CROSS-FLOW OF AIR THROUGH SEALED ELEVATOR ENCLOSURES

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Key words: Granular Materials, Bulk Material Transfer, Air Suction, Local Exhaust Ventilation.

Abstract. Both the direction and the flow rate of ejected air in bucket elevator [1,2] enclosures that feature a separate arrangement of carrying and idle conveyor runs would depend on the ratio between ejection heads and the difference between static pressures inside the enclosures of elevator head and elevator boot. A forward motion of air (along the bucket travel direction) arises inside the enclosure of the carrying run when ejection forces prevail and inside the return run enclosure at any ejection forces differential pressures. A counterflow of air is only possible in a single enclosure.

Relative velocities and flow rates of air inside the elevator enclosures depend on two parameters, *t* and *g*, representing the ratio of differential pressures and resistances of enclosures to ejection forces.

When pressures inside the upper and lower elevator enclosures are equal. With ejection forces large enough air velocities become equal to the velocity of traveling elevator buckets.

Absolute velocities of airflows inside enclosures are dependent not only on the velocity of moving buckets but also on the differential pressure, head resistance of elevator buckets and aerodynamic drag of enclosures, as well as spillage of particles.

In the case of a forward flow pattern, air flow rate inside the return run enclosure is greater than the one inside the carrying run enclosure of the elevator conveyor. The explanation is that ejection forces arise in an opposite direction to forces caused by differential pressure inside the carrying run enclosure (both forces act in the same direction inside the return run, thus intensifying the air ejection process and boosting additional ejection forces which occur when buckets are unloaded, producing streams of spilled particles), as well as different values of the drag coefficient for empty and laden buckets.

When air moves in a counterflow pattern, ejection forces of buckets create additional drag and therefore the absolute flow rate of ascending air inside the return run enclosure, as well as descending air inside the carrying run enclosure, increase less markedly than in the forward flow case.

1 INTRODUCTION

Consider the most common case of an elevator with two buckets. Let the carrying and return runs of the elevator with buckets be located in separate sealed enclosures that will not experience cross-flows of air over their entire length. These enclosures are aerodynamically coupled only in their bottom (loading) and top (unloading) parts.

2 THE RESULTS OF THE STUDY

Let static pressure p be maintained in these parts respectively at p_k and p_n, additionally assuming that

$$p_k < p_n . \tag{1}$$

In this case air will arrive from the upper into the lower zone through the return run enclosure but will only pass through the carrying run enclosure when ejection head caused by laden buckets is lower that differential static pressure.

$$\Delta p_e \le p_n - p_k , \tag{2}$$

Then, the limit case (at $v = 0$) owing to (7.65) and (7.66) will be written as:

$$p_n - p_k > \zeta_1 \frac{v_e^2}{2} \rho \tag{3}$$

or the following inequality can be used to describe the trigger condition for ejection properties of the carrying run:

$$h_a = \frac{p_n - p_k}{\frac{v_e^2}{2} \rho} > \zeta_1 \tag{4}$$

or

$$t_1 = \frac{h_a}{M_1} \ge 1 . \tag{5}$$

Hereinafter a subscript “1” will continue to denote characteristic parameters of airflow inside the enclosure of conveyor carrying run (i.e. “1” will be substituted for index 'v', e.g. longitudinal air velocity u_1 instead of v, ζ_1 instead of ζ_v, M_1 instead of M_v etc.), whereas subscript “2” will denote longitudinal airflow in the return run enclosure (airflow velocity u_2 instead of u, parameter ζ_2 instead of ζ_u, M_2 instead of M_u etc.)

Generally (when p_n may also be less than p_k), two patterns of air cross-flows through bucket elevator enclosures are possible: a direct-flow pattern with positive velocities u_1 and u_2 and air moving in the same direction with buckets, and a combined pattern whereby airflow and bucket traveling directions are the same in one enclosure but opposite in the other (Fig. 1).

