ANALYSIS OF CYCLONE COLLECTION EFFICIENCY

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Rezumat. Separatorul centrifugal (ciclonul) se distinge prin simplitate constructivă, eficienţă ridicată, siguranţă în exploatare, cost redus de intreţinere şi funcţionare fiind printre cele mai adecvate şi utilizate separatoare de praf din aplicaţiile industriale. Studiile ştiinţifice demonstrează faptul că eficienţa ciclonului depinde de dimensiunea particulelor separate, viteza gazului la admisie şi densitatea particulelor. Scopul acestei lucrări este de a arăta influenţa dimensiunii particulelor şi a vitezei de intrare a gazului în ciclon asupra eficienţei colectării.
Cuvinte cheie: eficienţa ciclonului, densitatea particulelor, diametrul limită al particulelor.

Abstract. Cyclones have been considered as one of the simplest type of separator and because of their high efficiency, adaptability, simple design and low maintenance, construction and operation costs, they are ideal for use in the various industrial applications. The literature indicates that the cyclone efficiency is dependent on the particle size, inlet air velocity and particle density. The objective of this paper is to demonstrate the influence of the particles size and the input velocity of the gas into the cyclone over the collection efficiency.
Keywords: cyclone collection efficiency, particle density, cut-off diameter.

1. INTRODUCTION

The separation of solid particles is required in many industrial processes because of growing concern for the environmental effects of particulate pollution.

Cyclone separators has a cutoff aerodynamic diameter greater than 5 to 10 μm and therefore it is often used as common devices for pre-cleaning gas in front of other high efficiency devices.

Selecting a particulate emissions control system is generally based on knowledge of four elements: particle concentration in the stream to be cleaned, particles size distribution, the flow gas rate and final allowable particulate emission rate.

Although cyclones were traditionally regarded as relatively low efficiency collectors at present they can achieve efficiencies of 90% for particles larger than 15 to 20 m.

A cyclone separator is a device that separates particles from a gas stream using centrifugal force. By this method, it is possible to separate the larger particles from the gas.

The cyclones may be constructed of any material (metal or ceramic) that is capable of withstanding the abrasive particles, high temperatures and corrosive environments. It is necessary that the inner surface be smooth so that the collected particles can easily slip down the wall into the bunker. Cyclone has no moving parts so the operation is generally simple and requires no maintenance.

Their low capital cost and free maintenance operation makes them ideal for use as pre-cleaners for more efficient final control devices such as electrostatic precipitators.

2. BASICS OF CYCLONE SEPARATORS

Cyclone separators are gas cleaning devices that use the centrifugal force of a gas stream. The gas flow due tangential entry is forced to follow the curved geometry of the cyclone while the inertia of particles in the flow causes them to move towards the outer wall, where they collide and collect.

In a cyclone the particles from the spinning gas stream move progressively closer to the outer wall and execute several complete rotations as they flow through the device.

This type of cyclone is used frequently as a pre-cleaner to remove fly ash and large particles and its main advantages are low pressure drop and high volumetric flow rates.

The cyclone separates solid particles from a gas, based on the principle of centrifugal force, which is much stronger than gravitational force. It works more efficiently at high gas flow rates, because a large velocity creates a swirling movement inside the column.

The basic principle of cyclone is to force the particles laden gas in a vortex, where inertia and gravitational forces affect particle separation.

In this device, the fluid enters tangentially into the cylindrical chamber and the flow descends rotating near the wall, until the vortex end position where the axial velocity component reverses itself, thus making the flow to ascend. The ascension proceeds near the cyclone axis and is formed a double vortex structure, as indicated in the figure.

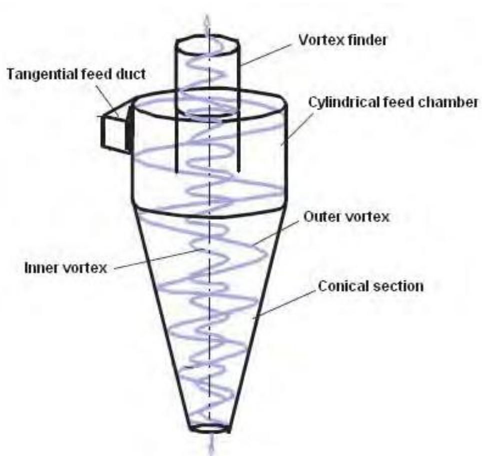

Fig. 1. *Sketch of the two flow patterns in a reversed-flow cyclon*

The inner vortex will lead the flow out through a central duct, called the vortex finder. The vortex finder goes into the cyclone body and protects the inner vortex from the high inlet velocity and stabilizes it.

