EXPERIMENTAL STUDY OF PARTICLE SIZE EFFECT ON SEPARATION EFFICIENCY OF DUAL CYCLONE SEPARATOR

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ABSTRACT: A cyclone separator is a device for separating solid particles and fluids. In this study, the performance of a cyclone separator was enhanced by adding a smaller cyclone. The objective is to separate coconut shell powder particles and determine the efficiency of the dual cyclone separator. The experiment involved varying the inlet airflow velocity to 7 m/s, 10 m/s, and 15 m/s and using different coconut shell powder particle sizes, ranging from mesh numbers 80 to 120. The results of the experiment showed that the efficiency of particle separation was significantly influenced by both the particle size and air velocity. Higher air velocity and larger particle size resulted in greater separation efficiency. The best performance was observed with the mesh particle size of 80 at an air velocity of 15 m/s, which achieved an efficiency value of 98.33%. The experiment also measured the particles' precipitated and wasted mass.

KEY WORDS: Cyclone Separator, Particle Size, Velocity, Particle Separation Efficiency

1. INTRODUCTION

In many industrial processes, separating solid particles from fluids is a crucial operation affecting product quality and process efficiency. Cyclone separators are widely used in various industries such as chemical, petrochemical, food, and pharmaceuticals to remove solid particles from fluids [1]. However, the separation efficiency of cyclone separators is influenced by various factors such as particle size, inlet air velocity, cyclone geometry, and particle concentration.

Cyclone separators create a swirling flow inside a cylindrical chamber, which causes the particles to be thrown outward due to centrifugal force [2]. The gas flow, which contains solid particles, undergoes a centrifugal force that pushes it toward the wall of the cyclone separator, causing it to move radially outward. From there, the gas follows a downward path along the cylindrical and conical walls, ultimately reaching the bottom of the cyclone and exiting through the solid particle outlet. On the other hand, the cleaned gas swirls upward in the center of the cyclone and exits through a vortex finder at the top of the separator [3].

In recent times, researchers have focused their attention on improving the efficiency of cyclone separators by modifying their geometries. There have been efforts to enhance the performance of cyclones by improving the design of the input section [4], conical section [5], cylinder height [6], and the impact of geometric modifications on their overall performance [7]. Another report shows the effect of the length and shape of the outlet duct on performance [8].

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Despite the widespread and successful use of aerodynamic cyclone separators in gas-particle separation and classification within particle science and technology, specific challenging issues persist, particularly in characterizing their separation performance [9-11]. Generally, two indicators are used as cyclone separators' performance criteria: particle cutoff size and grade separation efficiency [12]. Particle cutoff size refers to the aerodynamic diameter of particles in a gas stream that is separated with 50% efficiency by a cyclone separator. In other words, it is the size of the smallest particle that the cyclone can effectively remove, cyclone size is a crucial parameter for evaluating the performance of a cyclone, as it determines the size range of particles that can be removed efficiently. The particle cutoff size of a cyclone can be affected by several factors, including the geometry of the cycloneelocity of the gas stream, and the physical properties of the particles being separated.

A lower particle cutoff indicates a higher separation efficiency of the cyclone separator and, hence, a higher yield of the desired product. Therefore, it is essential to determine the particle cutoff size for a given cyclone design and operating conditions; this can be done experimentally by measuring the particle size distribution of the inlet and outlet gas streams and then determining the aerodynamic diameter of particles separated with 50% efficiency (D50).

The D50 cut point is an essential characteristic for describing cyclone separators in terms of their particle size separation performance. However, the performance of cyclone separators depends not only on the D50 cut point but also on their operating parameters, such as flow rate, as well as their structural design and material properties [12]. Developers of particle monitoring systems must consider these factors to ensure accurate particle detection and quantification. Ignoring these characteristics may lead to inaccurate results and misinterpretation of the data.

Therefore, understanding the influence of operating parameters, structural design, and material properties on cyclone performance is critical for developing reliable and accurate particle monitoring systems. The objective is to separate coconut shell powder particles and to determine the efficiency of a low-cost dual cyclone separator system.

2. METHOD

The experimental study utilized the Dual Cyclone Separator system with a unique geometry that employs two cyclones in series, as presented in Figure 1, with the outlet of the first cyclone to the inlet of the second cyclone used as the source of air for the system. Three different particle sizes were used in the experiments, including 80,100,120 grit mesh of coconut shell powder particles, and varying inlet air velocities of 7 m/s, 10 m/s, and 15 m/s were applied. The air velocity was measured using a digital anemometer, and the blower adjustment was used to regulate the air velocity.

The 150 grams of sieved particles were loaded into the particle-feeding vibrator container to experiment. The particles were then flown into the first cyclone, a connecting pipe, where the first separation occurred, and the collected particles were directed downwards towards the dustbin. The airflow continued into the second cyclone The first cyclone connected to the second cyclone's Separation then occurred again in the second cyclone separated particles pointed downwards towards the dustbin, resulting in a mass of collected particles. The same steps were repeated for different inlet flow speeds.

