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INFLUENCE OF PARTICLE SIZE AND INLET GEOMETRY IN CYCLONE OVER THE SEPARATION EFFICIENCY

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Abstract: *Cyclones are applied in both heavy and light industrial applications and may be designed as either classifiers or separators. The motion of a particle, and its separation in a cyclone, obviously depends on its size, amongst other important factors, such as its density, shape, and tangential velocity. The literature reveals that the cyclone efficiency is dependent on the particle size from the mass of the mixtures heterogeneous solid-fluid. The theoretical research is done based on complex mathematical models that allow estimating the separation efficiency and collection solid particles. The paper presents the mathematical model used in theoretical research of the influence of particle size and geometric characteristics of the inlet section over the separation process efficiency in the static devices type cyclones, study based on Leith and Licht relationship.*
Keywords: *particles size, inlet geometry, efficiency, cyclone.*

1. INTRODUCTION

The cyclone separator is a device for the separation of the dense phase from a two-phase flow, by the action of centrifugal forces.

Cyclones are inertial separators without moving parts, used as primary tools for the removal of relatively coarse particles. In some cases, they are the only pollution control devices used, but more often they serve as precleaners, followed by more effective collectors, such as electrostatic precipitators, wet scrubbers, or fabric filters. In the latter case, the cyclones serve to reduce the emissions at times where the secondary control equipment is out of service; and also to reduce the particle load to the secondary dust collector, simplifying the design, increasing the reliability, and even reducing the size of the secondary collector and accessory equipment. The efficiency of cyclones varies widely with the particle size [2].

Although they cannot meet very stringent particulate emission standards, their low capital cost and robust construction make them ideal particle-gas separators. Whereas they have considered as low efficiency separators in the past, advanced design principles have significantly improved their efficiency, now in excess of 98% at ambient operating conditions for particle sizes larger than approximately 5µm when these design principles have adhered [7].

The particle-laden gas stream enters the cyclone at the cylinder top, where the configuration of the tangential entry causes the gas to spin, forming a vortex. The performance of a cyclone can be quantified by its collection efficiency [1].

Cyclone efficiency characterizes its ability to retain from fluid environment the solid particles of a certain minimum size required. At the same cyclone, changing the particle density and fluid viscosity, changes its efficiency. To retain the minimum of particles diameter required is necessary to align the input speed of the fluid in the cyclone with product characteristics (density of the medium, particle density, and viscosity) and constructive parameters of the cyclone. Separation in cyclones is favorable with large particles that would normally be entirely separate, the fluid, in the output will contain only particles smaller than the critical diameter. But, the swirling formed inside the cyclone influence the process of separation [3].

The objective of this paper is to describe how the particle size and inlet geometry influences the separation efficiency in the static devices type cyclones.

2. WORK STEPS

For the theoretical research regarding the influence of particle size dimensions and inlet geometry on the separation efficiency have used the following dimensions of the intermediate products resulting from the grist: big semolina= 1200 [mm]; middle semolina= 630 [mm]; small semolina= 400 [mm]; harsh dunst= 66 [mm]; soft dunst= 56 [mm]; flour = 40 [mm] [4].

To calculate cyclone efficiency have used the relationship given by Leith şi Litch (1972) [5].

The Leith and Licht (1972) model predicts the grade efficiencies based on the concept of continual radial back mixing of the uncollected particles, and on the calculation of an average residence time for the gas in the cyclone. The Leith and Licht equation proposed and used in this theoretical research is:

$$\eta = 1 - \exp\left[-2\left(C\Psi\right)^{\frac{1}{2m+2}}\right] \cdot 100\left[\%\right], \tag{1}$$

where: η is the efficiency of the cyclone; C is an parameter that depends on the size of the cyclone; Ψ - Inertial impact parameter which depends on the nature of gas-solid; m - Alexander's number, which is consistent with the size and temperature gas cyclone: m = 0, 5 [5].

The inertial parameter value which is depending on the nature of gas-solid heterogeneous system is determined by the relationship:

$$\Psi = \frac{\rho_s \cdot d_p^2 \cdot \upsilon_{t_2}}{18\mu \cdot D}\left(m+1\right), \tag{2}$$

where: ρ is the solid particle density, ρ=1110 kg/m^3; μ - gas mixture dynamic viscosity, Pa·s; v_{t2}- velocity of the gas to the entry into the supply: v_{t2} =15 m/s; d_p –diameter of particles.

