure- 0 Pascal
3. Backflow Temperature for air is taken as 300K
4. Wall Conditions: No slip condition was used for gas and solid phase and a Temperature of 373K was specified for Mixture phase.

IV. SOLUTION CONTROLS

Segregated solver is used which solves the equations individually unlike coupled solver. Second order implicit unsteady formulation is used. Velocity formulation is taken as absolute. Multiphase model is taken as Eulerian. Under relaxation factor for pressure, momentum and volume fraction were taken as 0.5, 0.2, and 0.2 respectively. The discretization scheme for volume fraction and energy used is QUICK and for Momentum second order upwind scheme is used. Pressure-velocity coupling scheme is Phase Coupled SIMPLE. The maximum number of iterations per time step was chosen as 40.The convergence criteria in these simulations was set to the value 0.001.

V. RESULTS AND DISCUSSION

Simulations have been carried out for a two phase fluidized bed reactor of 1350mm height, 76mm diameter and static bed height of 300mm. The simulations are done till a quasi steady state is obtained. The solid phase volume fraction changes in due course of time are shown in figure 1. The fluidization process is a highly transient phenomenon, thus the solutions should progress until the flow image is "quasi-stable. The figure 1 clearly shows that solids were relatively quiescent , when fluidization velocity was below the minimum and the fluctuations was significant as the bed started fluidizing. Initially there is very little change but when fluidization starts, gradually the volume fraction of sand changed and after a quasi steady state is obtained there is no further change in the bed. At the beginning the silica sand as bed material are located at bottom of the reactor as time goes on, fluid drag force and particle contact force make particles mix with each other.High gas velocity causes the upward motion of sand in the bottom layer easier as a result, a more significant mixing takes place in the higher velocity region. After $t = 0.3$ s, the volume fraction profile shows the relatively steady state and the particle volume fraction decreases along the reactor height.

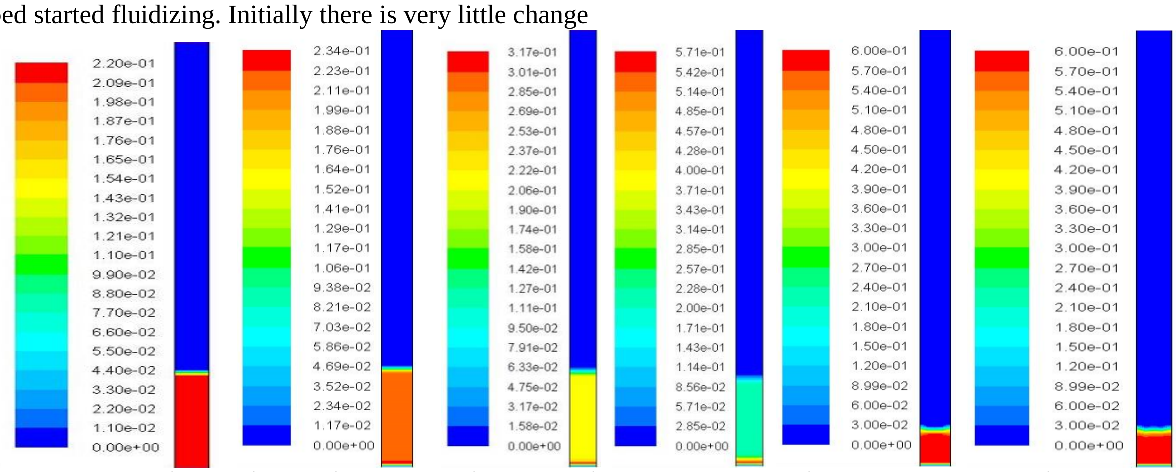

Figure1: Contours of volume fraction of Sand particles for minimum fluidization air velocity of 0.07m/s at time intervals of 0s ,0.02s ,0.05s ,0.1s ,0.3s and 0.5s respectively.

