Automatic Dust Collector for Construction sites

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***Abstract*—Previous research indicates a connection between the dimensions of the cyclone cone and particle separation efficiency. The efficiency will increase with modifications made to the cone's dimensions. However, adjusting diameters in accordance with varying particle sizes is impractical. This paper suggests a way to maximize a cyclone separator's separation efficiency without changing its dimensions. The method focuses into the relationship between particle diameter and input air flow speed rather than design modifications. The study evaluates flow characteristics and separation efficiency, making use of the Reynolds stress model (RSM) because of its higher accuracy in capturing pressure drop and vortex behavior. This work attempts to make a automatic system to match the inlet air flow speed in order to obtain improved separation efficiency and lower power usage.**

***Index Terms*—component, formatting, style, styling, insert**

I. Introduction

Industrial activities often involve various dust particles, posing significant health risks to workers. These dust particles, composed of materials like cement, gypsum, and metals, can become suspended in the air, leading to high concentrations in construction sites. Numerous studies have linked exposure to these dust particles with serious health consequences, including:

- Respiratory issues: Dust inhalation can irritate airways, leading to coughing, wheezing, and chronic lung diseases.[1]
- Cardiovascular diseases: Exposure can contribute to heart problems, increasing the risk of heart attacks and strokes.[1]
- Cancer: Certain dust types, like silica, are classified as carcinogens, raising the risk of cancer development.[1]

While the extent of health risks depends on the specific dust composition and particle size, the construction industry faces a particularly high burden due to the frequency and intensity of dust exposure. This is especially true in regions with a thriving construction sector, like Lar, Iran.[1]

This research undertakes a critical examination of two predominant dust collection methods that can be used in the construction sites:

- vacuum systems
- water spraying system
- static electric system

Past literature review shows the possibility of using a water spray for dust suppression. Liu [2] have wrote about the possibility of using a U-shaped spray device on a front boom-type roadheader for dust suppression in a metro tunnel. Again Liu [3] have wrote about the possibility of using a spray device during drilling and blasting construction in the metro tunnel. Swanson [4] have witten the possibility of using a water spray system for mining operation. By investigating these past literature it can be seen that water spray systems are best suited for outdoor scenarios. In this paper the main focus is about more on indoor construction scenarios. Therefore this paper focuses on building a efficient vacuum system for dust removal.

When using a vacuum system there are different techniques available for dust separation.

- Cyclone separation technology
- filter separation technology
- static electric separation technology

Onozuka [8] have described about a dust removal system using static electricity. This method uses complex electronic parts therefore it's difficult to maintain and repair a dust removal system. Filter system requires to continuesly changing the filters. Therefore it is efficient, durable and cost effective to use cyclone seperation technology. In this paper main focus is to build a efficient automatic system for dust removal in construction sites.

II. System Design

A. Main Components

Design contains six main components

1) Air inlet
2) cyclone separator
3) vacuum motor and filter protecting the motor
4) particle size and density sensor unit
5) power supply and control unit
6) air outlet

1) Air inlet: Flexible hose is used with the ability to hold the shape with various nozzles.

2) cyclone separator: In this paper main focus is this cyclone separator. Air is sucked in to the cyclone chamber using the vacuum motor. Dust particles are removed from the air by use of centrifugal, gravitational, and inertial forces. The dust mix air enters the chamber tangentially from the air inlet. Because of the shape of the cyclone chamber air is traveling in a circular motion closer to the walls of the

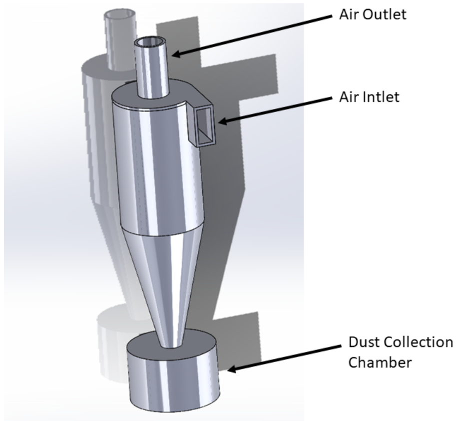

Fig. 1. An image of the cyclone separator

chambers. centrifugal force that is acting on dust particles is high comparing it on air particles. Due to that dust particles are pushing to the walls separating them from the air. Then the dust particles are sliding down and deposit in the deposition chamber. The filtered air stream comes up in the middle of the chamber because the chamber is air sealed and due to the suction of the vacuum motor. Then clean air is released from the outlet.