The solid particles which are denser than the gas, have a high centrifugal force, which directs them to the walls, where they collide and lose momentum so become disengaged from the flow. The separated solids slide on the conical wall and are collected at the lower part.

The main part of the cyclone is the cylindrical feed chamber whose function is to extend the cyclone length to increase the retention time. Another important parameter is the inlet nozzle area in the feeding chamber which is normally a rectangular orifice.

The next important parameter is the vortex finder whose main function is to control both the separation process and flow leaving the cyclone. Vortex finder size is about 0.35 times of the cyclone diameter and it is sufficiently extended as to prevent the entry of supplying material directly into the overflow.

For the basic cyclone, its length should be 100% of its diameter. The conical section has an angle between 10^{o} and $20^{\,o}$ and has a similar role with cylinder section to increase retention time.

The discharge orifice is located at the end of conical section and its diameter is determined by the application involved and must be large enough to permit the solids that have been classified to underflow to exit the cyclone without plugging.

3. COLLECTION EFFICIENCY OF CCYCLONE SEPARATORS

The capacity of the cyclone to collect particles is measured by its efficiency η, defined as the fraction of the inlet flow of solids separated in the cyclone. Since a cyclone typically collects a wide range of particle sizes, it is common to work also with different efficiencies, each defined for a particular and limited range of particle sizes.

It is also evident that very large particles will be always separated, while the very fine material will always escape.

The cutoff diameter is defined as the particle diameter corresponding to 50% cyclone collection efficiency.

Because of the turbulent flow in the cyclone separator the particle concentration is assumed to be uniform and their removal occurs in a thin layer at the outer wall.

The collection efficiency of a cyclone that has an angle θ_f is:

$$\eta = 1 - \exp\left[-\frac{2 v_{r_2} r^2 \theta_f}{v_{\theta_2}\left(r_2^2 - r_1^2\right)} \right]$$

The two velocity components, axial velocity and radial velocity are:

- axial velocity :

$$v_{\theta_2} = \frac{Q}{W r_2 \ln\left(r_2 / r_1\right)}$$

- radial velocity :

$$v_{r_2} = \frac{\rho_p Q^2 D_p^2}{18 \mu r_2^3 W^2 \left(\ln r_2 / r_1\right)^2}$$

The collection efficiency in terms of the physical variables of the cyclone is:

$$\eta = 1 - \exp\left[-\frac{\rho_p Q D_p^2 \theta_f}{9 \mu r_2 W \left(r_2^2 - r_1^2\right) \ln\left(r_2 / r_1\right)} \right]$$

where: η is the efficiency of the cyclone; D_p - dimensions of particles, m; r_2 - inner radius of cylindrical body; r_1 - outer diameter of central tube; ρ_p –particle density; μ - gas mixture viscosity; Q - gas flow rate, m^3/s.

Figure 2 shows the collection efficiencies for the cyclone analyzed and we can see that the relation predict an asymptotic approach to complete collection with increasing particle diameter. The separation efficiency increases with the increasing of particle size.

