EXPERIMENTAL RESEARCH REGARDING THE INFLUENCE OF INLET GEOMETRY AND AIR STREAM CHARACTERISTICS OVER SEPARATION EFFICIENCY

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Abstract: In this paper is presented the dependence of the efficiency of separation process for system such as solid-gas in the cyclone according to the geometrical characteristics of the inlet and outlet . The measurements were made on a laboratory pilot plant witch permits the modification of cyclone inlet and outlet sections. The determination of the separation efficiency was made by comparing the quantity of material introduced in system and the quantity recovered in the cyclone collection bunker. During the experimental research it were also measured the speed and the temperature of the air stream and the pressure in different points of transport and separation route.

Key words: separation, cyclone, airflow.

1. INTRODUCTION

Cyclone separators are widely used in many industrial and research areas where it is necessary to achieve separation from the mass of the gases. The advantages afforded by cyclones, refer to: no moving parts, compactness of construction, simple operation, low cost manufacturing, service and repair, operate in a wide field variance suspension and adaptability to a wide range of grain solid particles in suspension. In terms of construction, the cyclones are simple devices, but the mathematical model equations that describe the flow and separation processes that occur within them are highly complex. Researchers, who have studied the work of these devices, have developed a series of theories and empirical models that can be used for designing [1].

The separation processes are ubiquitous in various technological processes of various industries, belonging to the chemical, petrochemical, mining, pharmaceutical and agro-food processes. In general, this process is a physical separation of two phases (Gas/Liquid, Gas/Solid, Liquid/Solid), formed from a continuous phase (carrying particles), and a dispersed phase (particles). Cyclones are the most widely used separator devices which are based on the action of particle centrifugal force in suspension, being created by the vortex of fluid in the cyclone [2]. The collection efficiency of a cyclone is better than that of a baghouse, venturi scrubber or electrostatic separation systems [3].

Inside the cyclone, due the inlet geometry and the cyclone housing, elements mass of the fluid are moving simultaneously in three directions: after a direction parallel to the vertical axis of the cyclone, with speed v_z; a rotating movement around a vertical axis, with the peripheral speed u and on radial direction, perpendicular to the axis of rotation, with speed v_r (Figure 1).

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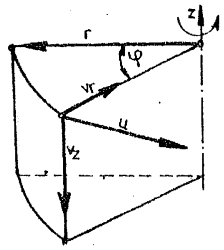


Fig. 1. The directions of motion for a fluid mass element.

In different parts of the cyclone, the value of these rates is not constant, changing according to local conditions of flow. Movements in the vertical direction and rotation cause the spiral motion of fluid.

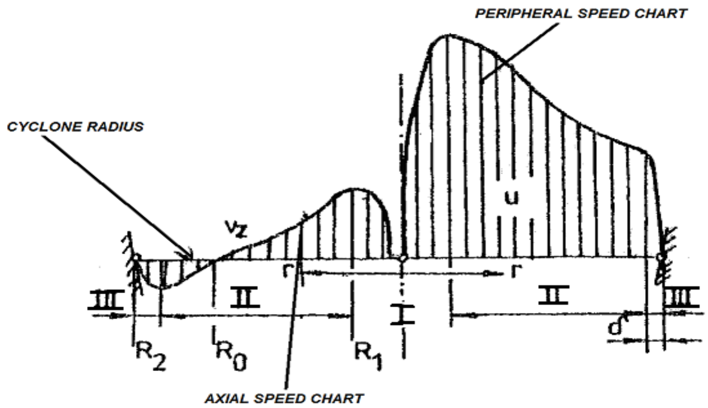


Fig. 2. Diagram of fluid circulation within the cyclone.

Depending on the values of the three speeds: v_z, u, v_r, inside the cyclone is three main streams:
I - central area, called the secondary vortex, which is an ascending stream formed in the center of the cyclone around the vertical axis, representing the spiral movement of the fluid phase which separated from the solid phase. The limit on the radial direction of this vortex is in the area of radius R_1, where the upward velocity v_z and peripheral velocity u have the maximum values (Figure 2). The radial velocity of the fluid at level and within the secondary vortex, is zero (v_r=0). Characteristic for this stream of fluid is that the axis of symmetry of the cyclone may present local eccentricities (undulations in the axis of symmetry of the truncated part of the cyclone) or general (on the entire height of the cyclone).

II - the primary vortex who is a fluid stream forming in the area between the radii R_1 and R_2 of the cyclone, representing the spiral motion of heterogeneous mixture who is placed inside the cyclone tangentially through the supply pipe. From Figure 2, it can be observed that near the critical radius R_0, the velocity v_z changes its sign, so that between the range R_1-R_0, located closer to the cyclone axis, the velocity v_z is oriented upward (the current is upward), and in the range R_0-R_2, located closer to the cyclone wall, velocity v_z is facing down (the current is downwards).

