International Journal of Mechanical Engineering and Robotics Research

ISSN 2278 – 0149 www.ijmerr.com
Vol. 4, No. 1, January 2015

Research Paper

COMPUTATIONAL FLUID DYNAMICS APPROACH FOR PREDICTION OF CYCLONE SEPARATOR PRESSURE DROP

Snehal S Gawali[1]* and M B Bhambere[2]

*Corresponding Author: ***Snehal S Gawali,*** ✉ *snehalg10@gmail.com*

The paper presents a Computational Fluid Dynamics calculation to predict and evaluate the influence of cyclone inlet velocity on the cyclone pressure drop. The numerical solutions were carried out using commercial CFD code. The study was conducted for cyclone separator, based on the available literature. When compared with the presented data the prediction proved to be satisfactory. Analysis of cyclone pressure drop fordifferent cyclone separator models was carried out at different inlet velocities.

Keywords: Cyclone, CFD, Pressure drop, Inlet velocity

INTRODUCTION

To separate particles from carrier gas cyclone employs a centrifugal force generated by a spinning gas stream. In its simplest form, a cyclone consists of anupper cylindrical part with an tangential inlet through which the gas stream enters. An axial inlet pipe for discharging the clean air and a lower conical part with particles discharge.In the cyclone separator the vortex is created which will centrifuge the particles to the walls, due to the influence of the spinning gases the particles can be transported to the dust collector.

The pressure drop through the cyclone and the collection efficiency of particle are the two important parameters regarding the performance of cyclone separator. As pressure drop is directly related to the operating cost, therefore an accurate prediction of pressure drop is very important. Computational Fluid Dynamics (CFD) helps to predict the flow field characteristics,pressure drop and particle trajectories.

In this study, pressure drop calculations are performed using CFD and compared with the study available in the literature (Niki Gopani and Akshey Bhargava, 2011).

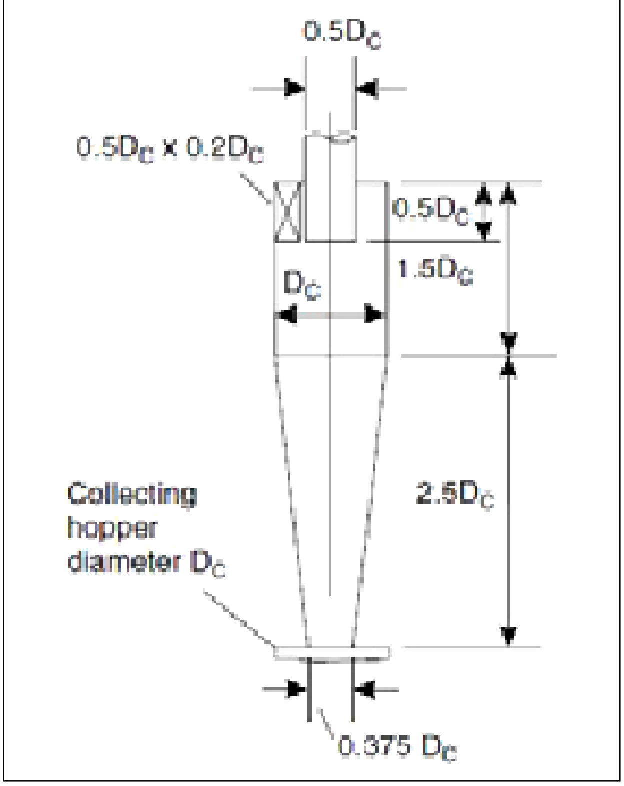
MODEL DISCRIPTION

The continuity and momentum balance

[1] ME Student, Department of Mechanical Engineering, Shri Sant Gajanan Maharaj College of Engineering, Shegaon, Maharashtra 444203, India.

[2] Assistant Professor, Department of Mechanical Engineering, Shri Sant Gajanan Maharaj College of Engineering, Shegaon, Maharashtra 444203, India.