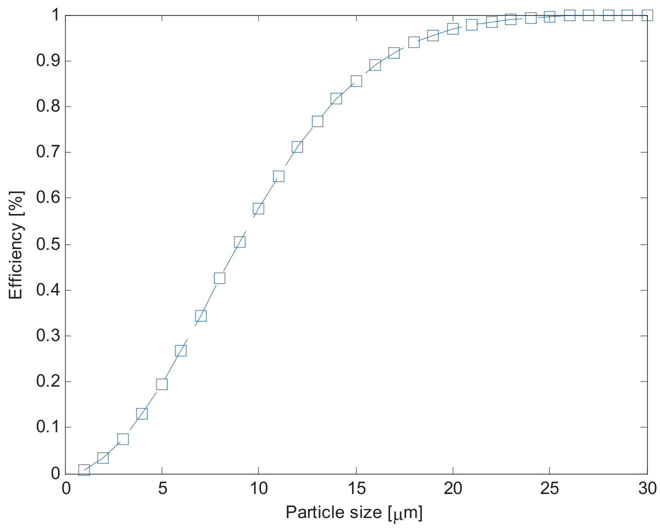

Fig. 2. *Variation of separation efficiency based on particles diameter*

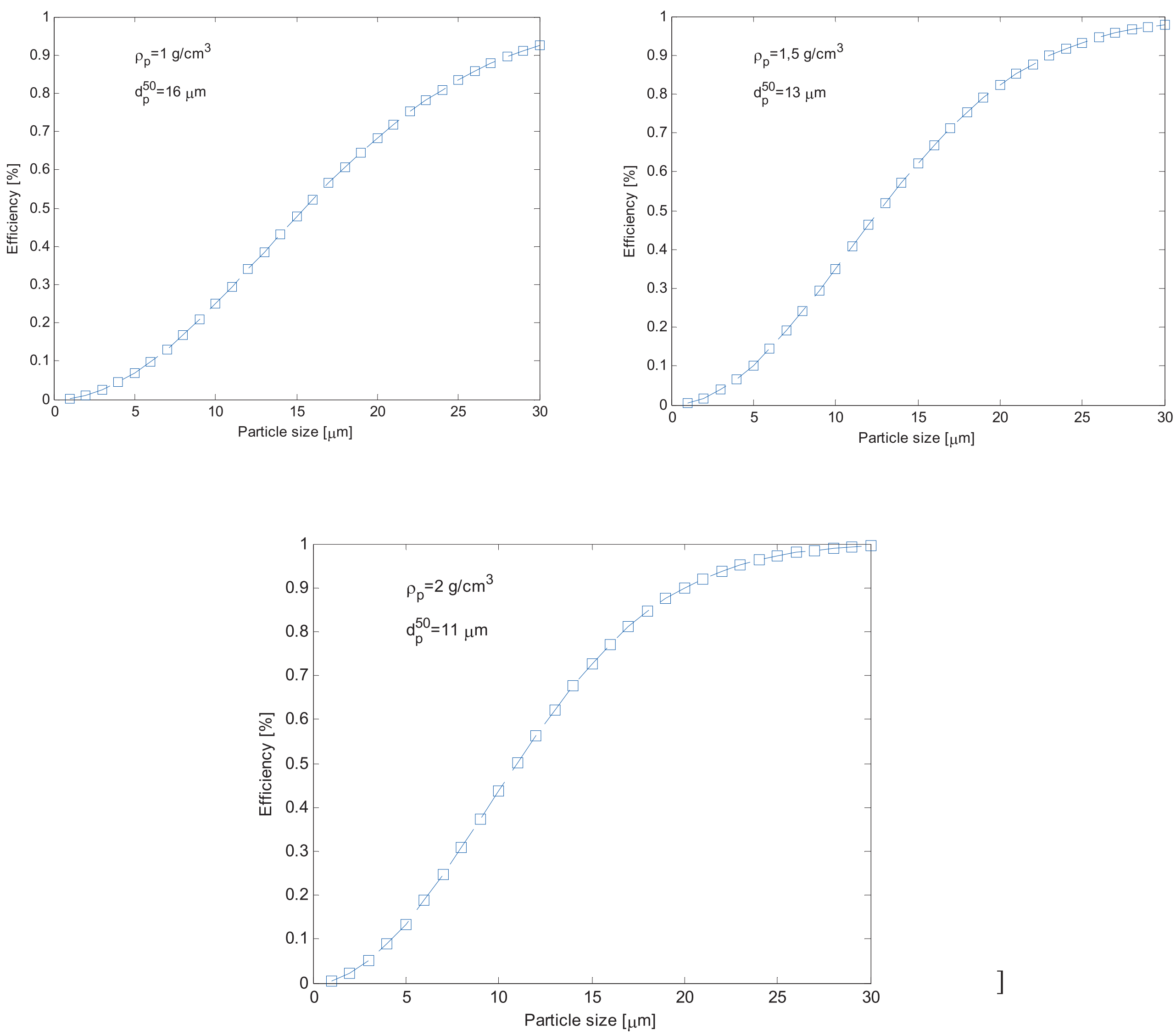

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Fig. 3. *Variation of separation efficiency based on particles density*

Figure 3 shows the variation of 50% cutoff diameters for different particle density. We can observe that the cutoff diameter of the particle is highly influenced by particle density and their diameter.

The graph shows that the lowest 50% cutoff diameters was obtained to gas mixture viscosity input of 1 g/cm3 while for a gas mixture viscosity input of 2 g/cm3 cyclone has reached a 50% cutoff diameter of 11 µm.

3. CONCLUSIONS

Cyclones are reliable devices widely used in industry.

There are many parameters which must be considered when designing a cyclone including geometry of the cyclone, flow rate and inlet geometry. In this study, an empirical model was computationally solved by a Matlab algorithm to predict the cyclone efficiency and cutoff diameter of the particles.

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