III - the flow in the boundary layer, (Figure 3) containing a thin layer δ, which is the whole inner surface of the cyclone. Inside the cyclone two regions differ, in each of this, the fluid flow in the boundary layer is presented different characteristics.

The first region comprises the top cover of the cylindrical sector of the cyclone and the outer surface of the central exhaust tube, in which fluid motion is stable, without fluid trends mixing from the boundary layer with the fluid from the other areas.

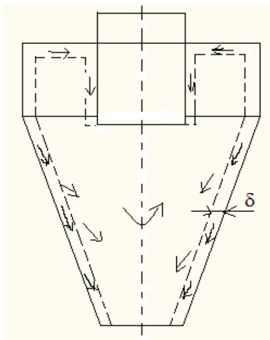


Fig. 3. The fluid flow from the boundary layer inside the cyclone.

The second region is the conical part of the cyclone in which the fluid motion from the boundary layer is unstable, with fluid elements and solid particles which are tend to move toward the center of the cyclone, and on radial direction with entrance tended in the central vortex. (Figure 3)

The geometry inlet influences the nature of the primary vortex and has a key role in the general eccentricity of the secondary vortex. The slit shaped tangential has a rectangular section and created within the cyclone a general eccentricity of the secondary vortex with the axis of symmetry of the cyclone [4].

2. MATERIALS, EQUIPMENTS AND RESEARCH METHODS

For the experimental investigations it was used the installation presented in Figure 4 composed of a centrifugal fan driven by an electric motor single phase and a cyclone with tangential entry. Measurement equipment used allowed to measure the airflow velocity in the fan input, output and exit gate of the central tube, the pressure loss from inside the pipe pneumatic conveying powdery material, mixture temperature and the quantities of solid material circulated. These measuring devices have consisted of a propeller anemometer equipped with temperature sensor, an electronic scales and a liquid-column manometer. For the airflow velocity and temperature measuring it was used the multifunctional device VT 300 which permits the air speed measuring with two probes: the hot wire anemometer and the propeller anemometer. The VT 300 is a multifunctional instrument compatible with all SMART PRO probes and with all thermocouple K temperature probes. In this case it was used the propeller anemometer.

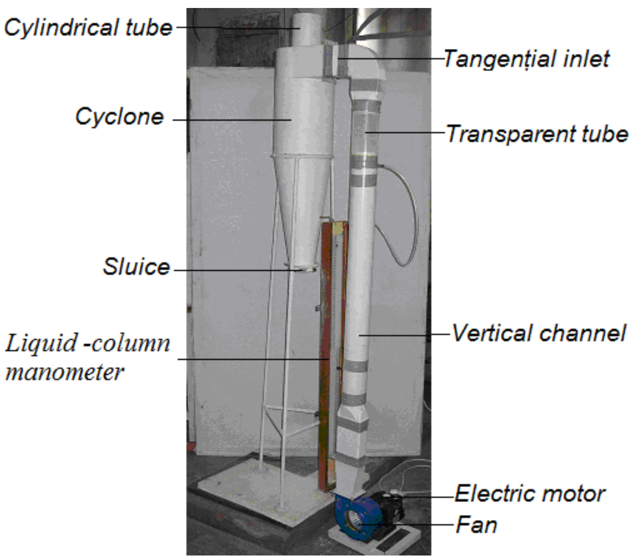
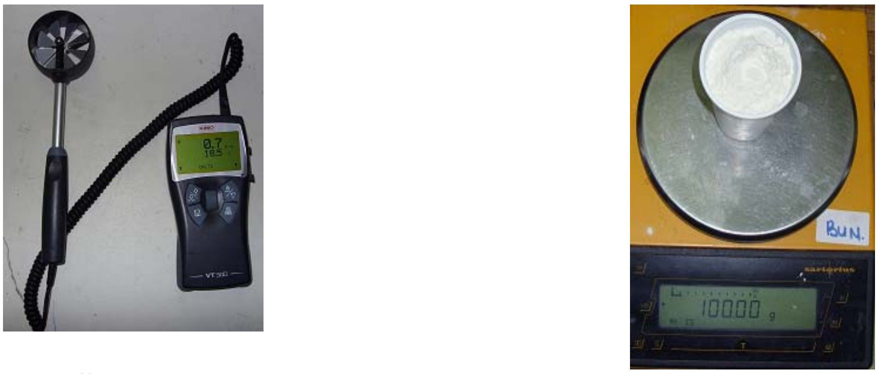


Fig. 4. Pilot plant with cyclone.



Propeller anemometer Electronic scales

Fig. 5. Measuring instruments.

The measurements of air flow velocity were performed for three values of surfaces of the cyclone inlet section (Figure 7), aiming to influence this has on the efficiency of centrifugal field separation.

Fig. 6. The samples used in research.

S_1=6608 mm^2 S_2=4928 mm^2 S_3== 2912 mm^2

Fig. 7. Sectional areas of the cyclone inlet.

