Airflow Inside a Vane Separator Zigzag Deflectors

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Abstract: An experimental study of the airflow inside a vane separator zigzag deflectors is made. Experimental techniques are used in air velocity evaluation. The experimental study is done inside a vane separator system constituted by zigzag and semi-circular deflectors, built in stainless steel, placed inside an experimental module made in Perspex. The air velocity fluctuation, using hot-wire anemometry, is measured inside the zigzag deflectors. The air velocity fluctuations are used to evaluate the mean air velocity, the air velocity root mean square, the air turbulence intensity, the air velocity fluctuation equivalent frequencies and the air velocity fluctuations frequencies. In the air velocity fluctuations equivalent frequencies the analytical numerical expression is used, while in the air velocity fluctuations frequencies the power spectra is used.

Key-Words: Experimental methods, Internal airflow, Vane separator, Air velocity fluctuations, Power spectra.

1 Introduction
Vane mist eliminators are among the most effective devices used to separate liquid from a airflow. Separation efficiency of these devices is largely dependent on the airflow velocity, vane spacing and vane turning angles [1]. Vane mist eliminators are the devices that can effectively remove entrained liquid from a airflow, usually by inertial impingement [2]. In these eliminators, the wavy vanes (zigzag shaped plates) cause the airflow to move in a zigzag manner between pairs of them. The liquid drops cannot follow these changes in the direction due to their higher inertia. Thus they impinge, adhere on the solid surfaces, coalesce and, when the amount of liquid is sufficiently high, form a film which drains away under gravity [1], [2], [3] and [4]. The drops inertia and the airflow drag control the drops motion through zigzag passages. The efficiency is dependent of the airflow turning that could centrifuge drops out of the stream. Drop size, plate spacing and bend angle as well as fluid properties are important [2]. The vane’s design is crucial for the separation efficiency, and the vane may contain “pockets” where the collected fluid can drain without influence from the passing gas [5]. This paper presents the experimental study that is developed on a system for treating waste gas with a centrifugal vane mist eliminator made with stainless steel deflectors (made with a zigzag and semi-circular system).

The mean air velocity, the air velocity root mean square, the air turbulence intensity, the air velocity fluctuations equivalent frequencies and the air velocity fluctuations frequencies, inside the vane separator zigzag deflectors, influences the separation of the liquid from the airflow flow. Thus, in this work, the study of these field variables inside the vane separator zigzag deflectors is detailed analyzed. In the air velocity fluctuations equivalent frequencies the analytical numerical expression [6] and [7] is used, while in the air velocity fluctuations frequencies the power spectra is used.

2 Experimental Setup
The experimental setup, used in this test, consider a fan, a system of deflectors and a experimental module built in Perspex (see fig. 1a). In the experimental tests, an inlet air velocity of 1.185 m/s is considered and 72 points are measured (see fig. 1b).

In the experimental test a hot-wire anemometry sensor connected to a data acquisition system PXI is used, with a 1000 points for second sample rate. The obtained voltage values are converted to respective air velocity values using the King formula [8].

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The air fluctuations are measured at the inlet (1, 2, 37 and 38), between the zigzag deflectors (3, 4, 8, 9, 10, 14, 15, 16, 20, 21, 22, 26, 27, 28, 32, 33, 34, 39, 40, 44, 45, 46, 50, 51, 52, 56, 57, 58, 62, 63, 64, 68, 69 and 70), between the semi-circular deflectors (5, 6, 7, 11, 12, 13, 17, 18, 19, 23, 24, 25, 29, 30, 31, 41, 42, 43, 47, 48, 49, 53, 54, 55, 59, 60, 61, 65, 66 and 67) and at the exit (35, 36, 71 and 72).

In the inlet environmental conditions are measured the air velocity of 1.185 m/s, the air temperature of 22.2 ºC, the air velocity turbulence intensity of 1.35% and the air relative humidity of 47%.

In this work, only the information associated with the vane separator zigzag deflectors is presented.

3 Results and Discussion
In this section the air velocity field, the air velocity root mean square field, the air turbulence intensity field, the air velocity fluctuations equivalent frequencies field and the air velocity fluctuations frequencies field are presented.

3.1 Air velocity field
In fig. 2 is presented the air velocity field, V, inside the zigzag deflectors, measured experimentally at 19 different points, for an inlet air velocity of 1.185 m/s. This figure includes the air velocity fluctuations.

In accordance with the obtained results is possible to conclude that:
• The air velocity root mean square values are higher at the upstairs and downstairs corners than at the downstream points;
• The air velocity root mean square values are higher at the exit than at the beginning of the zigzag deflectors;
• The air velocity mean square values at the zigzag deflectors, in general do not significantly change, with the increase of distance.

3.2 Air velocity root mean square
Fig.3 shows the air velocity root mean square field (RMS) inside the zigzag deflectors, measured experimentally at the 19 points for an inlet air velocity of 1.185 m/s.

In accordance with the obtained results is possible to conclude that:
• The air velocity root mean square values are higher at the upstairs and downstairs corners than at the downstream points;
• The air velocity root mean square values are higher at the exit than at the beginning of the zigzag deflectors;
• The air velocity mean square values at the zigzag deflectors, in general do not significantly change, with the increase of distance.
3.3 Air turbulence intensity field
In fig. 4 is presented the air turbulence intensity (Ti) inside the zigzag deflectors, measured experimentally at the 19 points for an inlet air velocity of 1.185 m/s.

