iJRASET
International Journal For Research in
Applied Science and Engineering Technology

# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

**Volume:** 7 **Issue:** IV **Month of publication:** April 2019

**DOI:** https://doi.org/10.22214/ijraset.2019.4499

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 7 Issue IV, Apr 2019- Available at www.ijraset.com

# Modeling and CFD Analysis of Fluidized Bed: An Advance Equipment for Moisture Removal from Coal

Nilesh V.Pise[1], V. V. Dongaonkar[2], Akash A. Kolhe[3], Shubham R. Lonkar[4]
[1, 2, 3, 4]*Babasaheb naik college of engineering, Pusad*

***Abstract: In rainy season, the coal from coal mines are totally wet and it take lots of time (10 to 12 days) to get dry. Such type of coal cannot be use for boiler. The Additional new equipment like a rotary kiln, metal chamber for removal of coal moisture can be used. If CHP will work on such advance equipment which is reliable and having less maintenance cost. In present paper, the advance coal handling unit consists of Metal chamber (Fluidized bed dryer). An integrated solution of coal handling plant is given to meet the increasing production needs. CFD analysis of fluidized bed was carried out in Ansys-Fluent 16.0 and tuning the solid-fluid exchange coefficient, fluid-fluid exchange coefficient, the constant rate drying period, combustion kinetics was successfully simulated. Spontaneous combustion kinetics of bituminous was studied.***
***Keyword: CFD analysis, fluidized bed, CHP, coal moisture, bituminous coal.***

## I. INTRODUCTION

The advance equipment fluidized bed with heat exchanger is designed by considering the moisture contain in the coal. In rainy season the coal is totally wet, and such type of coal cannot be used directly for thermal power plant. Coal is a cost-effective fuel for power plants and industries due to its high abundance and low cost. Around 45 % of the world's coal reservoirs consist of lignite, a cheap coal type, low in sulfur but high in moisture (25-40%), resulting in a low calorific value compared to other coal types. The coal from the coal mine are having moisture greater than 50% and most of the time the coals are like a mud. Generally in coal handling plant the wet coal from coal mine are put into stock yard for 10-12 days to remove the surface moisture from the coal. Great tendency for spontaneous combustion, and high transportation costs are other disadvantages of lignite, making it undesirable for industrial processes.

Moisture reduction can increase the quality and efficiency of coal to a desirable amount for different processes. However, due to high amount of moisture in lignite, drying requires a large amount of energy. For the production of 1 unit 0.700 kg of coal is required. If coal contain moisture by 1% then the flame stability of coal get disturb by 0.07%.

## II. PROBLEM STATEMENT

In the present coal handling plant there is no any kind of arrangement for the moist coal. If coal is contain 1% moisture then the flame stability get disturbed by 0.07% and the boiler efficiency get reduced by 0.1% to 0.2%. With increase in 1% moisture the CO2 emission get increase by 0.4%. In the present coal handling plant the conventional method is used to dry the coal that is coal is put in stock yard for 10-15 day to remove the surface moisture from the coal. By adopting this method only surface moisture is get removed to some extend but the other type of moisture cannot be removed here. To increase the efficiency of the plant it is necessary that the coal which plant using is free from moisture or contain less amount of moisture. There is also need to focus on the rate of moisture removed from the coal. The time required to remove the moisture should be less in order to achieved higher efficiency.

## III. FLUIDIZED BED

Fluidized beds are widely used in different industrial processes including drying, cooling, granulation, coating etc. They can be used for both heat sensitive and non-heat sensitive materials. In coal industry, fluidized beds are used in processes such as drying, gasification and de-volatilization. Fluidized bed dryers (FBD) are useful for drying powders, granulates, agglomerates, and pellets in the size range of 50 to 5000 µm. Particles out of this size range are either too small or too big to fluidize and may require additional forces, i.e. vibration, to fluidize.