Let's determine air flow rates Q_1 and Q_2 as well as their difference:

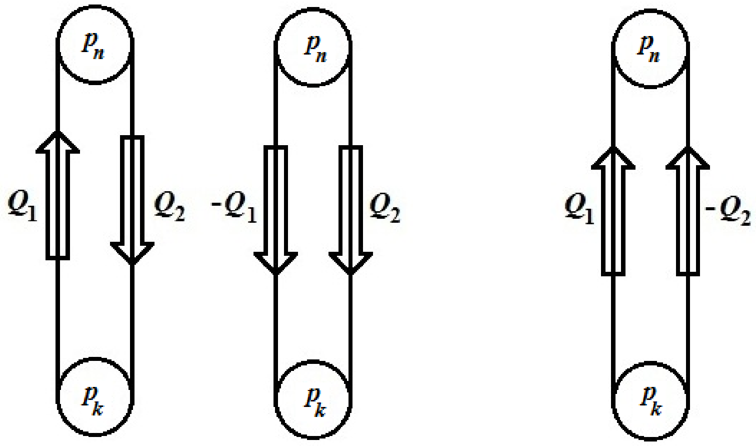
$$\Delta Q = Q_2 - Q_1 .$$

Air flow rates can also become negative, depending on the sign and magnitude of velocity vectors u_1 and u_2.

First we'll determine the flow rate Q_2. Dynamics equation (7.43) will be used to find out the flow rate in the return run enclosure. In this case static pressure at inlet and outlet of the enclosure will be expressed through pressures p_n and p_k using local resistance coefficients for air entering the enclosure (ζ_{2n}) and leaving the enclosure (ζ_{2k}).

$$p_2(0) = p_n - \zeta_{2n} \frac{u_2^2}{2} \rho , \tag{6}$$

$$p_2(l) = p_k + \zeta_{2k} \frac{u_2^2}{2} \rho . \tag{7}$$



a) At $p_n > p_k$ b) At $p_n < p_k$

Figure 1: Aerodynamic diagrams for cross-flows of air in two sealed enclosures of a bucket elevator

In view of the accepted conditions we'll rewrite equation (7.43) and expand the values of E_k and E_p based on (7.47), (7.48) and (7.52),

$$p_k - p_n + \sum \zeta_2 \frac{u_2^2}{2} \rho = M_2 \frac{|v_e - u_2|(v_e - u_2)}{2} \rho , \tag{8}$$

where $\sum \zeta_2$ is the sum total of LRCs of the enclosure.

$$\sum \zeta_2 = \zeta_{2n} + \lambda_w \frac{l}{D_w} + \zeta_{2k} , \tag{9}$$

M_2 is a parameter describing the ejection capacity of the return run of the conveyor and flow of spilled material (in accordance with formula (7.78)).

If both sides of the equation are divided by $\rho \frac{v_e}{2}$, a dimensionless equation would result:

$$-h_a + \sum \zeta_2 \varphi_2^2 = M_2 \left|1-\varphi_2\right|\left(1-\varphi_2\right), \tag{10}$$

where $\varphi_2 = \frac{u_2}{v_e}$;

$$h_a = \frac{p_n - p_k}{\rho \frac{v_e^2}{2}} = \frac{h_k - h_n}{\rho \frac{v_e^2}{2}}, \tag{11}$$

where h_k is the negative pressure maintained inside an aspirated cowl of elevator boot by an aspiration system fan (Pa); h_n is the sustained negative pressure occurring inside an unaspirated cowl of the bucket elevator head as a result of air cross-flow through the unloading chute and elevator enclosures (Pa).

The sought flow rate Q_2 is determined by an obvious relation

$$Q_2 = \varphi_2 v_e S, \tag{12}$$

where $S = a \cdot b$.

The value of φ_2 is determined with equation (10) which, owing to random nature of h_a, can be written as the following dimensionless equation:

$$h_a + M_2 \left|1-\varphi_2\right|\left(1-\varphi_2\right) = \sum \zeta_2 \varphi_2 \left|\varphi_2\right|, \tag{13}$$

or

$$t_2 = g_2 \varphi_2 \left|\varphi_2\right| - \left|1-\varphi_2\right|\left(1-\varphi_2\right), \tag{14}$$

where dimensionless numbers have been introduce to dispense with some determinant parameters:

$$t_2 = \frac{h_a}{M_2}, \tag{15}$$

$$g_2 = \frac{\sum \zeta_2}{M_2}, \tag{16}$$

representing a ratio of the available pressure and pressure losses to the total resistance that the enclosure poses to ejection head created by the bucket elevator [1].

Expanding signs of absolute values reduces equation (14) to the following three combined equations:

$$t_2 = g_2 \varphi_2^2 - \left(1-\varphi_2\right)^2 \quad \text{at } 1 \ge \varphi_2 \ge 0; \tag{17}$$

$$t_2 = -g_2 \varphi_2^2 - \left(1-\varphi_2\right)^2 \quad \text{at } -\infty < \varphi_2 \le 0; \tag{18}$$

$$t_2 = g_2 \varphi_2^2 + \left(1-\varphi_2\right)^2 \quad \text{at } +\infty > \varphi_2 \ge 1. \tag{19}$$

[1] One should keep in mind that the parameter g_2 may change as a result of possible changes in $\sum \zeta$ when the sign of φ_2 reverses.

