https://doi.org/10.46335/IJIES.2023.8.9.3 **e-ISSN: 2456-3463**
Vol. 8, No. 9, 2023, PP. 13-17

International Journal of Innovations in Engineering and Science, www.ijies.net

Optimization of Flow Parameters for Granular Material Flow through Hopper by CFD & EDEM Simulation

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***Received on**: 19 May, 2023* ***Revised on**: 17 June, 2023* ***Published on**: 19 June, 2023*

Abstract – *The concept of discrete & numerical discrete element method (DEM) will going to study for The effect of particle having circular/noncircular shapes on granular flow through the hoppers of Plane wedge shape, space wedge shape & flat bottom shape. During this fixed volume will going to Use with each shape of hopper, and discharge outlet of hopper may going to keep constant for each Case. The investigation of flow patterns will go too made. The coal will go to be used as a granular Material considering regular & irregular shape and size for the computerized analysis. For this high-end mechanical engineering software may go too used like as CATIA for 3D Modelling, CFD for meshing & E-DEM for modelling of particles and simulation of whole process to Obtain the numerical result data and associate flow parameters in each case. Here the study will Make on effect of particle shape, size, and density on the discharge flow rate of material which will Be compared with the case of circular particles. In the end of the whole study & after getting the Simulation results in each case, this may result with the optimization of some flow parameters and a Suitable hopper design.*

Keywords:-Discrete Element Method, flow parameters, Hopper, Granular Materials, Coal, Particle Shape.

I-INTRODUCTION

Flow Of Granular Materials Through Hopper Is Important In The Field Of Mining, Mineral Processing And Parma Industry. This Also Has A Considerable Scientific Interest Because They Exhibit Some Phenomena Which Are Specific To Granular Materials. Hoppers Are The Intermediate Equipment During Material Handling Which Act As Temporary Storage And Control The Amount Of Feed To The Next Stage Of Material Handling Like Screens, Conveyors Or Chute. Proper Design Of The Hopper Is Necessary So That The Material Which The Hopper Is Handling Flow To The Next Equipment Without Any Hindrance. The Present Day Development In The Field Of Cad, Cfd And Edem Provides The Opportunity To The Design Engineer For Devising Best Possible Equipment.

The Engineering Discrete Element Method (Dem) Is Very Sophisticated Tool For Studding The Granular Flow And Behavior Of The Granular Materials. Here The Particle Can Be Modeled As An Assembly With Considering The Dynamic Parameters Like Its Positions, Velocity, Its Orientation, Etc. Modeling In Dem Allows Us To Consider The Nature Of Granular Material, And The Fundamentals Of The Granular Flow.

Many Of Researchers Were Made Research On The Flow Of Granular Material; Some Of Them Have Also Used The Discrete Element Method To Perform The Analysis Of Granular Materials, But Still Researchers And Scientist Are Working On The Study On The Flow Of Granular Materials. The Past Development And Researches Made On Granular Materials Were Discussed In The Literature Review.

II -LITERATURE SURVEY

As we discussed earlier that the field of granular material study is interest part of many researchers and scientist,

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so some relevant research done were discussed as follows,

The effect of particle shape on granular flows through hoppers based on method of generation of packing of realistic sand samples were discussed in **"The Influence of Particle Shape of particle on Granular Hopper Flow"** ***by G. Mollon and J. Zhao*** in **AIP Conference Proceedings 1542, 690 (2020),** Concluded that the use of non-circular particles during the granular flow leads to reduce the flow rate.

A summary of the studies based on discrete particle simulation in the past two decades were discussed in **"Discrete particle simulation of particulate systems : A review of major applications and Findings"** by ***H.P. Zhu, Z.Y. Zhou, R.Y. Yang, A.B. Yu,*** published in Science Direct **Journal-Elsevier : Chemical Engineering Science 63 (2018) 5728-5770,** which was categorized here in three subject areas : particle packing, particle flow, and particle–fluid flow, and concluded that discrete particle simulation is an effective method for particle scale research of particulate matter.

