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CFD ANALYSIS OF EFFICIENCY AND PRESSURE DROP IN A GAS-SOLID SQUARE CYCLONES SEPARATOR NOVI SYLVIA1*, YUNARDI2, ELWINA3, WUSNAH1, YAZID BINDAR4 1Chemical Engineering Dept., University of Malikussaleh, Lhokseumawe, Indonesia *Email: nxsylvia@gmail.com 2Chemical Engineering Dept, Syiah Kuala University, Banda Aceh, Indonesia 3Chemical Engineering Dept.,

State Polytechnics of Lhokseumawe, Lhokseumawe, Indonesia 4Energy and Processing System of Chemical Engineering Dept., Faculty of Industrial Technology, Bandung Institute of Technology, Bandung, Indonesia. Abstract. In this paper, there is a numerical comparison of two small cyclones with the same hydraulic diameter and volume, one of which is square and the other is round (Lapple tornado). A GAMBIT preprocessor software was used to set up the cyclone's setup, control, and boundary conditions.

The characteristics of the observed cyclone were 0.2 m in diameter, obtaining a gas flow rate of 0.1 m3/s with a particle mass loading of 0.01 kg/s. A commercial CFD code Fluent 6.2.16 was used for simulation of the cyclone's flow field and particle dynamics. The averaged Reynolds Navier – Stokes equations with the Reynolds Stress Turbulence Model (RSTM) are solved using the finite volume method based on the computational domain's SIMPLE pressure correction algorithm. The statistical Eulerian – Lagrangian method is used to predict monitoring of particles in the cyclones.

Using the Discrete Random Walk (DRW), the velocity fluctuations are simulated. Results show that square cyclone collection efficiency is better with increasing flow rate than round cyclone. In square cyclone the pressure drop is higher than in small round one.

Keywords: square cyclone; round cyclone; CFD; efficiency and pressure drop

Introduction Cyclones are are one of the most well-known equipment used in industrial processes to control the dust emissions from gaseous flow. Although current developments in engineering have made it possible , for example, to use cyclone as dryers and reactors, their fundamental application stays in the field of air contamination control, where high efficiencies are required to comply with the stringent regulations.

Compared to other air pollution control devices, cyclones are more desirable due to their design simplicity, manufacturing inexpensiveness, low maintenance costs, and adaptability to a wide scope of working conditions, for example, high temperature and pressure. Although they are often used as definite authorities for the removal of large particles, it was also common practice to use cyclones as pre-cleaners for a more effective gatherer, for example, an electrostatic precipitator, scrubber or fabric filter (Swamee, 2009).

A cyclone has four main components, the inlet, the cyclone core, the dust discharge system and the outlet all influence the cyclone's overall performance. The cyclone separation theory is simple: the gas – solid mixture flow is directed through the inlet at the top section into the cyclone. The cylindrical body then causes a spin, driving particulate matter to the cylinder wall.

The gas continues to the cone down the cyclone body which gives the gas ample rotational velocity to hold the particles against the wall. The gas changes course from downward to upward at the bottom of the pipe. The ascending vortex enters a tube extension sometimes referred to as a vortex finder, and exits the cyclone.

Meanwhile the particulate matter collected falls into a hopper, where it is drained regularly or continuously. A cyclone 's main performance is judged primarily from its gathering efficiency and drop in pressure. Despite its simple design and operation, the stream conduct and molecule elements inside the cyclone are confounded, requiring exact numerical models to give exact productivity and pressure drop predictions for the design and operation of a cyclone.

Many researchers have developed numerous semi-empirical models which lead to the predictions of assortment proficiency and pressure drop. Some of these models were summarized by Leith (1990), among them those developed by Stairmand (1951), Barth (1956), Shepherd and Lapple (1939), Lapple (1951), Leith and Licht (1972).

The Proceedings of The 4th Annual International Conference Syiah Kuala University (AIC Unsyiah) 2014 In conjunction with The 9th Annual International Workshop and Expo on Sumatran Tsunami Disaster and Recovery – AIWEST-DR 2014 October 22-24, 2014, Banda Aceh, Indonesia While most empirical models were developed based on the experimental data of real cyclone geometry, the use of different assumptions and geometry conditions is evidence of a significant error between the forecast and measured data in the cyclone performance. Consequently, the use of semi-empirical models has a drawback in cyclone intensity prediction.

Therefore, computational methods are proposed to model the flow field and particle dynamics of these devices in order to predict the efficiency of collection and the decrease in pressure. Following the first simulated cyclone simulation using computational fluid dynamics (CFD) technique (Boysan et al, 1982), a number of CFD modeling works were conducted on the cyclone performances.