The single-valued function $\varphi_2 = f(t_2)$ is plotted as a joint set of three parabolic arcs (Fig. 2):

$$y_1 \equiv t_2 = -\varphi_2(g_2+1)+2\varphi_2-1 \text{ at } -\infty < \frac{\varphi}{2} \le 0; \tag{20}$$

$$y_2 \equiv t_2 = -\varphi_2^2(1-g_2)+2\varphi_2-1 \text{ at } 1 \ge \varphi_2 \ge 0; \tag{21}$$

$$y_3 \equiv t_2 = -\varphi_2^2(1+g_2)-2\varphi_2+1 \text{ at } \infty > \varphi_2 \ge 1. \tag{22}$$

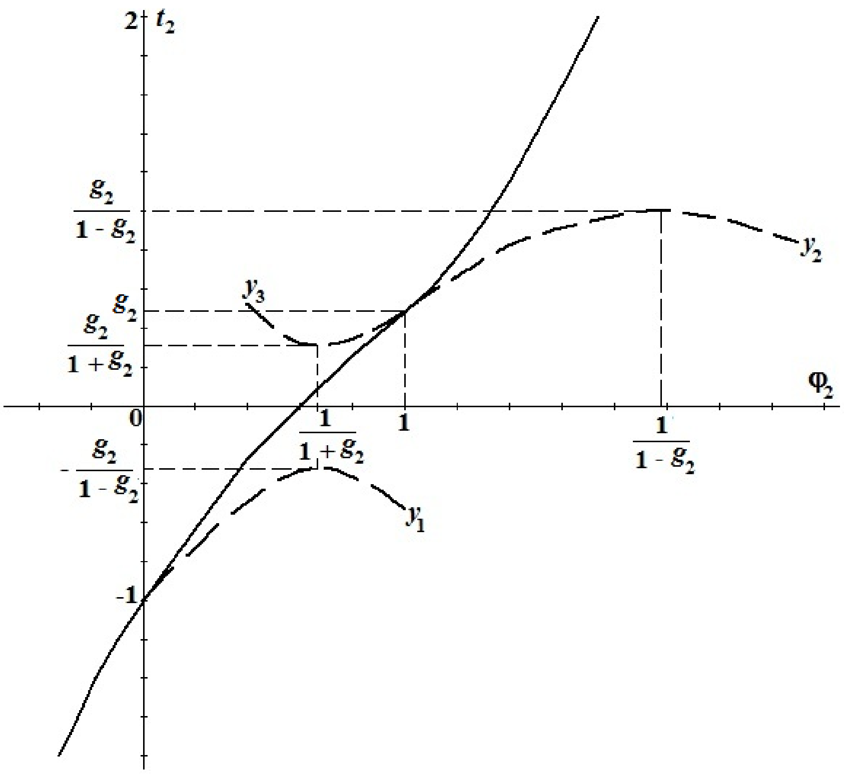


Figure 2: Variation in relative flow rate of air transferred the enclosure of elevator conveyor return run as a function of pressure transitions (solid curve – plot of single-valued function $\varphi_2 = f(t_2)$)

In order to obtain a single value for dimensionless flow rate φ_2 across the entire variation range of the parameter t_2, roots of the following equations have to be found:

$$-\varphi_2^2(1+g_2)+2\varphi_2-(1+t_2)=0 \text{ at } -\infty < t_2 < -1; \tag{23}$$

$$-\varphi_2^2(1-g_2)+2\varphi_2-(1+t_2)=0 \text{ at } g_2 > t_2 > -1; \tag{24}$$

$$\varphi_2^2(1+g_2)-2\varphi_2+(1-t_2)=0 \text{ at } \infty > t_2 > g_2. \tag{25}$$

As a result (at $g_2 < 1$),

$$\varphi_2 = \frac{1}{1+g_2}\left[1-\sqrt{1-(1+t_2)(1+g_2)}\right] \quad \text{at } -\infty < t_2 \le -1; \tag{26}$$

$$\varphi_2 = \frac{1}{1-g_2}\left[1-\sqrt{1-(1+t_2)(1-g_2)}\right] \quad \text{at } g_2 > t_2 \geq -1; \tag{27}$$

$$\varphi_2 = \frac{1}{1+g_2}\left[1+\sqrt{1-(1-t_2)(1+g_2)}\right] \quad \text{at } \infty > t_2 > g_2. \tag{28}$$