Modeling of hopper discharge through the DEM, the effect of particle aspect ratio & blockings have been investigated independently and then together in **"DEM modeling of industrial granular flows: 3D case studies and the effect of particle shape on hopper discharge"** by ***Paul W. Cleary, Mark L. Sawley*** published in **Applied Mathematical Modeling 26 (2018) 89–111,** Here the simulations of the charge flow in a 5 m ball mill, and complex motion were modeled and also the simulation of flow through a vibrating screen, discharge from single and four port cylindrical hoppers illustrates the potential of DEM.

The experimental result of an investigation of flow patterns of sand in plane shaped hopper were discussed in the **"Flow of Granular Material through a Plane Hopper"** published in the **Powder Technology, 39 (2014) 29-40,** by ***R.L. Michalowski*****.** Here he used the theoretical & experimental approach to the flow of granular cohesion less material through hoppers. Comparisons of the mathematical description of the advanced flow with the experimental results were done.

The approximate solution to the flow of a cohesion less granular material in a conical hopper were discussed in **"Gravity Flow of Granular Materials in Conical Hoppers"** ***by T.V.Nguyen, C.Brennen, R.H.Sabersky*** published in **Journal of applied mechanics, September 1999, vol. 46/529-535,** concluded that the continuum model describes the behavior of granular materials fairly well.

There are many researches were done in the field of granular flow and the discrete element modeling, the literature discussed above are most relevant and taken in consideration for the said project work.

III -PROBLEM STATEMENT

At present, some new products are always designed with experience, without any improvement. Consider the current situation in the EDEM.

At present our company needs to change CFD according studies will be conducted for the discharge flow pattern and flow rate. The effect of particle shape, size, and density on the discharge flow rate of material will be determined. The discharge time for each design will also be determined. After simulation problem areas in all the shapes will be seen and some techniques will be employed to solve that problem.

IV -OBJECTIVE

1) Studies on Circular granular material flow through different shape of hoppers by EDEM simulation.

2) Studies on Non-Circular granular material flow through different shape of hoppers by EDEM simulation.

3) Comparison between flows of Circular & Noncircular granular material through the different shapes of hopper.

4) Optimization the discharge flow rate & associated parameters of granular material flow through hoppers.

V -METHODOLOGY

- First the different shapes of hoppers (Plane wedge, space wedge, and flat bottom) will be created by 3D CAD software keeping the internal volume fixed for all the shapes. Internal & external body shapes will be created for analysis in the FLUENT & EDEM.

- Meshing of the 3D CAD drawing will be done by using ANSYS-ICEM CFD. The outer body shape will be exported to the EDEM software for analysis.

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- Circular particles of different sizes will be created by the factory plate of EDEM and studies will be conducted for the discharge flow pattern and flow rate. The effect of particle shape, size, and density on the discharge flow rate of material will be determined. The discharge time for each design will also be determined. After simulation problem areas in all the shapes will be seen and some techniques will be employed to solve that problem.

- Considering the case of coal particles, the simulation will be repeated as done for the circular particles. The effect of particle shape, size, and density on the discharge flow rate of material will be compared with the case of circular particles.

VI - DESIGN AND LINKAGES

1.DEM - Discrete Element Method

DEM - Discrete Element Method is a numerical method for computing the motion and effect of a large number of small particles. Simulation in E-DEM Software is transforming the business of designing and optimizing equipment for the handling and processing of bulk materials. In proper use DEM simulation can give key design information on bulk solid material flow behaviour that is very difficult to get using standard test methods or other methods of engineering simulation.
EDEM is high-performance DEM simulation software– the only commercially available software that is capable of generating the powerful DEM simulations and analysis required to solve complex problems in the design, prototyping, and optimization of equipment that handles and processes bulk solid materials–across a wide range of industry sectors, which was introduced to industry nearly a decade ago, EDEM is powered by state-of-the-art Discrete Element modelling technology and uniquely provides engineers with the capability to quickly and accurately simulate and analyse the behaviour of their granular solids systems.