For each measurement it was used 100 g of powdered material weighing with electronic scales. It was used a number of 5 samples of powdered material for each of the three areas of the inlet section in the cyclone (Figure 6).

After powdered material was introduced inside the installation, it was determined the quantities of the material recovered from the sluice, the quantities recovered from the cylindrical tube, and the quantities of losses from installation.

The determination of the separation efficiency was made by comparing the values of the quantities of material introduced in system and the values of the quantities of material recovered from the cylindrical tube.

3. RESULTS AND DISCUSSION

The results obtained from the experimental investigations for each of the three values of areas of the inlet section in the cyclone are presented in Tables 1, 2 and 3.

Table 1. Values registered for the S_1 sectional area.

S_1	m_i (g)	m_e (g)	m_{tc} (g)	m_p (g)	v_i (m/s)	v_e (m/s)	v_{et} (m/s)	p_c (mm col H_2O)	T (^0C)
P_1	100	83.02	0.32	16.66	11.4	2.6	2.8	14	18.3
P_2		89.57	0.36	10.07					
P_3		83.70	0.35	15.95					
P_4		85.48	0.27	14.25					
P_5		84.15	0.25	15.60					

Table 2. Values registered for the S_2 sectional area.

S_2	m_i (g)	m_e (g)	m_{tc} (g)	m_p (g)	v_i (m/s)	v_e (m/s)	v_{et} (m/s)	p_c (mm col H_2O)	T (^0C)
P_6	100	95.21	0.15	4.64	10	2.2	2.5	14	18
P_7		93.02	0.19	6.79					
P_8		97.68	0.12	2.2					
P_9		94.89	0.14	4.97					
P_{10}		96.23	0.18	3.59					

Table 3. Values registered for the S_3 sectional area.

S_3	m_i (g)	m_e (g)	m_{tc} (g)	m_p (g)	v_i (m/s)	v_e (m/s)	v_{et} (m/s)	p_c (mm col H_2O)	T (^0C)
P_{11}	100	84.90	0.24	14.86	9.8	2.5	2.3	14	17.5
P_{12}		83.10	0.20	16.70					
P_{13}		85.10	0.22	14.68					
P_{14}		82.14	0.23	17.63					
P_{15}		88.15	0.28	11.57					

where: S is the sectional areas of the cyclone inlet, (S_1=6608 mm^2, S_2=4928 mm^2, S_3= 2912 mm^2); m_i- mass of powdered material placed in the installation, in g; m_e- mass of material recovered from the sluice, in g; m_{tc} - mass of material ejected from the cylindrical tube, in g; m_p – losses mass of the plant, in g; v_i- input speed airflow, in m/s; v_e- speed out of sluice, in m/s; v_{et} - speed out of cylindrical tube, in m/s; p_c- airflow pressure in the pipeline, in mm col H_2O; T- Temperature, in ^0C.

Based on data obtained for the three values of sectional area of the inlet cyclone, it was drawn the chart of separation efficiency variation according to the sectional area inlet (Figure 8).

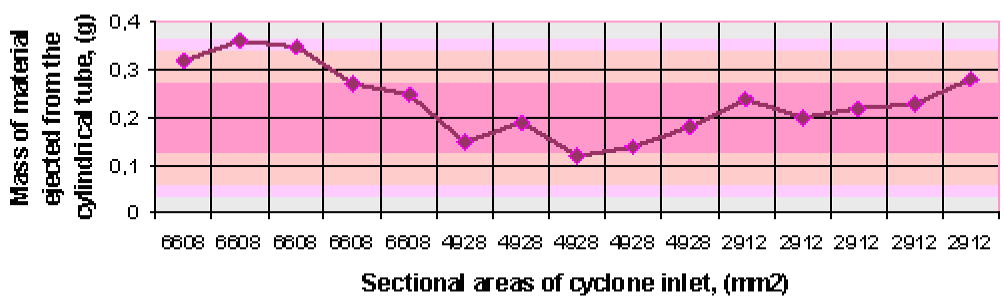


Fig. 8. Variation of separation efficiency according to the inlet sectional area.

It can be observed from these tables that for the S_2=4928 mm^2 of the sectional area of cyclone inlet, the mass material losses m_p due to leaks and the mass of material ejected from the cylindrical tube m_{tc}, it was obtained the minim values.

4. CONCLUSIONS

The literature in the field revealed that the number of parameters to be taken into account in designing a cyclone is numerous, including the type and geometry of the cyclone, the flow and geometry inlet.

In this experiment it was demonstrated the influence of surface value in the cyclone inlet section, drawing out the fact that for the installation considered the optimal value is S_2 = 4928 mm^2. Material losses in this case are the smallest, the separation is more efficient, and the resulting work can be seen in the graph of variation of separation efficiency according to the inlet sectional area.

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