### *A. Fluidization Definition*

When an upward fluid is passed through a bed of particles, due to the frictional forces between the fluid and the particles, fluid pressure will decrease. Increasing the fluid flow will increase the pressure drop up to a certain point where a small reduction in the pressure drop is observed (figure 2-1). For air superficial velocities larger than that no more increase in the pressure drop will be observed. The velocity at which the pressure drop stops increasing is called the minimum fluidization velocity, where the drag force applied to the particles will be equal to the apparent weight of the particles. This leads to particles being lifted slightly by the fluid and the bed is considered fluidized.

### *B. Type of Fluidization*

The fluid which we are using on that basis fluidized bed are classified into two type. They are as follows:

1) *Particulate Fluidization:* Particulate fluidization is the one in which particle are fluidized with fluid but it will be uniformly distributed throughout the bed. It can happened with gas but at lower velocity.
2) *Aggregative Fluidization:* Aggregative fluidization is the one in which article are fluidized with fluid but it will not be uniformly distributed throughout the bed and bubble are formed and move upward and goes on increasing these condition is called as aggregative fluidization. It actually happened with gases.

To differentiate fluidization type aggregative or particulate the criterion of Froude number was suggested and is given by

Froude No = $U_{mf}/gd$

Where

$U_{mf}$ - Minimum fluidization velocity.

d - Diameter of particle.

g - Acceleration due to gravity.

If the Froude number is greater than one then it is aggregative fluidization and if it is less than one then it is particulate fluidization.

## IV. MODELING OF FLUIDIZED BED

The modeling of fluidized bed is done in catia (modeling software). The below figure 4.1 showing the different views of fluidized bed.

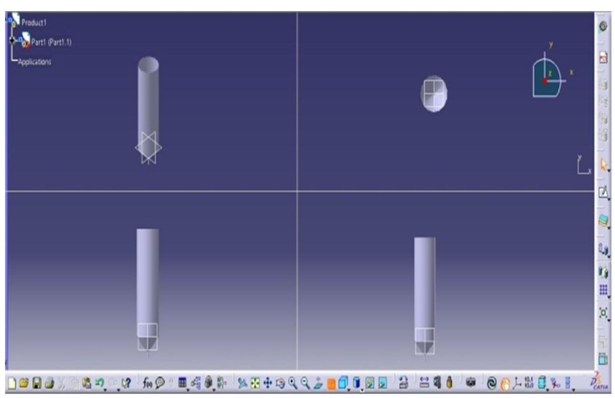


Figure 4.1: Showing Different View of Geometry of Fluidized Bed In CATIA

For the modeling purpose here we used different tool such as sweep tool, blend tool, and extrude tool and many other tools. After the complication of geometry, it is imported into the anysis for the purpose of the analysis of the fluidized bed. The geometry is made for the purpose of meshing.

## V. CFD MODELING OF BITUMINOUS DRYING IN A FLUIDIZED BED

CFD Modeling of fluidized beds is a challenging task due to the complex nature of the problem. The hydrodynamics and phase interaction of gas-solid flow are some of the problem complexities. In this paper, Ansys-Fluent 16.0 package has been used to simulate the drying of bituminous particles in a fluidized bed. Fluent provides three different Euler-Euler models:

### *A. The VOF*

The VOF is a surface tracking method suitable for immiscible fluids when the fluids interface position is to be studied. This model is applicable in problems such as free surface fluids.

*B. The Mixture*

This model is designed for two or more phases of fluids or particulates. The model solves the mixture momentum equations, and using the relative velocities, solves for the dispersed phases. Sedimentation is a good example of application of this model.

*C. The Eulerian*

This is the most sophisticated model for multiphase analysis. It solves momentum and continuity equations for each phase and couples the results using pressure and exchange coefficients between the phases. Fluidized beds are solved using this method. In this study, Eulerian model was used to simulate the fluidized bed dryer.