2. Granular Material

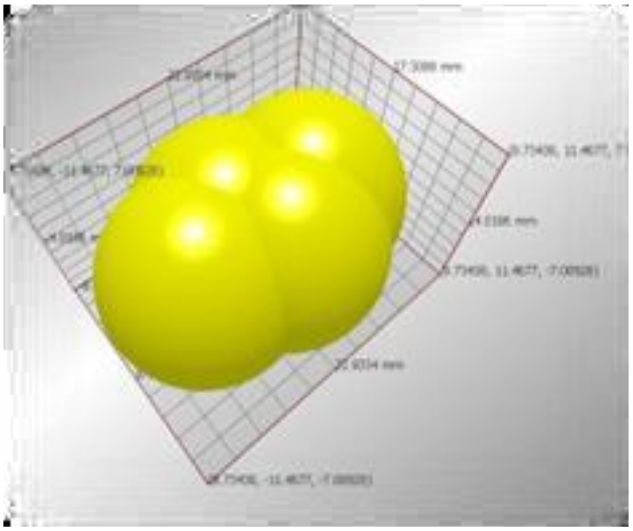
Granular materials are as a large conglomerations (a number of different things, parts or items that are grouped together) of discrete macroscopic particles. As explained in the article of “The Physics of Granular Material” by Jaeger & Nagel. This also tells, that granular material behaves different from the other familiar forms of matter-solids, liquids or gases-and might therefore be considered an additional state of matter in its own right.

3. Modeling of Granular Materials

Using Coal as a granular material and aiming to track the trajectories and study the behavior of coal with air media[7]. The modelling of particles is possible in EDEM but for this we need to provide some physical properties of respective material, this was taken from the Govt. Coal laboratory (CIMFR) by studding more about Coal we found that coal mostly has an irregular shape and size, in which it founds nearly as spherical shape, peanut type shape and plate type shape, so we made modelling of a coal particle as same.

VII -MODELING OF PARTS

Using Coal as a granular material and aiming to track the trajectories and study the behavior of coal with air media. The modelling of particles is possible in EDEM but for this we need to provide some physical properties of respective material, this was taken from the Govt. Coal laboratory (CIMFR) by studding more about Coal we found that coal mostly has an irregular shape and size, in which it founds nearly as spherical shape, peanut type shape and plate type shape, so we made modelling of a coal particle as same.



(A)

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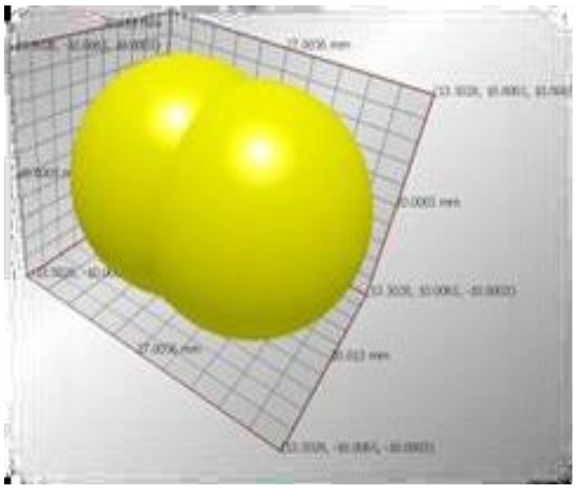

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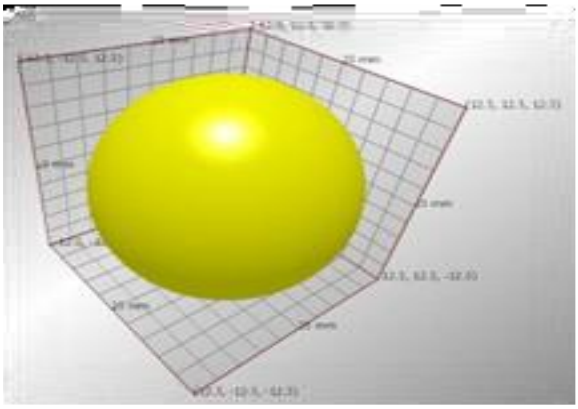

(C)

Fig.1. *Shape of Coal Particle generated in EDEM (a) plate, (b) peanut and (c) Spherical*

VIII-ANALYSIS OF MECHANISM

1. CAD & CFD work

Considering rectangular hollow box as working chamber and 3d modelling of same is made in the CATIA V5 R21, this chamber also has a hopper on its upper side, and opening and exit for air flow in its left and right side as, shown in figure 2. The same 3d modelling is also possible in EDEM itself, but as this is made for simulation and analysis work it makes more difficult to use this for 3d modelling. Airfield also needed to create in CFD-Fluent, which is shown in small blue vectors in 3d model of the chamber.