Dynamic viscosity depends on temperature and is calculating with the relationship:

$$\mu = \left(37.4 + 0.506 \cdot T\right) \cdot 10^{-5}; \ \mathrm{T} = 293\left[K\right]; \tag{3}$$

The C parameter that depends on the size of the cyclone can calculated with next relation ship:

$$C = \frac{8 \cdot K_C}{a \cdot b}, \tag{4}$$

where K_c is a constant of the basis time what is supporting the particles within the vortex system. The constant K_c is calculated by the following relationship:

$$K_c = \frac{V_s + \dfrac{V_{el}}{2}}{D^3}, \tag{5}$$

where V_s is the upper volume, m^3; V_{el} - volume actually heading back to the lower vortex in the cyclone, m^3. The volume values are determined by:

$$V_s = \frac{\pi D^2}{4} h, \tag{6}$$

$$V_{el} = \frac{\pi \cdot D^2}{4}\left(h - s\right) + \frac{\pi \cdot D^2}{4}\left(\frac{\ln + s - h}{3}\right)\left(1 + \frac{d}{D} + \frac{d^2}{D^2}\right) - \frac{\pi \cdot D_e^2 \cdot \ln}{4}, \tag{7}$$

where *ln* is the natural length of cyclone, in m;

$$\ln = 2.3 D_e \left(\frac{D^2}{a \cdot b}\right)^{1/3}, \tag{8}$$

$$d = D - \left(D - D_B\right)\left(\frac{s + \ln - h}{H - h}\right), \tag{9}$$

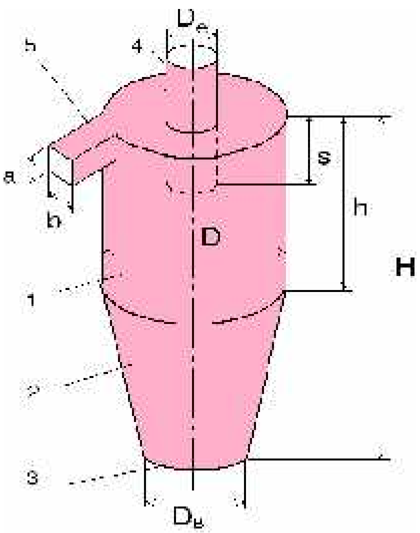
By replacing the known terms were obtained the following relations:

$$\eta = 1 - \exp\left\{-2\left[\left(\frac{8k_c}{a \cdot b}\right) \cdot \left(\frac{\rho \cdot d_p{}^2 \cdot v}{18 \cdot \mu \cdot D}\right) \cdot \left(m+1\right)\right]^{\frac{1}{2 \cdot 0,5+2}}\right\} \cdot 100, \tag{10}$$

$$\eta = 1 - \exp\left\{-2\left[\left(8 \cdot \frac{\dfrac{V_S \cdot \dfrac{V_{ei}}{2}}{D^3}}{a \cdot b}\right) \cdot \left(\left(\frac{\rho \cdot d_p{}^2 \cdot v}{18 \cdot \mu \cdot D}\right) \cdot \left(m+1\right)\right)\right]^{\frac{1}{3}}\right\} \cdot 100, \tag{11}$$

$$\eta=1-\exp\left\{-2\left[\left(\frac{8\cdot\frac{\pi\cdot D^2}{4}\cdot h\cdot\frac{\frac{\pi\cdot D^2}{4}\cdot(h-s)+\frac{\pi\cdot D^2}{4}\cdot\left(\frac{\ln+s-h}{3}\right)\cdot\left(1+\frac{d}{D}+\frac{d^2}{D^2}\right)-\frac{\pi\cdot De^2\cdot\ln}{4}}{2}}{\frac{D^3}{a\cdot b}}\right)\cdot\left(\left(\frac{\rho\cdot d_p^{\,2}\cdot v}{18\cdot\mu\cdot D}\right)\cdot 1{,}5\right)\right]^{\frac{1}{3}}\right\}\cdot 100 \qquad \textbf{(12)}$$

The cyclone dimensions used in theoretical research are presented in figure 1. These dimensions were derived from dimensional calculation and design using AutoCAD. For dimensional calculating it was chosen an input speed of impure gas in the inlet pipe 15 m/s and a volume flow 400 m^3/s. With this data was determined the size of the cyclone parts according to geometric similarity reports of a cyclone type chosen [6].



D – diameter cylindrical body, D = 0,244 m;
D_e - diameter of central tube exhaust gas purified, D_e = 0,122 m;
D_b – diameter exhaust side solid particles (dirt), D_b = 0,061 m;
H – cyclone height, H =1,06 m;
a – height of the cyclone feed inlet, a = 0,122 m;
b - width of the cyclone feed inlet , b = 0,061 m;
h – upper height of the cyclone, h = 0,56 m;
s – depth of penetration of purified gas hose, s = 0,028 m;

Figure 1*:* Cyclone with tangential entry:
1 - cylindrical body; 2 - cone-shaped body; 3 - outlet of solids particle; 4 - outlet of gas; 5 - gas supply hole doped.