*D. Parameters for Fluidized bed Calculation*

Table 5.1: fluidized bed file data

| | |
|---|---|
| Case | Fluidized Bed analysis |
| File Path | C:\Users\admin\Desktop\Neil Patil\Neil\Neil Patil\coal ansys\fluid bed files\dp0\FFF-2\Fluent\FFF-2-1-00038.dat.gz |
| File Date | 19 January 2019 |
| File Time | 03:51:30 AM |
| File Type | FLUENT |
| File Version | 16.0.0 |

*1) Boundary Conditions*
*a) Inlet*
*i)* Gas velocity : 0.4 m/s
*ii)* Gas temperature : 293K, 343 K
*iii)* Mass fraction of $H_2O$ : 0
*b) Outlet*
*i)* Outflow : pressure outlet
c) Wall
*i)* Momentum : No slip
*ii)* Species : Zero diffusive flux

After the catia file of fluidized bed geometry is imported into the anysis, the next step is meshing. In automatic meshing, there is need to make the meshing very fine and it is done by the face meshing. Face meshing is simply equate number of row equal to number of column. Many time when people goes for auto meshing, near the corners of geometry the mesh which generate is not that much good and there is need to generate fine mesh at that particular corner if the problem is related to flow and hence at such situation inflation and baising is done. The inflation is given to the bed and finally meshing is completed. If the geometry is 3D then the software take lots of time to solve the problem. So the best way is to go for 2D geometry. If 2D geometry is used then the number of equation to solve gets reduced and it takes less time compare to 3D geometry. After the preparation of geometry, the meshing is done on model there are different way to do meshing. The automatic meshing is used here, in automatic meshing the sizing is done by selecting relevant course centre as fine.

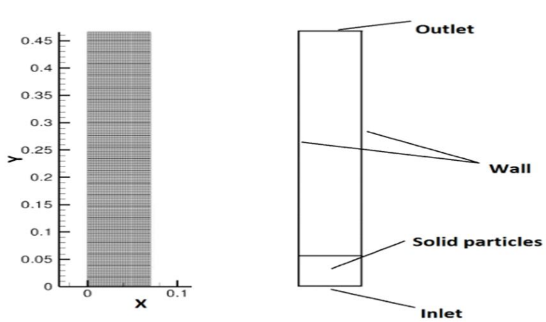



Figure 5.1: Bed mesh and Boundaries

*2) Initial Conditions*
*a)* Solid volume fraction : 0.55
*b)* Solid temperature : 300 K
*c)* Solid velocity : 0

This model was applied to the Fluent along with the input data and settings Given below

*3) Parameter Value*
*a)* Particle diameter : 1.3e-03 m
*b)* Particle density : 1400 kg/m3
*c)* Solid volume fraction : 0.55
*d)* Packing limit : 0.58
*e)* Gas velocity : 0.4 m/s
*f)* Gas temperature : 20˚C and 70 ˚C
*g)* Solid initial temperature : 20 ˚C (293 K)
*h)* Mass transfer rate : 0.06 and 0.21 kg/m3.s
*i)* Time steps : 10e-04 s
*j)* No. of iteration per time step : 70
*k)* Operating pressure : 101325 pa
*l)* Number of mesh cells : 5544
*m)* Min/Max cell size : 2.35e-03/2.493-03 m2
*n)* Mesh aspect ratio : 1.45
*o)* Smallest Residual : 10e-04

*4) Parameter and Spatial Discretization*
*a)* Gradient : Least square cell based
*b)* Momentum : Quick
*c)* Volume fraction : Modified HRIC
*d)* Energy : Quick
*e)* Gas species : Quick
*f)* Solid species : Quick

After the meshing, next step is to set the parameter which is called as setup. In the setup we provide the necessary data to the anysis software. Setup contains all information about the model starting from the dimension to the flow of the fluid flowing through it and all. In the setup all the properties are given to the model along with all boundary condition which are necessary. The condition are listed above which setup need to gives the write solution to the given problem. When fluid condition, boundary condition, energy, number of iterations and some other properties are given to setup then final result come without any error.

If there is any problem in meshing or geometry then the result displayed by software are not that much correct if the meshing is accurate mean if the aspect ratio and the element quality is maintained well then the final result are said to be correct.

After the setup, the main thing is result and the result from the software is as shown below. If we see initially there is aggregative type of fluidization is seen but after some time there is particulate fluidization. The total behaviour of coal is seen in the figure below.

