A Comparative Study Between Turbulence Model RSM Results of a Dual Inlet Cyclone Separator and K-Epsilon RNG Turbulence Model

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Abstract In this work, a dual inlet cyclone separator's Numerical result (RSM turbulence model) is contrasted with current numerical analysis (K-ε RNG turbulence model). K-ε RNG turbulance model result. The research evalute the results of Wang et al.'s (Chem Eng Process Intensification 158:108188, [2]) dual intake cyclone separator (known as 90° DI Cyclone) with a 7, 10, and 12 μm particle diameter and inlet velocity 15.5 m/s. The main topic of the findings and debate is the dual inlet cyclone separator's separation effectiveness. The result shows that average deviation between these two results is 1.25%. At particle diameter 7,10 and 12 the particle collection efficiency of Wang et al. was 88.81%, 98.32%, and 99.5% where in current result it is 90.32%, 100%, and 100%.

Keywords Cyclone separator · CFD · Dual inlet

1 Introduction

Cyclone separators play a vital role in numerous industries, employing their low cost, simplistic design, and impressive efficiency to separate solid particles from gas or liquid streams [1]. Cyclone separator simulation involves complex fluid flow, and

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a suita-ble turbulence is required to accurately capture the flow behavior inside the cy-clone separator geometry. There are few turbulence models which have been proved to provide accurate prediction of the performance, RSM and K-ε RNG are one of them. The Reynolds Stress Model (RSM) directly solves for Reynolds stresses, capturing complex turbulence characteristics like anisotropy, suitable for flows with strong pressure gradients or swirling motions. In contrast, the k-ε RNG (Re-Normalization Group) model is an enhanced version of the k-ε model which utilizes re-normalization group theory to improve predictions in adverse pressure gradient or highly curved flows. Both models are pivotal in Computational Fluid Dynamics (CFD), with RSM being computationally expensive due to solving additional transport equations, while k-ε RNG strikes a balance between accuracy and computational cost.

2 Material and Method

With reference to a 90 degree dual inlet cyclone separator 330mm diameter vortex finder with different particle sizes have been numerically analyzed. The objective of this work is to compare the numerical results of Wang et al. [2] with turbulence model k-ε RNG. Table 1 lists the specifications of the cyclone separator utilized in the numerical simulation. The geometry in Fig. 1 shows all the dimensions mentioned in Table 1 and defines all the inlet, outlet, particle trap surfaces, and meshed geometry of the analysis.

In the numerical analysis of cyclone separators, the separation efficiency is calculated differently compared to the traditional definition based on the mass of particles separated from the injected mass. In numerical analysis, it can be calculated by the following formula:

Table 1 Dimensions of the cyclone separator [2]

Geometry	Dimension
Barrel diameter, D/mm	900
Vortex finder diameter, De/mm	330
Vortex finder length, S/mm	419
Inlet height, a/mm	419
Inlet weight, b/mm	176
Barrel height, h/mm	1638
Cone height, He/mm	1620
Cone bottom diameter, Dc/mm	360
Bin diameter, Be/mm	630
Dipleg diameter, Hd/mm	156
Dipleg length, Hd/mm	800
h1/mm, h2/mm, h3/mm	250.750,700