Thus, forward airflow arises in the enclosure of the return run at $t_2 > -1$ i.e. at

$$M_2 > -h_a\,. \tag{29}$$

Otherwise, at

$$M_2 < -h_a\,, \tag{30}$$

a countercurrent of air is promoted by a significant negative pressure in the upper cowl at

$$h_n > h_k + M_2\frac{v_e^2}{2}\rho\,. \tag{31}$$

Absent differential pressure $(h_n = h_k)$, φ_2 reaches its limit value:

$$\lim_{t_2\to 0}\varphi_2 = \varphi_{2pr} = \frac{1}{1+\sqrt{g_2}}\,, \tag{32}$$

which converges toward one with increasing ejection forces

$$\varphi_{2pr} \approx 1, \text{ at } M_2 >> \sum\zeta_2\,, \tag{33}$$

i.e. the velocity of air inside the return run conveyor belt enclosure of the elevator reaches the velocity of the belt only with significant ejection forces.

Let's now determine air flow rate inside the enclosure of the carrying run of the bucket elevator. To that end we'll put forward an equation for the dynamics of air in this enclosure with a compound effect of differential pressure $\Delta p = p_n - p_k$ and of ejection head created by a belt with laden buckets. It will be recognized that air velocity u_1 may turn negative at significant differential pressures. The dynamics equation for airflow in this enclosure will be put down as follows[2]:

$$M_1\left|1-\varphi_1\right|(1-\varphi_1) - h_a = \sum\zeta_1\varphi_1\left|\varphi_1\right| \tag{34}$$

or

$$t_1 = \left|1-\varphi_1\right|(1-\varphi_1) - g_1\varphi_1\left|\varphi_1\right|, \tag{35}$$

where

$$t_1 = \frac{h_a}{M_1};\; g_1 = \frac{\sum\zeta_1}{M_1}\,. \tag{36}$$

An expansion of the signs at absolute values breaks down the equation (35) into three separate ones:

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[2] It should be noted that, generally, a reversal of airflow inside elevator enclosure will also change $\sum\zeta_1$ and $\sum\zeta_2$ ($\sum\zeta_1\uparrow \neq \sum\zeta_1\downarrow$; $\sum\zeta_2\downarrow \neq \sum\zeta_2\uparrow$, arrows indicate downward ($\downarrow$) and upward ($\uparrow$) airflow direction).

$$t_1 = (1-\varphi_1)^2 + g_1\varphi_1^2 \quad \text{at } -\infty < \varphi_1 \le 0; \tag{37}$$

$$t_1 = (1-\varphi_1)^2 - g_1\varphi_1^2 \quad \text{at } 1 \ge \varphi_1 \ge 0; \tag{38}$$

$$t_1 = -(1-\varphi_1)^2 - g_1\varphi_1^2 \quad \text{at } +\infty > \varphi_1 \ge 1. \tag{39}$$

The first of these equations describes the balance of dimensionless forces in the case of downward (from top to bottom) motion of air arising as a result of a significant difference in the available static differential pressure ($\Delta p = p_n - p_k$). The ejection head of a bucket-carrying belt reduces airflow, further hindering the downward motion. When the available differential pressure is small enough (the second and third equations), an upward airflow (from bottom to top) arises. In this case it is counteracted not only by the drag of enclosure walls but also by differential pressure Δp.

The single-valued function $\varphi_1 = f(t_1)$ is plotted as a joint set of three parabolic arcs[3] (Fig. 3):

$$y_1 \equiv t_1 = (1+g_1)\varphi_1^2 - 2\varphi_1 + 1 \text{ at } -\infty < \varphi_1 \le 0; \tag{40}$$

$$y_2 \equiv t_1 = (1-g_1)\varphi_1^2 - 2\varphi_1 + 1 \text{ at } 1 \ge \varphi_1 \ge 0; \tag{41}$$

$$y_3 \equiv t_1 = -(1+g_1)\varphi_1^2 + 2\varphi_1 - 1 \text{ at } +\infty > \varphi_1 \ge 1. \tag{42}$$