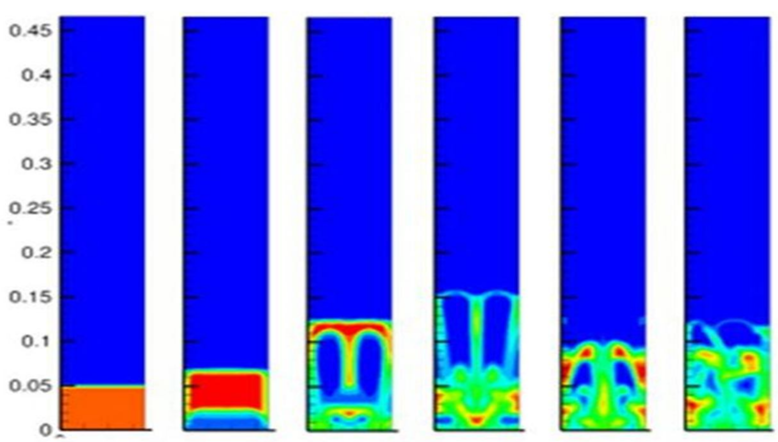
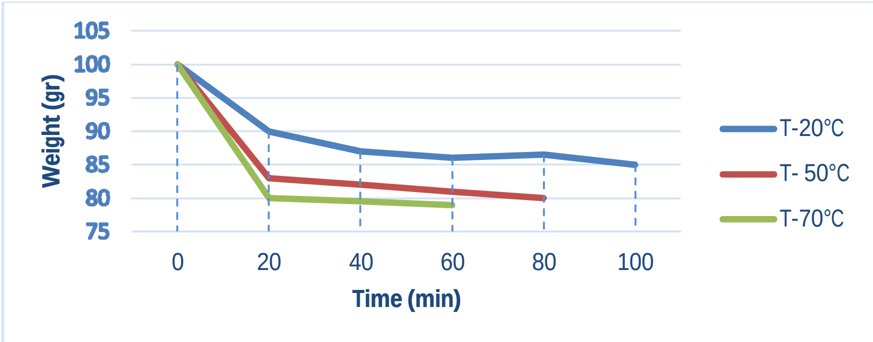



Figure 5.3: final result in the CFD of fluidization

## VI. EFFECT OF DRYING CONDITIONS IN FLUIDIZED BED

### A. *Effect of Inlet Gas Temperature*

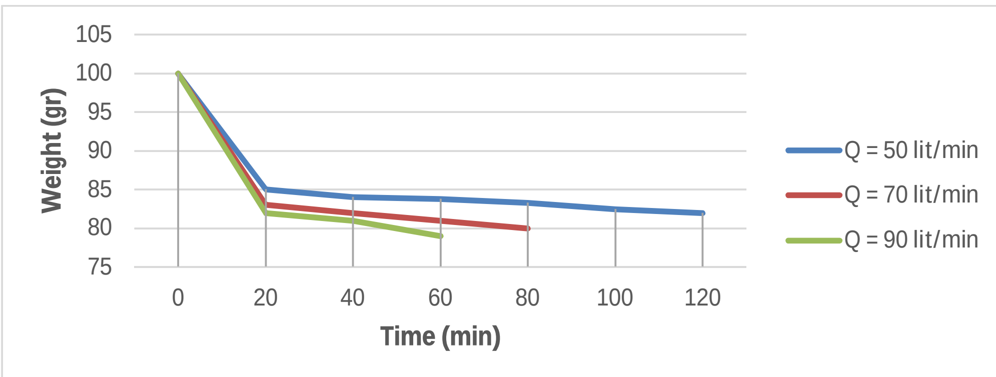
In order to investigate the effect of the inlet gas temperature on the drying behaviors of Bituminous coal, different tests with Tair =20 °C and Tair =50 °C and Tair =70 °C were carried out in the bed. The sample size was 1-1.7 mm, the mass of input sample was 100 gr and the initial moisture was 22 % with air flow rate of 90 lit/min. Graph 6.1 show the test results.




Graph 6.1: weight vs. time plots of 1-1.7 mm size under 90 lit/min for 100 gr of samples.