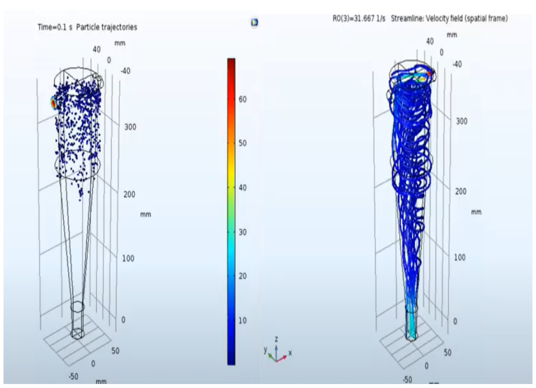

Fig. 2. An image of the cyclone separator simulation [5]

3) vacuum motor and filter protecting the motor: There are many suction motors available in the market. It is suggested to use a brush less DC as the vacuum motor. Because it is a more quite and efficient motor compared to other available motors in the market. Also any suction motor can be used according to the requirements. In the modeling process we have used a AC motor because of the wide availability of the motor. Before the air which went through the cyclone enter the motor a filter can be used to ensure no dust particles gets inside the motor. It will help to ensure the longevity of the motor.It is recommended to use a HEPA filter because it will theoretically filter out at least 99.97% of dust, pollen, mold, bacteria, and any airborne particles with a size of 0.3 microns (µm) [11]

4) particle size and density sensor unit: Using this unit it is possible to get a output varying with dust particle density in the air. This signal is used in the control unit to automatically switch on the the dust cleaner when particle density exceeds the limit of 10 μg/m^3 [9]. The used technology here is optical sensing of particles. Infrared or Laser light beam is used. There is a concave mirror placed under the light beam as shown in figure 3. When a dust particle goes through the light beam it scatters and scattered rays gets collected on a light detector. Pulses are used to get the particle count. Intensity corresponds to the particle size.[12]

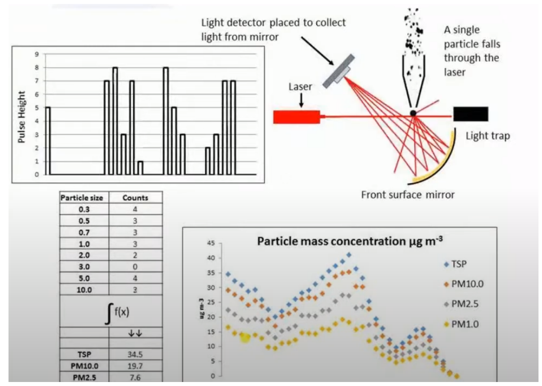

Fig. 3. An image of a optical dust sensor technology [12]

Fig. 4. An image of a sample dust sensor[13]

5) power supply and control unit: This system is designed to work in both manual and auto modes. When the machine works it will detect the amount of dust particles in the air using the data given by the sensor unit. Then it will change the motor speed accordingly to increase the electrical efficiency. The motor will supply the torque to the fan. If the system is manually turned on the motor will start running in lowest speed and then increase the speed according to the amount of dust particles in the air. If auto mode is on, it will check air sample in every 30 seconds. If the dust particle density is greater than 10µg/m3 [8], then machine will start running in lowest speed. After that it will run in the according speed. In this system required inlet wind speed is 10 m/s to 20 m/s. Therefore this system is built with motor with 5Hp.

6) air outlet: The air outlet is used to put out the purified air.