Figure 1: Standard Cyclone Dimension as per STAIRMAND High Efficiency



equation for the gas phase and the particles are tracked in the Lagrangian manner.

Gas Phase

Continuity equation for the gas phase is written as:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho U) = 0 \qquad ...(1)$$

The momentum balance equation for the continuous phase, gases flowing through the cyclone, is written as:

$$\frac{\partial \rho U}{\partial t} + \nabla \cdot (\rho U \otimes U) = -\nabla p + \nabla \cdot \mu \nabla U - \nabla \cdot (\rho \overline{u_i u_j}) \qquad ...(2)$$

Particle Transport

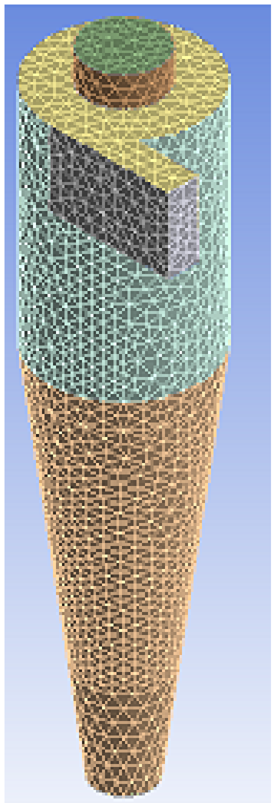
The particle transport is given by the following equation which considers the drag and buoyancy forces.

$$m_p \frac{dv_p}{dt} = \frac{1}{8}\pi \rho_f d^2 C_D |v_f - v_p|(v_f - v_p) + \frac{1}{6}\pi d^3 (\rho_p - \rho_{f)g} \qquad ...(3)$$

Numerical Simulation

The numerical calculation was made with a finite numerical grid as shown in Figure 2. The numerical simulation was carried out for five cyclone models having Dc 0.203 m, 0.25 m, 0.3 m, 0.35 m and 0.4 m.

Figure 2: CFD Surface Mesh of Cyclone



Boundary Conditions

The fluid is air at 25 °C, with an inlet velocity in range 15 to 20 m/s. An ‘opening’ atmospheric pressure condition is set for the clean air outlet, and an ‘free slip’ condition is set at the dust particle outlet. The particles with density 2500 kg/m^3 were injected with the same velocity as the fluid in the cyclone inlet.

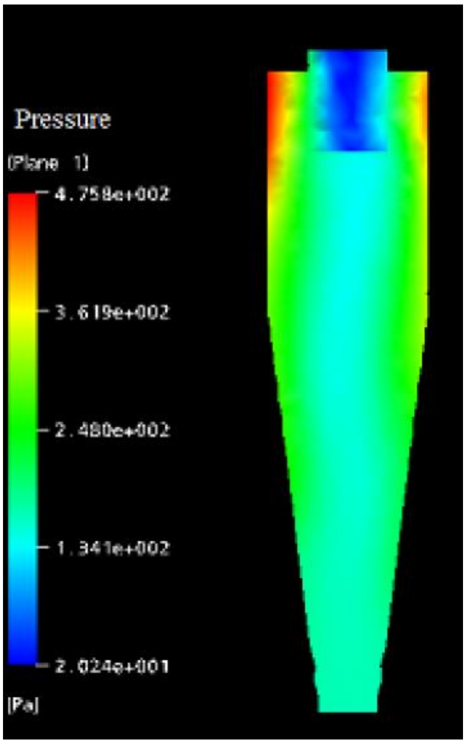
Result of Validation

In order to validate the numerical result, the result was compared with the result as given in the literature (Niki Gopani and Akshey Bhargava, 2011). The present simulation is compared with the measured pressure drop through the cyclone having Dc 0.3 m and inlet velocity 15 m/s.