![Fig. 4 – Air turbulence intensity, Ti, values inside the zigzag deflectors, for an inlet air velocity of 1.185 m/s.](image)

In accordance with the obtained results is possible to conclude that:

- The air turbulence intensity in the zigzag deflectors, in general do not significantly change, with the increase of distance;
- The air turbulence intensity values are higher at the exit and inside the zigzag deflectors than in its beginning.

3.4 Air velocity fluctuations equivalent frequencies field
In fig. 5 is presented the air velocity fluctuations equivalent frequencies (EF) values, inside the zigzag deflectors, measured experimentally at the 19 points for an inlet air velocity of 1.185 m/s.

![Fig. 5 – Air velocity fluctuations equivalent frequencies, EF, values inside the zigzag deflectors, for an inlet air velocity of 1.185 m/s.](image)

In accordance with the obtained results is possible to conclude that:

- The air velocity fluctuations equivalent frequencies values in the zigzag deflectors, in general, do not significantly change, with the increase of distance;
- In general, the air velocity fluctuations equivalent frequencies values in the zigzag deflectors are higher at the upstairs and downstairs corners than at the downstream points.

3.5 Air velocity fluctuations frequencies field
In this section the power spectra is evaluated, inside the zigzag deflectors, measured experimentally at the 19 points for an inlet air velocity of 1.185 m/s. From figures 6 to 11 the power spectra, obtained inside the zigzag deflectors, are presented. Figure 6 is associated to the inlet and outlet area, figures 7 (first downstairs zigzag deflector), 9 (second downstairs zigzag deflector) and 11 (third downstairs zigzag deflectors) are associated to the downstairs zigzag deflectors, figure 8 (first upstairs zigzag deflector) and figure 10 (second upstairs zigzag deflector) are associated with the upstairs zigzag deflectors.

In the presented figures, the abscissa axis represents the air fluctuations frequencies, f, in Hz, and the coordinate axis represents the dimensionless energy, \( \varphi \).

![Fig. 6 – Power spectra obtained at the points 3 (inlet) and 36 (outlet), for an inlet air velocity of 1.185 m/s.](image)

![Fig. 7 – Power spectra obtained in first downstairs zigzag deflectors at the points 8 (corner) and 10](image)
(after the corner), for an inlet air velocity of 1.185 m/s.

Fig.8 – Power spectra obtained in first upstairs zigzag deflectors at the points 15 (corner) and 16 (after the corner), for an inlet air velocity of 1.185 m/s.

Fig.9 – Power spectra obtained in second downstairs zigzag deflectors at the points 20 (corner) and 22 (after the corner), for an inlet air velocity of 1.185 m/s.

Fig.10 – Power spectra obtained in second upstairs zigzag deflectors at the points 27 (corner) and 28 (after the corner), for an inlet air velocity of 1.185 m/s.

Fig.11 – Power spectra obtained in third downstairs zigzag deflectors at the points 32 (corner) and 34 (after the corner), for an inlet air velocity of 1.185 m/s.

In accordance with the obtained results is possible to conclude that:

• The airflow at the inlet is lower energetic than in the exit and inside the zigzag deflectors;
• The airflow in the first downstairs zigzag deflectors corner is higher energetic than in the downstream points, but the airflow in the second and third downstairs zigzag deflectors corners is, in general, the same that in the downstream points;
• In general, the airflow’s energy in the downstairs zigzag deflectors slightly increase along the zigzag deflectors system;
• The airflow in the first and second upstairs zigzag deflectors corner is, in general, the same that in the downstream points;
• In general, the airflow’s energy in the upstairs zigzag deflectors slightly increase along the airflow’s energy in the upstairs zigzag deflectors slightly decreases along the zigzag deflectors system;
• In general, the airflow’s energy in the zigzag deflectors slightly increases along the zigzag deflectors system.

4 Conclusions

In this study an inlet air velocity of 1.185 m/s is used in order to evaluate the influence of air velocity in the system efficiency. In this study only the information associated with the vane separator zigzag deflectors is presented. The air velocity fluctuations is used to evaluate the mean air velocity, the air velocity root mean square, the air turbulence intensity, the air velocity fluctuation equivalent frequencies and the air velocity fluctuations frequencies. In the air velocity
fluctuations equivalent frequencies the analytical numerical expression is used, while in the air velocity fluctuations frequencies the power spectra is used.

According to the results it is possible to conclude that, in general, the air velocity values, the air velocity root mean square values, the air turbulence intensity values and the air velocity fluctuations equivalent frequencies values in the zigzag deflectors do not significantly change, along the zigzag deflectors system.

In general, the airflow’s energy in the upstairs and downstairs zigzag deflectors slightly increases along zigzag deflectors system.

The airflow in the semi-circular deflectors, where the waste treatment is done, depends on the zigzag deflectors’ airflow at downstairs and upstairs corner’s downstream. The inlet airflow influence the first semi-circular deflector (turned up semi-circular deflector), the upstairs zigzag deflectors airflow influence the airflow in the third and fifth semi-circular deflectors (turned down semi-circular deflectors) and the downstairs zigzag deflectors’ airflow influence the airflow in the second and fourth semi-circular deflectors (turned up semi-circular deflectors).

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6 References