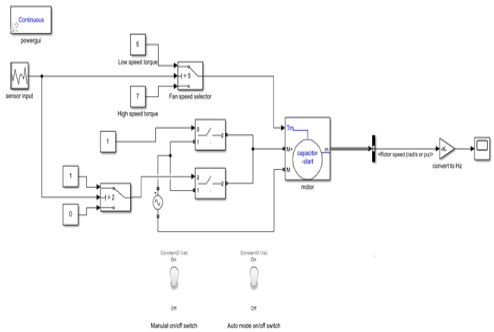

Fig. 5. An image of a power supply and control

III. System Overview

A. system flow

1) The suction hose collects dust particles from the construction site.
2) The dust-laden air enters the cyclone separator.
3) Centrifugal force separates dust particles from the air stream.
4) Dust particles are deposited in the chamber, while clean air flows upwards. Further fine dust particles are deposited in the HEPA filter before entering the suction motor.
5) The particle size sensor unit continuously monitors dust density in the air.
6) When the dust density exceeds a predefined threshold (e.g., 10 μg/m^3), the control unit automatically activates the system.
7) The vacuum motor creates suction, drawing air through the system.
8) Clean air exits the system through the air outlet.
9) Deposited dust particles can be removed periodically disassembling the dust collection chamber (Machine should be turned off manually before doing this)

Benefits:

- Improves air quality: Removes harmful dust particles from construction environments.
- Protects worker health: Reduces exposure to dust-related respiratory and cardiovascular illnesses.
- Increases efficiency: Automatic operation optimizes dust removal and minimizes human intervention.
- Reduces maintenance: Durable and efficient cyclone separator minimizes filter replacements.
- Cost-effective: Offers a long-term solution for dust control in construction sites.

IV. Models, Simulations and Results

A. MATLAB simulation for efficiency of the cyclone dust separator

Equation for the efficiency of the cyclone dust collector is model using the flow pattern performance using the Reynolds stress turbulence model.

Efficiency $= 1 - \exp\left(-\frac{\rho_p}{9\mu}\left(\frac{2d_p V_t}{D}\right)^2 t_{\text{res}}\right)$ [9] where

ρ_p = Particle density, μ = Viscosity of gas, d_p = Particle diameter, v_t = Tangential velocity, D = Cyclone diameter.

The gas residence time (t_{res}) is given by,

$t_{\text{res}} = \frac{V_{\text{in}}}{Q} + \frac{1}{0.9}\frac{V_s}{Q}$ [9] where

Q = Volumetric gas throughput of the system

This Simulink will find the dust collector's efficiency for three different air inlet velocities (10m/s, 15m/s, 20m/s) for different particle sizes (from 1 µm to 6 µm).

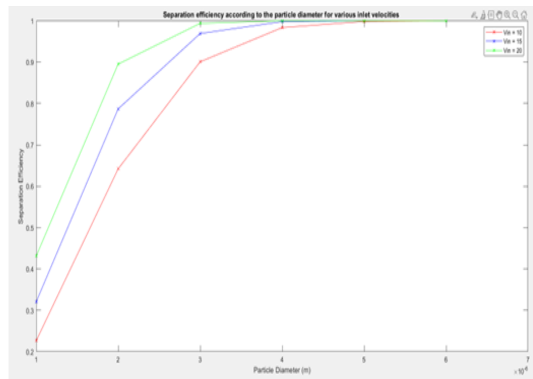

Fig. 6. An image of a Matlab simulation graph

B. Tangential Velocity Distribution modeled graph using matlab

Using the below equation tangential velocity with respect to radius graph is plotted using Matlab. Values for Vt got from this graph are used in the efficiency calculation model.[11]