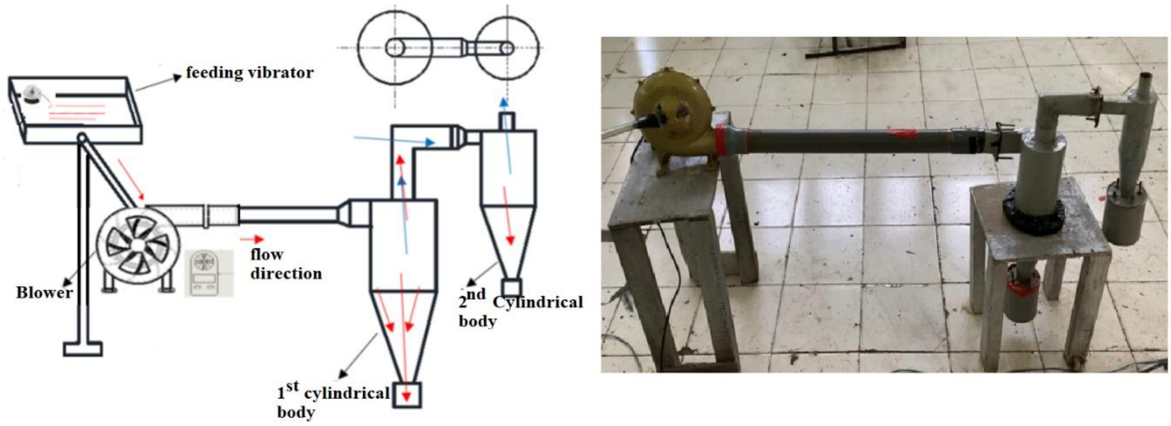

Fig. 1. Schematic and pictorial view of experimental setup

3. RESULTS AND DISCUSSION

The experimental data is displayed in Table 1.

Table 1: Experimental data

Mesh	Velocity (m/s)	Mass (g)			
		1st Cyclone	2nd Cyclone	cycloneloss	Final
80	7	145.9	0.15	3.95	146.05
	10	146.05	0.10	3.85	146.15
	15	147.44	0.06	2.50	147.50
100	7	142.40	0.30	7.30	142.70
	10	144.10	0.20	5.70	144.30
	15	145.57	0.13	4.30	145.70
120	7	141.50	0.40	8.10	141.90
	10	142.10	0.30	7.60	142.40
	15	142.80	0.20	7.00	143.00

The effect of particle mesh size and velocity on efficiency during the experiment is depicted in Figure 2. The efficiency of the dual cyclone separator was measured in percentage, and the results show that the efficiency increased with an increase in the airflow velocity. For instance, at a mesh size 80, the efficiency increased from 97.37% at 7 m/s to 98.33% at 15 m/s. Similarly, at a mesh size of 100, the efficiency increased from 95.13% at 7 m/s to 97.13% at 15 m/s. The same trend was observed for a mesh size of 120.

It is worth noting that the efficiency was also affected by the particle mesh size. At a constant airflow velocity, the efficiency decreased as the particle mesh size increased. For instance, at an airflow velocity of 7 m/s, the efficiency decreased from 97.37% for a mesh size of 80 to 94.6% for a mesh size of 120. The same trend was observed at airflow velocities of 10 m/s and 15 m/s.

The data suggests that particle mesh size and air flow velocity significantly affect the efficiency of the dual cyclone separator. Therefore, it is essential to optimize these parameters to achieve the desired level of efficiency. Additionally, it is important to note that the results obtained in this experiment may not apply to other types of cyclone separators or different operating conditions.

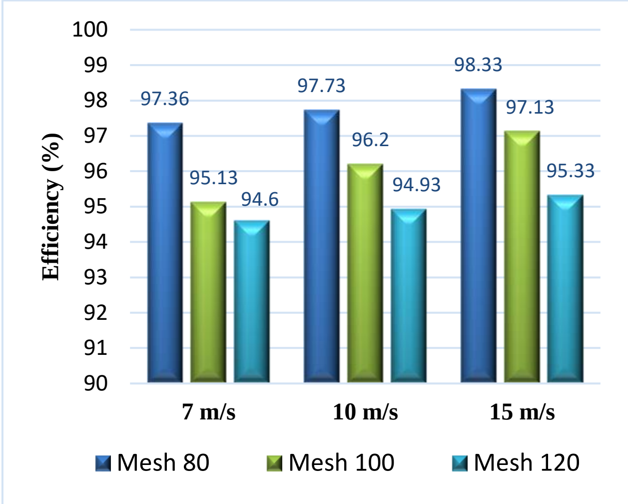

Fig. 2. Effect particle mesh size and velocity on efficiency

According to centrifugal force, the particles tend to move towards the wall and away from the center of rotation in a cyclone separator due to the large centrifugal force; this causes a significant loss of energy due to friction on the wall, which results in the particles eventually falling into the dustbin [13]. When the inflow velocity is high, it affects the particles so that the kinetic energy is greater, leading to frequent collisions between particles. These collisions facilitate particle interaction, which can form agglomerates or clumps of larger sizes.

