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THE CALCULATION OF PNEUMATIC CONVEYORS

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Abstract: *The calculation of pneumatic conveyors comes down to the determination of: conveying speed, conveying pipeline diameter, necessary air flow and load losses (pressure) on the conveying track, elements which lead to the determination of air pump parameters. The conveying speed is a multiple of the floating speed, the floating speed being the speed of a vertically steered air current (upwards) in which a particle remains in balance.*

The air speed within the v_a conveying pipeline should not only be a multiple of the floating speed, but also as higher, as the pipeline equivalent length L_{echiv} is longer. The equivalent length is the length of a horizontal pipeline which shows the same pressure loss (opposes the same resistance) as the real pipeline. Conveying installations are built with constant cross-section throughout the length of the conveying pipeline, in which case the speed varies inside the pipeline in inverted ratio to the pressure.

Keywords: *conveyors, pneumatic, speed, pipeline, floating, flow, air, pressure.*

The calculation of pneumatic conveyors comes down to the determination of: conveying speed, conveying pipeline diameter, necessary air flow and load losses (pressure) on the conveying track, elements which lead to the determination of air pump parameters.

The conveying speed is a multiple of the floating speed, the floating speed being the speed of a vertically steered air current (upwards) in which a particle remains in balance.

The force with which an air current acts upon a particle is:

$$F_a = \psi \rho_a A (v_a - v_m)^2 \qquad (4.1)$$

in which:

A is the particle load-bearing surface (the surface of particle projection, perpendicular on the direction of the air current), in m^2;

Ψ – load-bearing coefficient which considers the form and nature of the particle load-bearing surface;

ρ_a – air density $\left(\rho_a = \frac{\gamma_a}{g}\right)$, in N/m^3;

γ_a – specific air weight, in N/m^3;

v_a – air speed, in m/s;

v_m – particle speed , in m/s.

Considering a spheric particle with the diameter d and specific weight γ_m, under floating conditions with $v_m = 0$, the condition of floating shall be expressed by the equation:

$$\frac{\pi d^3}{6}\gamma_m = \psi \frac{\gamma_a}{g}\frac{\pi d^2}{4}v^2{}_p$$

of which:

$$v_p = \sqrt{\frac{2d\gamma_m g}{3\psi\gamma_a}} \text{ [m/s].}$$

To a spheric particle ψ = 0,23, therefore:

$$v_p = \sqrt{\frac{28{,}4d\gamma_m}{\gamma_a}} \text{ [m/s].} \qquad (4.2)$$

for a particle of random shape, the equation (4.2) has the following form:

$$v_p = k\sqrt{\frac{28{,}4d'\gamma_m}{\gamma_a}} \text{ [m/s],} \qquad (4.3)$$

in which:
d' is the particle equivalent diameter (diameter of the sphere which has the same volume as the particle) and
k – shape coefficient (tabelul 4.1)

Tabelul 4.1

Particle shape	k
- sphere	1,0
- round shape with irregular surface	0,64
- elongated shape with irregular surface	0,57
- flattened shape	0,45

The air speed in the conveying pipeline v_a should be not only a multiple of the floating speed, but as higher, as the pipeline equivalent length L_{echiv} is longer. The use of an empirical equation such as:

$$v_a = d\sqrt{\gamma_m} + \alpha B L^2{}_{echiv} \qquad (4.4)$$

in which:
α is a coefficient which has the value 17...20 for cereal seeds and for finer granulated materials (flours) α = 22...25 is recommended;
γ_m – average particle weight, in t/m^3;
B – coefficient with values ranging between $2\cdot10^{-5}$ and $5\cdot10^{-5}$ (increases by granulation size);

L_{echiv} – equivalent length of conveying pipeline.
The equivalent length is the length of a horizontal pipeline which has the same pressure loss (opposes the same resistance) as the real pipeline.