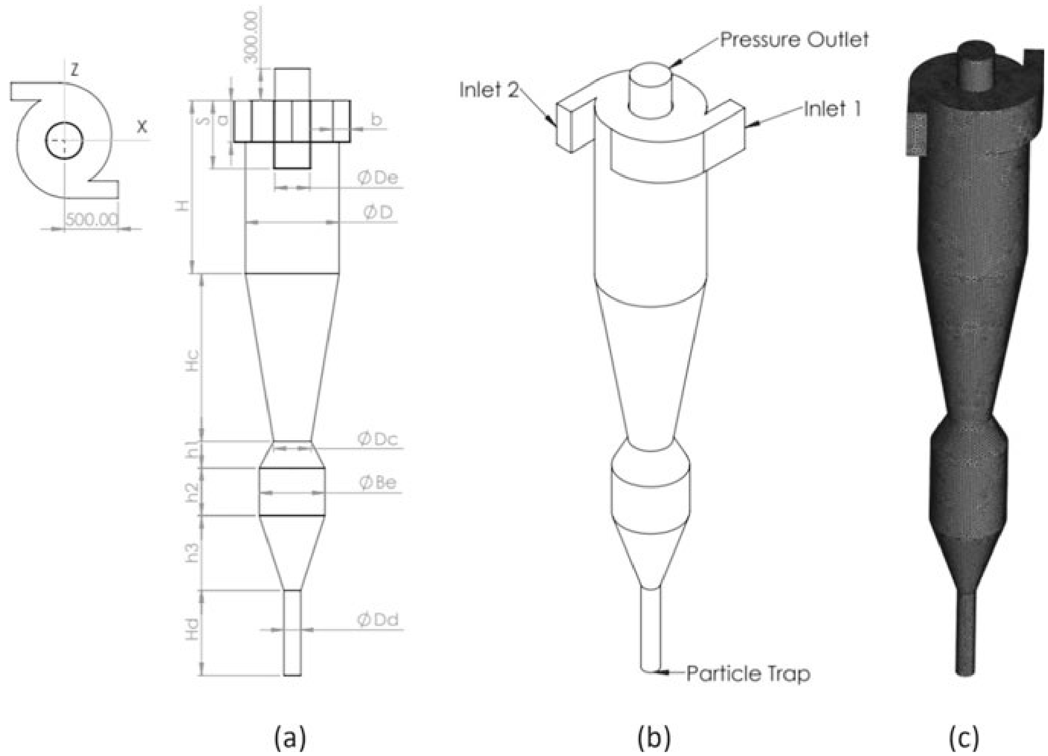

Fig. 1 Geometry with **a** dimensions and **b** boundary conditions and **c** meshed geometry

Separation efficiency (%):

$$\frac{\text{Number of particle trapped}}{(\text{Number of particle injected} - \text{Incomplete particles})} \times 100\% \tag{1}$$

Computational fluid dynamics (CFD) tool ANSYS 23 R1 has been used to analyze the discrete particle phase model, which is well known, to carry out numerical study. The study investigates three different partcile sizes 7, 10, and 12 μm to evalute the performance of the 90° DI cyclone at 15.5 m/s inlet velocity. The simulations used a particle density of 2700 kg/m^3, a particle concentration of 15 g/m^3, and hydraulic diameter 0.2476.

In this study, the simulation uses coupled scheme for pressure-velocity coupling and second-order upwind discretization scheme to precisely predict the turbulent kinetic energy, viscous dissipation rate, and moments. Strong gradients and discontinuities are captured by the second-order upwind technique by considering flow direction and neighboring cell information. The study is limited to steady-state conditions with a turbulence intensity of 3.36%, which represents the proportional level of turbulent fluctuations. Figure 2 shows the grid independence test result, which was conducted to determine the optimal mesh size and the results converged at an element size of 27 mm, with a total of 440281 elements.

