THE EFFECTS OF PARTICLE'S SHAPE ON CYCLONE'S COLLECTION EFFICIENCY. A THEORETICAL APPROACH.

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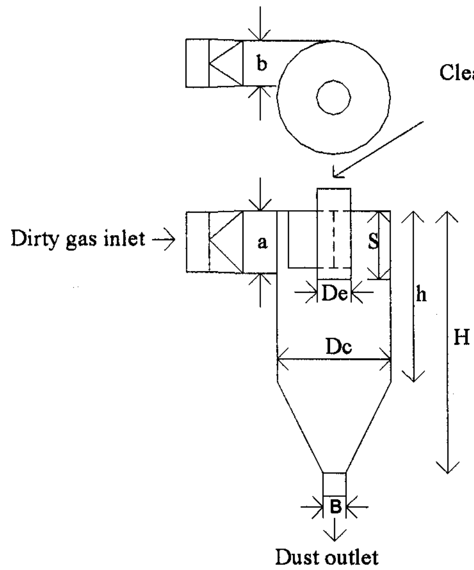
Cyclone separators have been used for about 100 years, and they are still one of the most widely used of industrial gas-cleaning devices[1]. The main reasons for the extensive use of cyclones are that they are inexpensive to purchase, have no moving parts, and can be constructed to withstand hard conditions[2]. However, the models that are presently used to predict their collection efficiency are not near to the real behavior of those devices. Figure 1 illustrates the cyclone's dimensions.



Term	Description
a	inlet height
b	Inlet width
S	outlet length
De	outlet diameter
h	cylinder height
H	overall height
B	dust outlet

Figure 1. Dimensions of a standard cyclone[2].

The main limitations of classical mathematical models that are used to calculate collection efficiency are originated by the following considerations:

- The flow inside the cyclone is laminar.
- Particles have spherical shape.

Those considerations have been done to simplify mathematical models to calculate cyclone's collection efficiency. However, it has been shown that the models, which are based on these considerations, can not predict accurately cyclone's collection efficiency.

Limitations in collection efficiency mathematical models have been studied for 2 years at the Instituto Politécnico Nacional of Mexico. This study has been carried out by experiments done using flake shape metallic particles.

It is proposed to take into account particle's shape, and to find out an equivalent diameter for them. This equivalent diameter is calculated by considering that particles have the same volume as a sphere whose diameter is the equivalent diameter.

To find out this equivalent diameter, it is necessary to consider the real diameter of the particle too. In the cases when particle's shape is totally different from spherical shape the largest particle's dimension is considered its diameter.

The mathematical model that was obtained to calculate collection efficiency by considering an equivalent diameter for non-spherical particles, continue considering that gas flow inside cyclone is laminar. This mathematical model is named GQJ, and it is shown in the equation (1)[3].

$$\eta(D_p) = \frac{N\pi(\psi D_p)^2(\rho_p - \rho)V_c}{9\mu K_b D_c} \tag{1}$$

Where:

ρ_p: Particles density (kg/m^3)
μ: Gas dynamic viscosity (N s/m^2)
ψ: Proportionality factor (different for each particle's shape)
ρ: Gas density (kg/m^3)
b: Cyclone's inlet width (m)
D_c: Cyclone's diameter (m)
K_b: b/Dc
N: Number of turns that the gas makes while flowing through a cyclone
V_c: Inlet gas velocity (m/s)

The proportionality factor is given by the relationship between equivalent diameter and particle's diameter. The proceeding to get this factor is next shown:

$$V_{sph} = \frac{\pi}{6} D_{eq}^3 \tag{2}$$

If $V_{sph} = V_p$, then

$$V_p = \frac{\pi}{6} D_{eq}^3 \tag{3}$$

Solving for D_{eq}, we have

$$D_{eq} = \left(\frac{6V_p}{\pi}\right)^{\frac{1}{3}} \tag{4}$$

The ψ's calculus would be

$$\psi = \frac{D_{eq}}{D_p} = \left(\frac{6V_p}{\pi}\right)^{\frac{1}{3}}\left(\frac{1}{D_p}\right) \tag{5}$$

Where:

V_{sph}: Sphere's volume (m^3)
V_p: Particle's volume (m^3)
D_{eq}: Equivalent diameter (m)

Comparison between experimental results and theoretical results, which were gotten by GQJ model to calculate cyclone's collection efficiency.

To continue, experimental results gotten in a cyclone used to classify metallic particles conveyed by air are shown. The experimental conditions under which results were obtained are: D_c=0.35m, b=0.11m, K_b=0.21428714, ρ=0.9975369 kg/m^3, ρ_p=8250 kg/m^3, μ=0.000018 N.s/m^2, ψ=0.21, N=4.2424, and V_c=14.9 m/s. In figure 2, results experimentally got, and theoretical results got by GQJ model are shown.