The diameter of conveying pipeline shall be determined by using the equation which expresses the mix concentration μ (in weight) as being the ratio between the material weight (load) and the weight of air which passes through a pipeline point in the same unit of time:

$$\mu = \frac{Q}{3{,}6Av_a\gamma_a} \qquad (4.5)$$

in which:
Q is the installation flow, in t/h;
A – pipeline cross-section, in m^2;
v_a- air speed, in m/s;
γ_a – specific air weight (γ_a = ~1,2 kg/m^3).
From the equation (4.5) we can infer:

$$A = \frac{Q}{3{,}6v_a\gamma_a\mu},$$

because the conveying pipelines are of circular cross-section we can write:

$$\frac{\pi d^2{}_i}{4} = \frac{Q}{3{,}6v_a\gamma_a\mu}$$

of which

$$d_i = 0{,}6\sqrt{\frac{Q}{\mu v_a\gamma_a}} \text{ [m]} \qquad (4.6)$$

we can note that the speed v_a and specific weight γ_a are to be considered at the beginning of the pipeline for aspiration installations and at the end of the pipeline for discharge installations.

Conveying installations are mostly built with constant cross-section throughout the length of conveying pipeline, in which case the speed varies inside the pipeline in inverted ratio to the pressure (the conversions are deemed isothermal, therefore the product p·V is constant).

In this case, considering a random point in the conveying track with the paramenters p,v, γ and the atmospheric pressure point p_a,v_a,γ_a we can write the ratios:

$$\frac{v}{v_a} = \frac{p_a}{p} = \frac{\gamma_a}{\gamma}$$

therefore:

$$v = v_a \frac{p_a}{p} = v_a \frac{\gamma_a}{\gamma} \qquad (4.7)$$

the choice of the mix concentration value is made considering the nature of material and type of installation.

The air flow necessary for the conveyor is also infered from the concentration equation:

$$Q_a = Av_a = \frac{Q}{3{,}6\mu\gamma_a},$$

or by replacing the value γ_a:

$$Q_a = \frac{Q}{4{,}3\mu} \qquad (4.8)$$

in which: Q_a is the air flow considered for the air pressure.

The pressure loss (pressure drop) is calculated considering the track configuration, for example:

$$h_{tot} = h_d + h_v + h_H + h_s + h_c \text{ [mm } H_2O]$$

in which:

h_d is the dynamic pressure drop due to the mix acceleration from the null speed to the conveying speed;

h_v – static pressure drop due to level difference (on vertical areas);

h_H – pressure drop on horizontal segments;

h_s – pressure drop on separator level;

h_c – pressure drop on cyclon level.

It is customary that h_{tot} to be increased with additional pressure losses which represents 15...25% on discharge installations and 5...10% on suction installations.

The power absorbed by the discharge conveying installation can be determined considering the elementary mechanical work done by an Av air flow passing through the conveying pipeline from pressure p to pressure p + dp:

$$dL = Av\,dp$$

the total mechanical work, equivalent to the passing from pressure p_0 to p is:

$$L = \int_{p_0}^{p} Avdp$$

and considering the equation (4.7) :

$$v = v_a \frac{p_a}{p}$$

resulted:

$$L = Av_a p_a \int_{p_0}^{p} \frac{dp}{p} = Q_a p_a \ln \frac{p}{p_a}$$

because p_a=~10000daN/m^2, resulted:

$$L = 10000 Q_a \ln \frac{10000 + h_{tot}}{10000} \text{ [daNm/s]} \quad (4.9)$$

in which: Q_a is the air flow (to air pressure) used for conveying.

In case of suction installation, we obtain by analog procedure:

$$L = 10000 v_a \ln \frac{10000}{10000 - h_{tot}} \text{ [daNm/s]} \quad (4.10)$$

the power of pump driving motor is:

$$P = \frac{kL}{10^2 \eta} \text{ [kW]} \qquad (4.11)$$

in which: η is the pump output;
k=1,1 – a coefficient which considers the losses by non-sealing.

CONCLUSIONS

The conveying pipeline diameter shall be determined using the equation which expresses the μ mix concentration (in weight) as the ratio between weight material (load) and air weight which passes through a pipeline point at the same time unit. The speed v_a and specific weight γ_a are to be considered at the beginning of the pipeline for aspiration installations and at the end of the pipeline for discharge installations.

Conveying installations are mostly built with constant cross-section throughout the length of conveying pipeline, in which case the speed varies inside the pipeline in inverted ratio to the pressure (the conversions are deemed isothermal, therefore the product p·V is constant).

BIBLIOGRAPHY

I. CHELEMEN, M. CAPROIU, s.a. – Animal Husbandry Machines and Installations, E.D.P., Bucharest, 1982.