Elsayed and Lacor (2010) optimized the geometry of the cyclone with the goal of obtaining minimum pressure drop with the aid of methodology of the response sheet. They used the Reynolds Stress Model to represent the flow field within the cyclone and the outcomes indicated that the most significant mathematical boundaries are the distance across of the vortex finder, the width of the inlet section, the tallness of the inlet section and the total height of the cyclone.

Shafikhani et al (2011) analyzes the numerical comparison of two small cyclones of the same hydraulic diameter, one of which is square, and the other is round. Obtaining results regarding pressure drop in small square cyclones is less than the pressure drop in small round ones and this difference is differentiated with increased flow rate, but collection efficiency of small square cyclone is less than round one, but this difference decreases by increasing flow rate.

In this paper, the characteristics of two small cyclones with the same hydraulic diameter and length, one of which is square and one of which is round (Lapple cyclone), are compared numerically. The goal of this paper is to present the performance cyclone evaluation results regarding efficiency and pressure drop. Turbulence Models Description Turbulence theory, simulation and modeling have often been important subjects of fluid dynamics and engineering, explanations of different approaches to turbulence can be found in various textbooks on computational fluid dynamics.

Any technique of modeling requires a number of concise equations whose solution must be obtained numerically. In general, three major classes of numerical simulations are currently being developed with regard to turbulence prediction alone: I direct numerical simulation (DNS); (ii) large eddy simulation (LES); and (iii) Reynolds averaged Navier-Stokes (RANS) approaches.

The turbulent flow DNS basically requires a complete numerical solution of the time-dependent Navier-Stokes equations, and accommodates turbulence scales of all times and lengths. It is essentially the easiest method to implement from a conceptual point of view, since no simulation of turbulence is necessary. In DNS, all turbulent motions are resolved from the largest scale to the smallest scale of turbulent eddy, in the computational model.

Consequently, the computational domain should be sufficiently large to accommodate the largest eddies, and the grid spacing should be good enough to solve the smallest eddies. Therefore, simulating even the simplest forms of flow (e.g. homogeneous turbulence) is extremely costly, largely due to the complex grid needed to overcome the small-scale turbulence structures, as well as the limited time-steps necessary for the time-scales of smallest eddies.

In the Reynolds-averaged Navier- Stokes (RANS) method, solutions are obtained by solving time-averaged transport equations, instead of explicitly solving for the turbulence region. The method models all scales and solves the time-averaged equations governing which introduces apparent unknown stresses known as the stresses of Reynolds.

It introduces a second-order tensor of unknowns, for which various models can have various closure rates. Essentially, two distinct types of RANS models were developed: closure models for the first moment and closure models for the second one. In the former, the stresses of the unknown Reynolds are minimized by first-moment correlation.

The second- moment conclusion models estimated the higher-request minutes (i.e., the triple fluctuating speed connections) by second- moment terms, and explicitly settle transport conditions for stresses from Reynolds. 9

The Proceedings of The 4th Annual International Conference Syiah Kuala University (AIC Unsyiah) 2014 In conjunction with The 9th Annual International Workshop and Expo on Sumatran Tsunami Disaster and Recovery – AIWEST-DR 2014 October 22-24, 2014, Banda Aceh, Indonesia Numerical Computation All transport equations shown in the above definition of the turbulence model are solved numerically using a commercial CFD code, Fluent 6.2.16 (Fluent Inc., 2005).

Approach to volume regulation was used to discrete the equations of transport. For turbulent kinetic energy and momentum equations, respectively, the SIMPLE calculation was used to solve pressure-velocity coupling and first order and second order interpolation schemes. It was believed that flows within the cyclone are in steady state.

The numerical calculation for the whole flow field parameters was performed with a precision of 10-3. Computational Domain and Boundary Conditions Fig. 1 illustrates a square cyclone, having a diameter, D of 0.2 m employed in this study with the ratio of geometric parameters is shown in Table 1, where W inlet width, H inlet height, De outlet diameter, S outlet height, Lb cylinder height, Lc cone height and Dd dust outlet diameter. On Fig. 1, the cyclone geometry drawn using GAMBIT code was set up with boundary conditions.