### B. *Effect of Gas Inlet Rate*

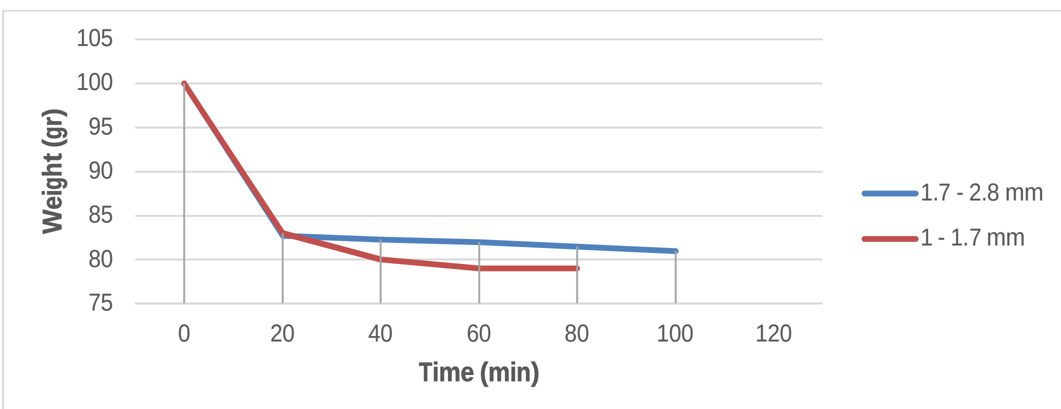
To investigate the effect of gas inlet flow rate samples of 1-1.7 mm size with initial moisture of 21 % were tested under Tair=50 °C and different air flow rates. Air flow rates of 90 lit/min, 70 lit/min and 50 lit/min were applied to the samples. Graph 6.2 show effect of gas flow rate.




Graph 6.2: weight vs. time for 1-1.7 and T=50 ˚C at different air flow rates.

### C. *Effect of Particle Size*

To investigate the effect of particle size on the drying of lignite, two samples in the size range of 1-1.7 mm and 1.7-2.8 mm were dried in the fluidized bed under the same temperature and air velocity. Graph 6.3 show the effect of particle size.




Graph 6.3: weight vs. time in T=50 ˚C and Q=90 lit/min

## VII. CONCLUSION

Based on the data analysis, when drying bituminous coal particles in a packed bed dryer, it is more efficient to use higher drying temperatures in the constant drying period and lower drying temperatures in the falling rate period. If spouted bed is not desired to be used for bituminous drying, packed bed of bituminous particles can be dried efficiently without increasing air velocity to the theoretical minimum fluidization. If the particle size of coal increased then the mass transfer rate decreased. After the particular limit there is that much change mass transfer rate with increase in the flow rate of fresh air. The boiler efficiency increased with decreased in moisture content in coal.

## REFERENCES

[1] Gupta S. and P.C. Tewari, (2009) "The Development Of A Performance Model Of Power Generation System Of A Thermal Plant.", International Journal of Quality and Reliability Engineering, Vol.23, No. 9, pp 411-423.
[2] Gupta S., P.C. Tewari, (2009) "Performance Modeling of Power Generation System of Thermal Plant.", International Journal of Engineering and Technology, Vol. 24, No. 3, pp 239-48.
[3] Hada, A., Coit, D., Agnello M., Megow, (2011) "System Reliability Models With Stress For Changing Load Profile.", Reliability And Maintainability Symposium (RAMS), Proceedings-Annual, pp1-7.
[4] Hao Peng, David W. Coit, Qianmei Feng (2012) "Component Reliability Criticality or Importance Measures for Systems With Degrading Components." IEEE Transactions on Reliability, Vol. 6, pp 4-12.
[5] Ismihan Bayramoglu (2013) "Reliability and Mean Residual Life of Complex Systems With Two Dependent Components per Element." IEEE Transactions on Reliability, Vol. 62, pp276-285.
[6] Miss. Shivani Thote, Thermal power plant, Paras. - Manual Internet / Web site links & dept. data of CHP 250X2 MW.