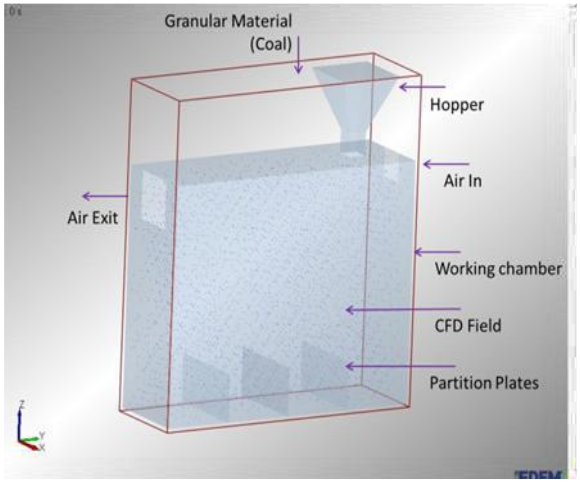

Fig.2. *Working Chamber and CFD Field*

2. CFD-DEM Simulation

The coupling of CFD field is needed to do with EDEM, for which parameters needed to use like as the mass flow rate of the granular materials, time step and unit cell size, etc[3]. So one can able to vary the mass flow rate of granular material, but to make change in air velocity its needed to create another CFD field for each time.

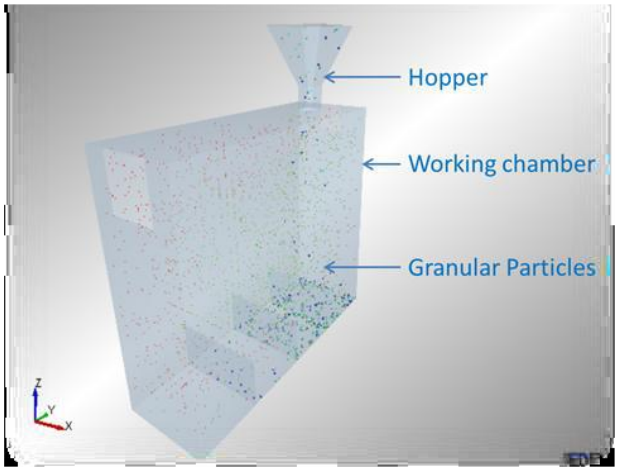

Fig.3. *In Simulation*

IX-AIMS & OBJECTIVE

a) Studies on Circular granular material flow through different shape of hoppers by EDEM simulation.
b) Studies on Non-Circular granular material flow through different shape of hoppers by EDEM simulation.

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c) Comparison between flows of Circular & Noncircular granular material through the different shapes of hopper.
d) Optimization the discharge flow rate & associated parameters of granular material flow through hoppers.

ADVANTAGES:

The advantages for the said research work are as follows,

a) To obtained the mutual behavior in between the particles
b) The simulation of whole process will helps us to visualize the process very closely.
c) The Flow parameters will going to be optimized with respective of granular materials.
d) The suitable design for Hopper may obtain with the optimized flow parameters.

APPLICATIONS:

This research work can be implemented in following industries,

a) Mineral Industry,
b) Pharmaceutical industries,
c) Coal handling plants,
d) Cement industries,
e) Food industries, and
f) Process industries.

X-RESULT

After doing much experimentation with CFD-DEM simulations, important of them are presented here for discussion.

To fix the air velocity, we made experimentation on EDEM using similar sized & shaped coal particles but of different sp. gravity was tested at three different air velocities. The above graph clears that in 35 m/s velocities, travelled distance for different sp. gravity coal is resulting with more distance in between than the other, so for better understanding fixing the velocity for further experimentations.

XI-CONCLUSION

Segregation of different density particles by air medium can be effectively utilized for separation of various densities particles in Agri. and Mineral industries. To study the behavior of segregation of particles at different input parameters EDEM software along with 3D CAD, FLUENT can be effectively used.

FUTURE SCOPE

The a future scope for research work is as follows,

a) Studies on effect of particle shapes on granular material discharge flow rate.

b) Studies on the problem areas of granular material flow inside the hopper geometry and ways to solve the problem.

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