Table 1: Comparison of Pressure Drop

Performance Parameter	Literature Result	Computational Fluid Dynamics (CFD) Result
Pressure Drop (Pa)	480	455

Figure 3: Pressure Distribution Contour Plot of Cyclone Having Dc 0.3 m

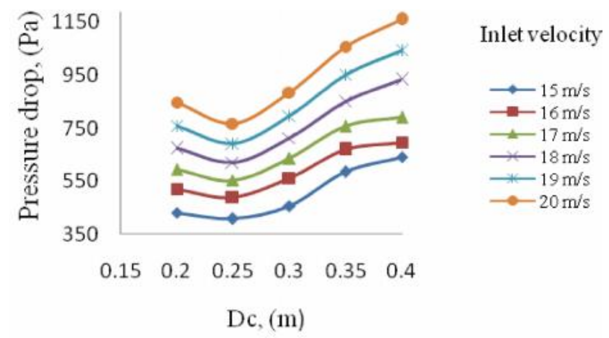


RESULTS AND DISCUSSION

Prediction of cyclone Pressure Drop

The pressure drop across the cyclone is a significant variable since it is directly related

Figure 4: Prediction of Pressure Drop



to the operating cost. Prediction of the pressure drop of cyclone with a five cyclone models was carried out for inlet velocity ranging from 15 to 20 m/s using CFD.

CONCLUSION

The simulation was carried out for five cyclone models having Dc 0.203 m, 0.25 m, 0.3 m, 0.35 m, 0.4 m at different inlet velocity. The low pressure drop values areobtained for cyclone separator model having Dc 0.25 m. From the simulation it was observed that the pressure drop varies with changing theinlet velocity.

REFERENCES

1. Faulkner W B and Shaw B W (2006), "Efficiency and Pressure Drop of Cyclones Across A Range of Inlet Velocities", American Society of Agricultural and Biological Engineers, ISSN: 0883-8542.

2. Iozia D L and Leith (1990), "The Logistic Function and Cyclone Fractional Efficiency", *Aerosol. Sci. Technol.*, Vol. 12, p. 598.

3. Jolius Gimbun, Chuah T G, Fakhru'l-Razi A and Thomas S Y Choong (2004a), "The Influence of Temperature and Inlet Velocity

on Cyclone Pressure Drop: A CFD Study", Chemical Engineering and Processing.

4. Jolius Gimbun, Thomas S Y Choong, Fakhru'l-razi A and Chuah T G (2004b), "Prediction of the Effect of Dimension, Particle Density, Temperature, and Inlet Velocity on the Cyclone Collection Efficiency", *Chemical Engineering and Processing*.
5. Khairy Elsayed and Chris Lacor (2010), "Numerical Study on the Effect of Cyclone Inlet Height on the Flow Pattern and Performance", Proceedings of ICFD 10: Tenth International Congress of Fluid Dynamics.
6. Koch W H and Licht W (1977), "New Design Approach Boosts Cyclone Efficiency", *Chem. Engineering*, Vol. 17, p. 80.
7. Lapple C E (1951), "Process Uses Many Collector Types", *Chem. Eng.*, Vol. 58, p. 144.
8. Li Enliang and Wang Yingmin (1989), "A New Collection Theory of Cyclone Separator", *A.I.Ch.E.J.*, Vol. 35, p. 666.
9. Niki Gopani and Akshey Bhargava (2011), "Design of High Efficiency Cyclone for Tiny CementIndustry", *International Journal of Environmental Science and Development*, Vol. 2, No. 5.
10. Singh V, Srivastava S, Chaval R, Vitankar V, Basu B and Agrawal M C (2006), "Simulation of Gas-Solid Flow and Design Modificatins of Cement Plant Cyclones", 5th International Conference on CFD in the Process Industries CSIRO, Melbourne, Australia.
11. Wang L, Parnell C B, Shaw B W and Lacey R E (2006), "A Theoretical Approach for Predicting Number of Turns and Cyclone Pressure Drop", ASABE.

APPENDIX

Nomenclature
C_D: Drag coefficient
d: Particle diameter
U: Velocity
u_i: Velocity component
v_p: Particle velocity
°: Gas density
t: Time
μ: Viscosity of fluid
Dc: Diameter of cyclone