The known parameters and formulas were introduced in Microsoft Office Excel 2003 and was drawn the chart which shows the influence of particle size and inlet geometry in cyclone over the separation efficiency.

In table 1 are recorded the values obtained by calculating the separation efficiency with the relationship given by Leith and Licht (1972) for five values of the surface cyclone section entry: S_1=0, 001575 m^2; S_2=0, 002912 m^2; S_3=0, 004928 m^2; S_4=0, 006608 m^2 and S_5=0, 007440 m^2.

Table 1: Separation efficiency values based on particle diameter

dp [m]	**η_1[%] (S_1=0,001575)**	**η_2[%] (S_2=0,002912)**	**η_3[%] (S_3=0,004928)**	**η_4[%] (S_4=0,006608)**	**η_5[%] (S_5=0,00744)**
0,0012	100	100	100	100	100
0,00063	99,935	99,972	99,876	99,713	99,606
0,0004	99,559	99,762	99,285	98,675	98,326
0,000066	80,439	83,746	77,382	72,769	70,781
0,000056	76,831	80,374	73,610	68,834	66,803
0,00004	68,917	72,778	65,510	60,607	58,569

3. RESULTS AND DISCUSSIONS

In the graph from figure 2 it can be observed that separation efficiency increases with the increasing of particle size. Also, it can be observed that for the sectional area of entry into the cyclone S_2 = 0,002912 m^2 the separation efficiency is higher, and for the sectional area of entry into cyclone S_5= 0, 00744 m^2 the separation efficiency decreases significantly.

It also can be observed that for a diameter of 0.0012 [m], separation efficiency is maximized, regardless of the inlet geometry.

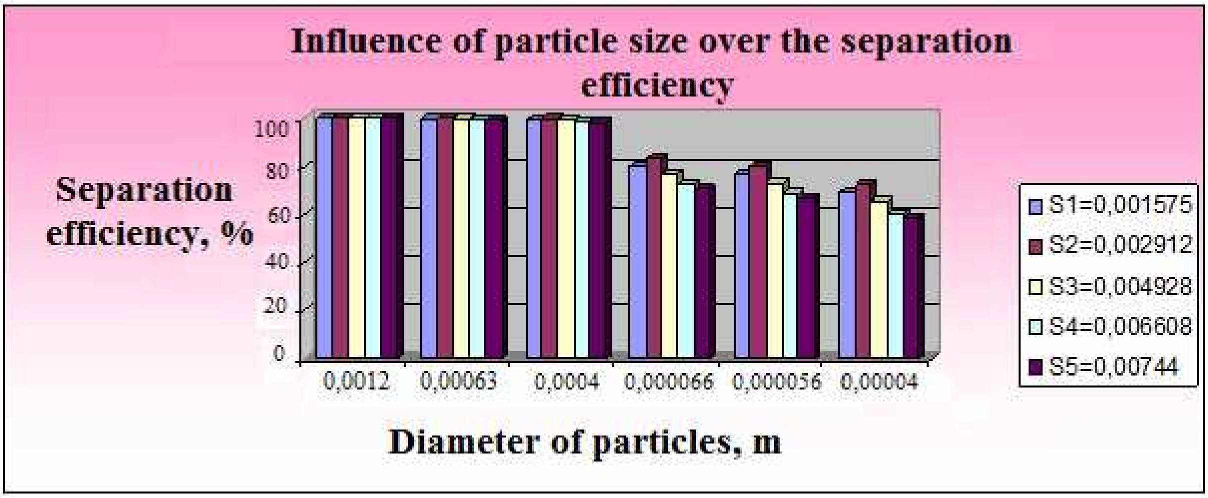


Figure 2: Variation of separation efficiency based on particle diameter

4. CONCLUSIONS

Separation in cyclones is favorable with large particles that would normally be entirely separate, the fluid, in the output will contain only particles smaller than the critical diameter.

To retain the minimum of particles diameter required is necessary to align the input speed of the fluid in the cyclone with product characteristics (density of the medium, particle density, and viscosity) and constructive parameters of the cyclone.

The efficiency of the separation process increases with particle size solids involved in the separation operation, the size of solid particles which will be separated is a very important factor in choosing the cyclone type.

So, if the particle size is larger and the sectional area of entry into cyclone is smaller, the separation efficiency of the cyclone is higher.

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