The figure 2 represents the contour plots, behaviour of the bed variation at fluidising velocity of 0.7 m/s at different time intervals
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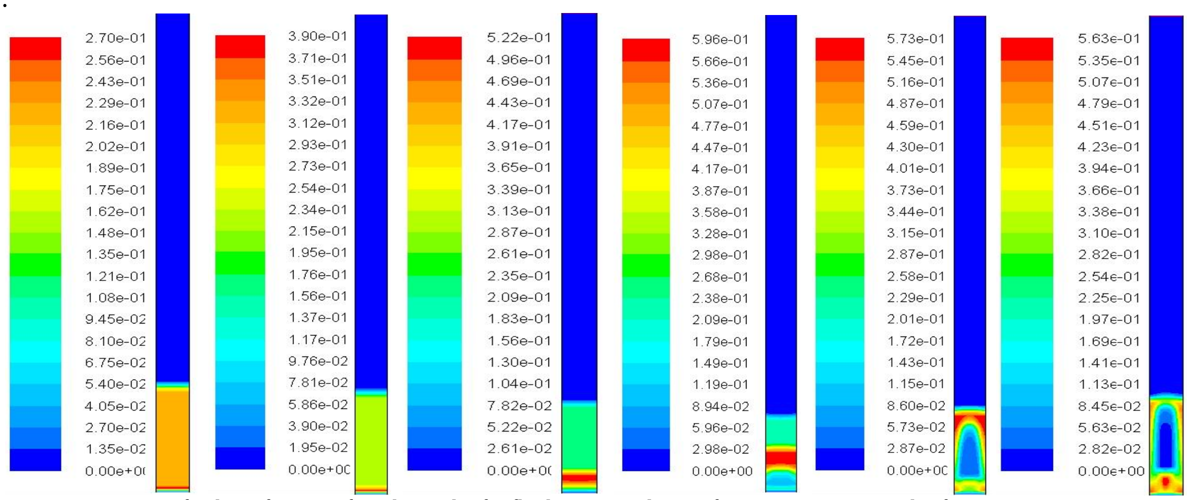

Figure 2: Contours of volume fraction of sand particles for fluidizing air velocity of 0.7m/s at time intervals of 0.05s ,0.1s ,0.2s ,0.3s ,0.5s and 0.6s respectively.

The figure-2 illustrates the behaviour of the bed variation at fluidising velocity of 0.7 m/s in the due course of time. It can be observed that the bed height increases with passage of time. The large bubbles or intense slugs (void structures) formed when gas moved up. The growth can be observed whereas the coalescence and eruption are difficult to identify because of the high gas velocity. Particles gradually move up driven by gas-particle interactions
.

The Figure-3 shows the contours of volume fraction of Sand at fluidising velocity of 1.4 m/s taken at different time intervals. Initially there is almost no change in the bed height but when the velocity of air was increased the bed starts to expand at higher velocities and the bed has risen by a considerable amount. The bed height of bed materials gradually increased with time at constant air velocity and bed expanded with increase in superficial velocity of fluid. As the particles have higher energy it moved more rapidly when gasified by air and this rapid movement resulted in the smaller bubbles to coalesce more rapidly and form larger bubbles

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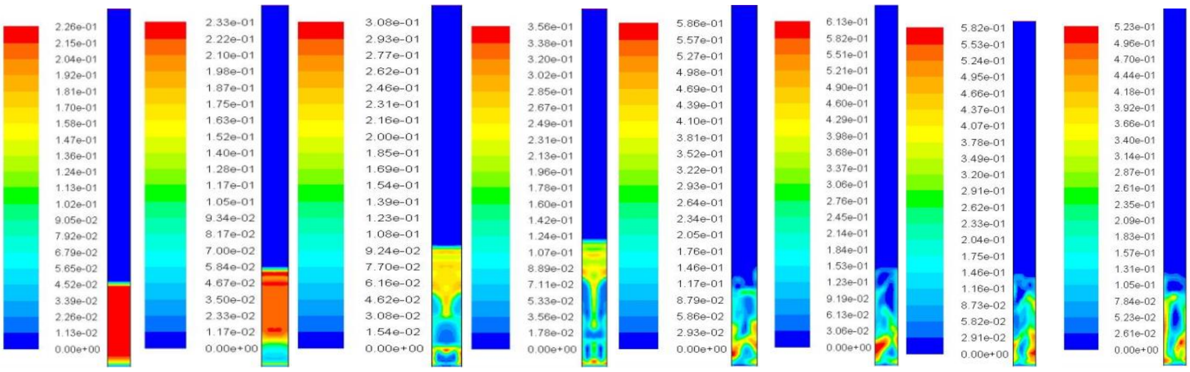

Figure-3: Contours of volume fraction of Sand particles for air velocity of 1.4m/s at time intervals of 0.1s,0.3s ,0.6s,0.7s,1.5s,3s,5s and 9s respectively.

VI. CONCLUSION:

It can be concluded that the modelling of sand particles in a fluidized bed is characterized well because of nearly ideal particle properties and thus it provides a good platform for studying the basic hydrodynamic properties of fluidized beds. Further it was understood that the fluidization process is a highly transient phenomenon, and the solutions should progress until quasi-stable state is reached. The bed height of bed materials gradually increased with time at constant air velocity and bed expanded with increase in superficial velocity of fluid. As the particles have higher energy it moved more rapidly when gasified by air and this rapid movement resulted in the smaller bubbles to coalesce more rapidly and form larger bubbles. The distributor plate encompassed in experimental setup (but not typically modelled in simulations) causes bed material to agglomerate between jets of gas phase. Due to these dead zones, not all of the bed mass is fluidized. High gas velocity caused the upward motion of sand in the bottom layer easier as a result, a more significant mixing took place in the higher velocity region and thereafter sand particles remained in fluidised state due to drag force of fluidising air.

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VII. REFERENCES

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