The effect of particle mesh size and velocity on settled mass is depicted in Figure 3. The highest settled mass was observed with a mesh size of 120 and an inlet velocity of 7 m/s, with a settled mass of 6.8 grams. The second-highest settled mass was observed with a mesh size of 100 and an inlet velocity of 7 m/s, with a settled mass of 5.1 grams. In general, it seems that higher mesh sizes and lower inlet velocities result in higher settled masses. The settled mass generally decreases as the inlet velocity increases, indicating that higher velocities lead to fewer particles settling; this can be explained by the fact that higher velocities cause more turbulence and mixing, which prevents particles from settling out.

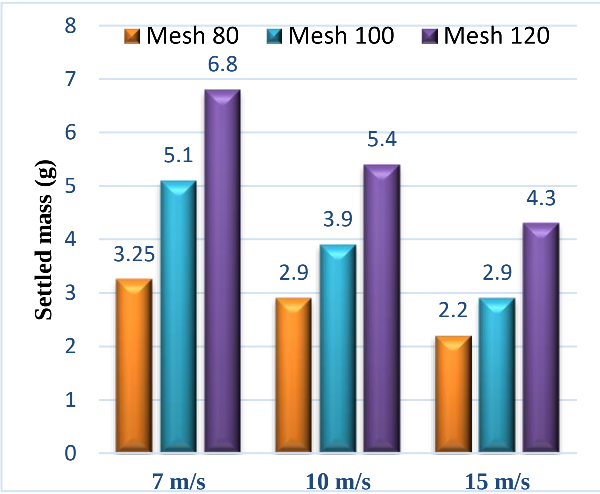

Fig. 3. Effect particle mesh size and velocity on settled mass

Regarding the effect of particle size on settled mass at different velocities, it can be expected that larger particles will settle more easily than smaller particles due to their greater mass and inertia. At lower velocities, this effect may be more pronounced, as the air's kinetic energy is insufficient to keep the larger particles suspended in the air stream. However, as the velocity increases, the kinetic energy of the air will be sufficient to keep larger particles in suspension, resulting in a decrease in settled mass. Therefore, the effect of particle size on settled mass is expected to depend on the air velocity, with larger particles settling more easily at lower velocities and smaller particles settling more easily at higher velocities.

The effect of particle mesh size and velocity on loss mass is depicted in Figure 4. It can be seen in the data, a smaller mesh size (larger particles) generally results in a higher loss mass. The highest loss mass was observed with a mesh size of 100 at 2.2 g for a velocity of 7 m/s compared to a 1.4-gram mass loss at 15 m/s. In comparison, the lowest loss mass was observed with a mesh size of 80 at 0.7 g; this may be because larger particles have more mass and momentum, making them harder to separate from the gas stream in the Cyclonecyclone consider the effect of inlet velocity, as the velocity increases, the loss mass generally increases as well; this may be because higher velocities lead to more turbulence and stronger centrifugal forces, which can make it more difficult to separate the particles from the gas stream.

The experimental data also showed that the lowest loss mass was observed at a particle size of mesh 80 and a velocity of 15 m/s. However, as the particle size decreased, the loss mass increased; this may be due to the greater displacement between particles caused by an increase in inlet velocity, resulting in more collisions and particle reflections. As a result, particles may be carried by the upward airflow towards the outlet of the cyclone separator [14].

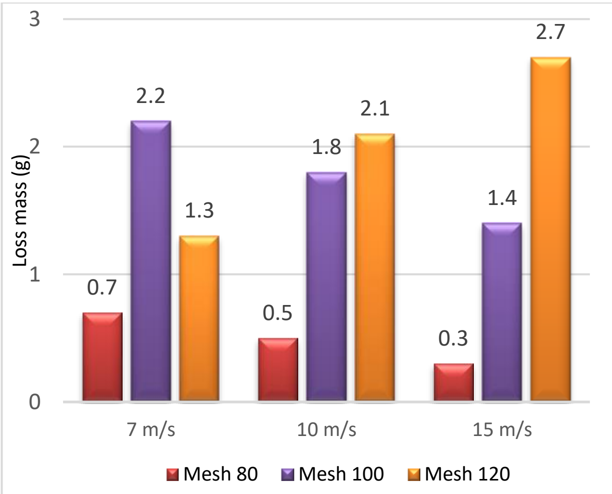

Fig. 4. Effect particle mesh size and velocity on loss mass

4. CONCLUSION

In light of the research findings, it can be inferred that the base conclusion is that the mass of particles collected increases with greater incoming air flow velocity and particle size. In contrast, the mass of wasted particles decreases. Additionally, the highest sediment mass is observed at particle size (mesh 120) with a speed of 7 m/s, while the highest wasted mass occurs at particle size (mesh 120) with a speed of 15 m/s. Moreover, the efficiency of the dual cyclone separator exceeds 90%, with the highest efficiency observed at particle size (mesh 80) with a speed of 15 m/s, producing an efficiency value of 98.33%. The value was 94.6%, which is the lowest efficiency, and at a larger particle size (mesh 80) with a speed of 15 m/s, producing an efficiency value of 98.33%, which is the largest efficiency in this study.

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