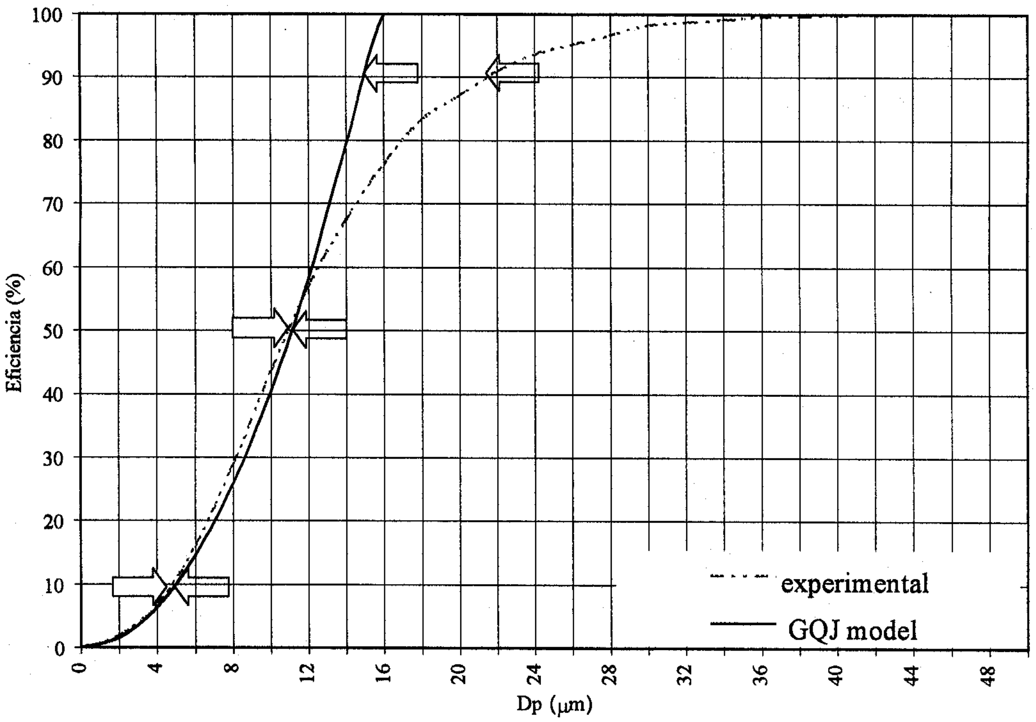


Fig. 2 Collection efficiency results got by using GQJ model and experimental results.

In figure 2, it can be seen that results, which were gotten by using the GQJ model, are very closed to experimental results at the same operation conditions. When it is considered a particle's shape different from spherical shape, this model shows good results, closed to experimental ones. Due to it, this model can be considered as a good model to predict cyclone's behavior.

The points that are point out in each curve, show the particle's diameter values which have a collection efficiency of 10, 50 and 90% respectively. These values and the values got by using other mathematical models are shown in table 1.

Mathematical Model	D_{10} (10%)	ERROR(%)	D_{50} (50%)	ERROR(%)	D_{90} (90%)	ERROR(%)
Experimental results[3]	4.78μm	--	10.91μm	--	21.35μm	--
Block Flow Model[4]	1.043μm	78.18%	2.332μm	76.63%	3.129μm	85.34%
Mixed Flow Model[4]	1.071μm	77.59%	2.746μm	74.83%	5.343μm	74.97%
Leith y Licht Model[5]	--	--	1μm	90.83%	5.45μm	74.47%
Ideal Laminar Flow Model[2]	1.051μm	78.01%	2.52μm	76.9%	3.78μm	82.3%
Ideal Turbulent Flow Model[2]	2.69μm	43.72%	7.25μm	33.54%	13.3μm	37.7%
Data Adjusted Model[4]	3.57μm	25.31%	10.91μm	0%	32.77μm	53.49%
GQJ Model[3]	4.915μm	2.82%	11.10μm	1.74%	14.74μm	30.96%

Table 1. Comparison among experimental results and results gotten by using different mathematical models[3].

As in can be observed at table 1, the results gotten by using GQJ model to 10 and 50% efficiency values are very closed to experimental results and show error values less than 3%. These error values are quite less than error values gotten by using other mathematical models.

Because of that, GQJ model is a reliable model to calculate collection efficiency between 10 and 50% values. When this model is used to calculate efficiency values more than 50%, the error values increase. However, the error value gotten by using GQJ model to 90% efficiency value is less than results gotten by using the other mathematical models.

CONCLUSION

Mathematical models that are found in specialized literature to evaluate cyclone's collection efficiency are quite far from real cyclone's behavior description. Due to it, They can not be used without analyzing their limitations.

Generally, mathematical models to evaluate cyclone's collection efficiency use the following parameters: gas density, particle density, gas dynamic viscosity, cyclone's dimensions (diameter, inlet height, inlet width, overall height, cylinder height), and in some models gas temperature. However, none of them consider that particles can have a shape different from a spherical one.

A mathematical model to calculate cyclone's collection efficiency was developed. This model was named GQJ and it is considered as an original result in the particle separation field. This model considers that particle's shape can be different form spherical one and includes a factor named ψ. This factor is gotten from the supposition that we should find an equivalent diameter, which belongs to a sphere with the same particle's volume. This equivalent diameter is different from particle's diameter (the longest dimension). Factor ψ is equal to the relationship between sphere's equivalent diameter and particle's diameter.

Because of results gotten by using GQJ model are very closed to experimental results, it can be said that particle's shape has great influence on cyclone's collection efficiency.

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