$$v_t = \frac{V_{\text{in}}}{\gamma^{0.52}\left(\frac{D}{2}\right)^{0.52}}$$

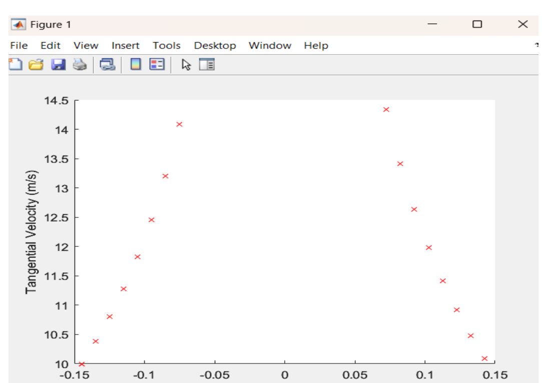

Fig. 7. An image of a Matlab simulation graph

V. Conclusion

In conclusion, this paper proposes a novel approach to enhance the efficiency of dust removal systems for indoor construction, focusing on cyclone separation technology. By investigating the relationship between particle diameter and inlet air flow speed. It identified a method to maximize the cyclone separator's separation efficiency without altering its dimensions. After a certain diameter of the particle, efficiency does not depend much on the inlet velocity. Therefore, the speed of the suction fan can be reduced, which increases efficiency. To obtain it, the Reynolds stress transport mode is used in this paper. The work also shows the distribution of tangential velocity inside the chamber with a radius of r. The power supply and control mechanisms of the system are also demonstrated in this paper.

This proposed method of an automatic dust collector can be used efficiently at construction sites to uplift the health of construction workers.

VI. Reference

References

[1] E. Sekhavati and R. J. Yengejeh, "Particulate matter exposure in construction sites is associated with health effects in workers," Front. Public Health, vol. 11, p. 1130620, Mar. 2023, doi: 10.3389/fpubh.2023.1130620.

[2] N. Liu, X. Wu, E. Deng, X. Liu, and Y. Wang, "A U-shaped spray device on a front boom-type roadheader for dust suppression in a metro tunnel," Sustain. Cities Soc., vol. 89, p. 104369, Feb. 2023, doi: 10.1016/j.scs.2022.104369.

[3] [3] N. Liu, K. Chen, E. Deng, W. Yang, and Y. Wang, "Study on dust suppression performance of a new spray device during drilling and blasting construction in the metro tunnel," Tunn. Undergr. Space Technol., vol. 133, p. 104975, Mar. 2023, doi: 10.1016/j.tust.2022.104975.

[4] [4] J.-G. Swanson and O. Langefeld, "Fundamental research in water spray systems for dust control," Min. Technol., vol. 124, no. 2, pp. 78–82, Jun. 2015, doi: 10.1179/1743286315Y.0000000005.

[5] Cyclone simulation using COMSOL, (May 01, 2023). Accessed: Dec. 12, 2023. [Online Video]. Available: https://www.youtube.com/watch?v=43-s-zN1IvQ

[6] Dyson Powered Cyclone Separator Vacuum, (Jul. 19, 2023). Accessed: Dec. 12, 2023. [Online Video]. Available: https://www.youtube.com/watch?v=gaGYWqRb0E0

[7] M. Onozuka, Y. Ueda, K. Takahashi, Y. Seki, S. Ueda, and I. Aoki, "Dust removal system using static electricity," Vacuum, vol. 47, no. 6, pp. 541–544, Jun. 1996, doi: 10.1016/0042-207X(96)00016-4.

[8] "World Health Organization (WHO)." Accessed: Dec. 12, 2023. [Online]. Available: https://www.who.int

[9] K. Park, C.-H. Hong, J.-W. Han, B.-S. Kim, C.-S. Park, and O. K. Kwon, "The Effect of Cyclone Shape and Dust Collector on Gas-Solid Flow and Performance," vol. 6, no. 1, 2012.

[10] O. US EPA, "What is a HEPA filter?" Accessed: Dec. 12, 2023. [Online]. Available: https://www.epa.gov/indoor-air-quality-iaq/what-hepa-filter

[11] A. J. ter Linden, "Investigations into Cyclone Dust Collectors," Proc. Inst. Mech. Eng., vol. 160, no. 1, pp. 233–251, Jun. 1949, doi: 10.1243/PIMEPROC194916002502.

[12] Reliable Dust Measurements and Nephelometer Data Processing Webinar with Dr John Wagner, Aeroqual, (May 25, 2015). Accessed: Dec. 12, 2023. [Online Video]. Available: https://www.youtube.com/watch?v=VOUKIqTKB6w

[13] "Optical Dust Sensor - GP2Y1010AU0F - COM-09689 - SparkFun Electronics." Accessed: Dec. 12, 2023. [Online]. Available: https://www.sparkfun.com/products/9689