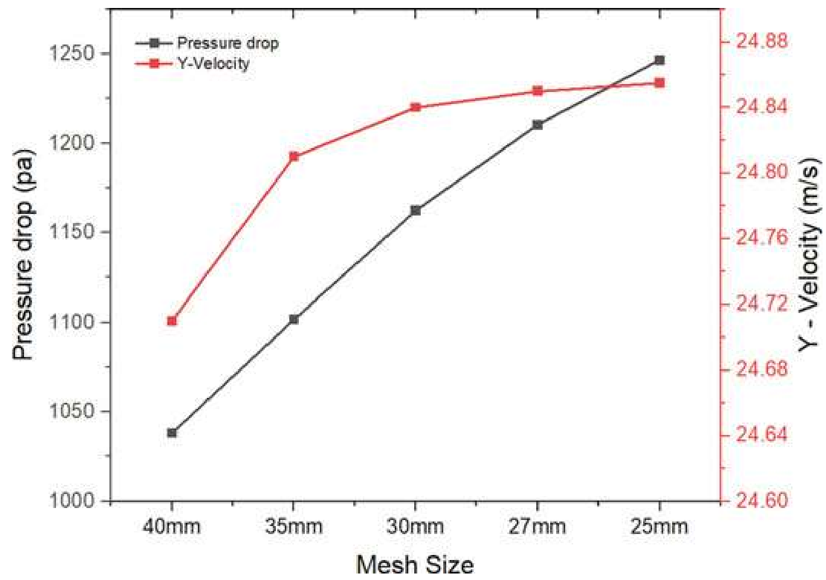

Fig. 2 Grid independency test

3 Result and Discussion

Based on experimental findings given by Wang et al. [2] and numerical analysis performed using ANSYS 23 R1 software, the separation efficiency of the dual inlet cyclone separator was assessed. The average difference between the experimental and numerical analysis for 7 μm, 10 μm, and 12 μm is 1.5%, 1.7%, and 0.5% respectively, as shown in Fig. 3. The numerical result shows that by increasing the particle diameter there is a slight increase in collection efficiency, which supports the previous numerical analysis.

From experiment analysis, the increase in particle diameter to 7 μm to 10 μm and 10 μm to 12 μm, the efficiency increased 9.7% and achieved 100% collection efficiency 0% respectively. The wang et al.'s numerical analysis also captured the same phenomenon where the increased difference found is 9.5 and 1.17%. These results suggest that there are fewer particles being carried out outside with increasing particle diameter.

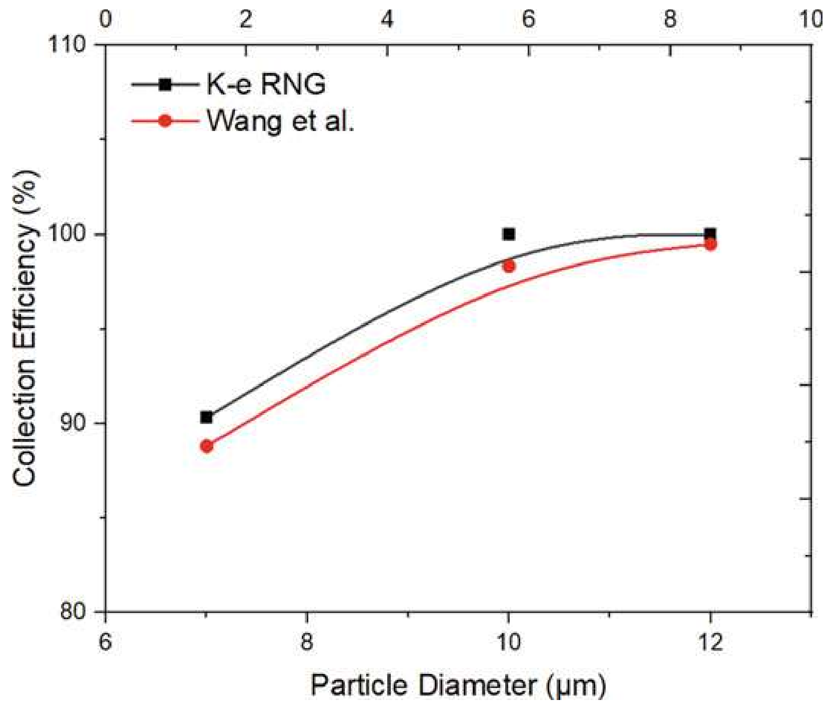

Fig. 3 Comparison between Want el al.'s numerical result and current numerical data (Particle diameter versus separation efficiency)

4 Conclusion

This study presents a comparison between turbulence RSM and K-ε RNG using ANSYS fluent 2023 R1 software to investigate the performace of a dual inlet cyclone separator. The numerical results indicate that the large particles more than 7 can be easily collected from air or gas.

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