Information on material data for the cyclone computation is presented in Table 2. It should be noted here that these data are similar to the experimental data presented Wang et al (2005) Table 1. Cyclone geometry used in this study (D=0.2 m) _a/D _b/D _De/D _S/D _h/D _H/D _B/D _ _ _ _ _ _ _ _ _ _ _ _0.25 _0.5 _0.5 _0.625 _2.0 _4.0 _0.25 _ _ _ _ _ _ _ _ _ _Table 2 Material data used as input of the cyclone calculation _ _ _ _ _ _Temperature of _air flow _ _25 0C _ _ _ _ _ _ _ _ _ _ _ _ _ _Min.

diameter of particle _ _5 μm _ _ _ _ _ _Max. diameter _of particle _ _200 μm _ _ _ _ _ _Mean diameter _of particle _ _29.90 μm _ _ _ _ _ _Spread parameter _ _0.806 _ _ _ _ _ _Ash density _ _ _3320 kg/m3 _ _ _ _ _ _Air density _ _ _1.225 kg/m3 _ _ _ _ Flow field Calculation and Validation Flow field computation was done with Reynold Stress Turbulence Model (RSTM) using FLUENT 6.2.16.

Computing was achieved using a 4.00 GB RAM laptop computer with 32 bit operating system. The predictions were confirmed by comparison with the experimental data reported by Wang et al (2005) who used a cyclone in Lapple. Experimental tests in the forms of output and decreased pressure were provided. Prediction and Validation of efficiency and pressure drop in the Cyclone Fig.

2 shows a contrast between expected performance and experimental results. Both

experimental data and predictions show that they are significantly below the experimental knowledge. Cyclone performance as speed rise. For this analysis, the performance shown by the square cyclone for effectiveness prediction is higher than that of the Lapple cyclone (Wang experiment).

Though in the round cyclone the predictions of efficiency follow the pattern of experimental results. Output shown in the above research is highly dependent on flow rate and the round cyclone has more output than square one at any flow rate. This question is less seen at lower flow levels and a square cyclone may be a safer option at high flow rates, due to less pressure drop of square cyclone.

_ _ _The Proceedings of The 4th Annual International Conference Syiah Kuala University (AIC Unsyiah) 2014 _ _ _ _In conjunction with The 9th Annual International Workshop and Expo on Sumatran Tsunami Disaster and Recovery – AIWEST-DR 2014 _ _ _100 _ _October 22-24, 2014, Banda Aceh, Indonesia _ _ _ _ _ _ _ _98 _ _ _ _ _96 _ _ _ _ _94 _ _ _ _% _92 _ _ _ _Efficiency, _ _ _ _ _ _90 _ _ _ _ _88 _ _ _ _ _86 _ _ _ _ _ _ _ _ _ _84 _ _ _ _ _82 _ _ _ _ _80 _(a) _(b) _ _ _ _ _ _ _ 5 _10 _15 _20 _25 _ _ _Figure 1. Cyclone geometry used in this study.

(a) round cyclone; (b) square cyclone _ _Velocity, m/s _100 _ _ _ _ _ _ _98 _ _ _ _ _ _ _96 _ _ _ _ _ _ _94 _ _ _ _ _ _% _92 _ _ _ _ _ _Efficiency, _ _ _ _ _ _ _ _90 _ _ _ _ _ _ _88 _ _ _ _ _ _ _86 _ _ _ _ _ _ _ _ _ _ _ _ _ _ _84 _ _ _ _ _ _ _82 _ _ _ _ _ _ _80 _ _ _ _ _ _ _5 _10 _15 _20 _25 _ _ Velocity, m/s Fig. 2. Comparison between efficiency predictions and experimental data (symbols: experimental data; line: results predictions - round cyclone; - - square cyclone) _12000 _ _ _ _ _ _Pa _10000 _ _ _ _ _ _ _ _ _ _ _ _ _ _drop, _8000 _ _ _ _ _ _ _ _ _ _ _ _ _ _Pressure _6000 _ _ _ _ _ _ _4000 _ _ _ _ _ _ _2000 _ _ _ _ _ _ _0 _ _ _ _ _ _ _5 _10 _15 _20 _25 _ _ Velocity, m/s Fig. 3.

Comparison between pressure drop predictions and experimental data (symbols: experimental data; line: results predictions - round cyclone; - - square cyclone) Figure 3 presents a comparison of pressure drop predictions by round and square cyclones with experimental data. The results shown that there was no significant differences among predictions of round and square cyclones but round cyclone is the less pressure drop than square cyclone. Conclusions Results obtained show that CFD is a efficient instrument for studying cyclone flow Round cyclone is the less pressure drop than square cyclone.

Output shown in the above research is highly dependent on flow rate and the round cyclone has more output than square one at any flow rate. 11

Square cyclone collection performance is higher with increased flow rate than the round cyclone. Because of the same length, the other parameters such as square cyclone optimisation may be used to compare the characteristics of round and square cyclones for future studies.

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