Single-valued functions of dimensionless air velocity φ_1 inside the enclosure of the carrying run of the conveyor within the entire range of variations in the parameter t_1 are determined by roots of the following equations:

$$(1+g_1)\varphi_1^2 - 2\varphi_1 + (1-t_1) = 0 \text{ at } \infty > t_1 \ge 1; \tag{43}$$

$$(1-g_1)\varphi_1^2 - 2\varphi_1 + (1-t_1) = 0 \text{ at } -g_1 \le t_1 \le 1; \tag{44}$$

$$(1-g_1)\varphi_1^2 - 2\varphi_1 - (1+t_1) = 0 \text{ at } -\infty < t_1 \le -g_1, \tag{45}$$

which gives (at $g_1 < 1$):

$$\varphi_1 = \frac{1}{1+g_1}\left[1 + \sqrt{1-(1+t_1)(1+g_1)}\right] \quad \text{at } -\infty \le t_1 \le -g_1; \tag{46}$$

$$\varphi_1 = \frac{1}{1-g_1}\left[1 - \sqrt{1+(t_1-1)(1-g_1)}\right] \quad \text{at } 1 \ge t_1 \ge -g_1; \tag{47}$$

$$\varphi_1 = \frac{1}{1+g_1}\left[1 - \sqrt{1+(t_1-1)(1+g_1)}\right] \quad \text{at } \infty > t_1 \ge 1. \tag{48}$$

[3] Parabola sections outside of the range of single-valued function $t = f(\varphi)$ are shown on Fig. 3.6 as dotted lines.

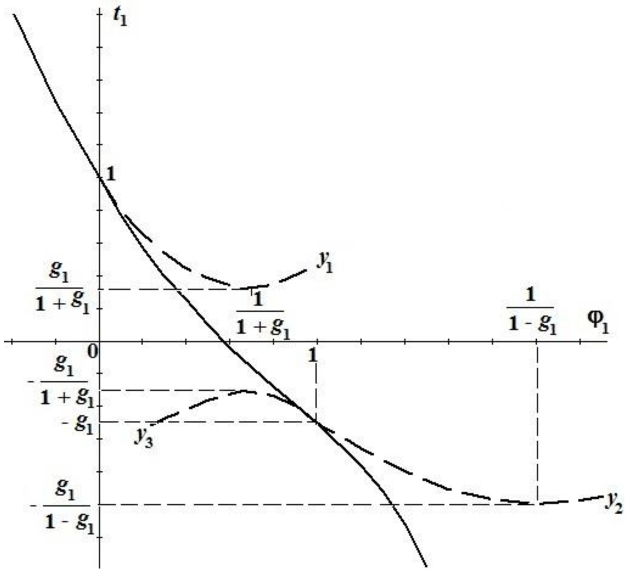

Figure 3: Variation in relative flow rate of air flowing over the enclosure of elevator conveyor carrying run as a function of differential pressure (solid curve – plot of single-valued function $\varphi_1 = f(t_1)$)

As is evident from these results, counterflow of air $(\varphi_1 < 0)$ inside the enclosure of conveyor belt carrying run may only arise at greater values of the parameter t_1, i.e. at

$$t_1 > 1\,,\ \ h_k > h_n + M_1 \frac{v_e^2}{2} \rho\,. \tag{49}$$

The limit value of dimensionless air velocity (flow rate) inside the enclosure of the conveyor carrying run (at $h_k = h_n$) is

$$\lim_{t_1 \to 0} \varphi_1 = \varphi_{1pr} = \frac{1}{1+\sqrt{g_1}} \tag{50}$$

and air velocity u_1 reaches the velocity of buckets v_e

$$\varphi_{1pr} = 1 \text{ at } M_1 >> \sum \zeta_1\,. \tag{51}$$

When static differential pressure is small ($t_1 < 1$) only the forward airflow pattern may arise inside enclosures. Airflow follows the traveling conveyor belt inside enclosures of the bucket elevator. Additionally, as a rule,

$$Q_2 > Q_1\,.$$

This is explained by the influence of ejecting capacity of spillage when grain is unloaded from buckets in the upper part of elevator, and by the difference between the drag of an empty bucket and a grain-laden bucket. In addition the available differential pressure promotes airflow inside return run enclosures while hindering it in the carrying run enclosure. The latter explains the fact that, given equal ejection forces ($M_1 = M_2$) and aerodynamic drag forces (

$\sum\zeta_1 = \sum\zeta_2$), velocities (airflows in bucket elevator enclosures) fail to equalize (Fig. 4).

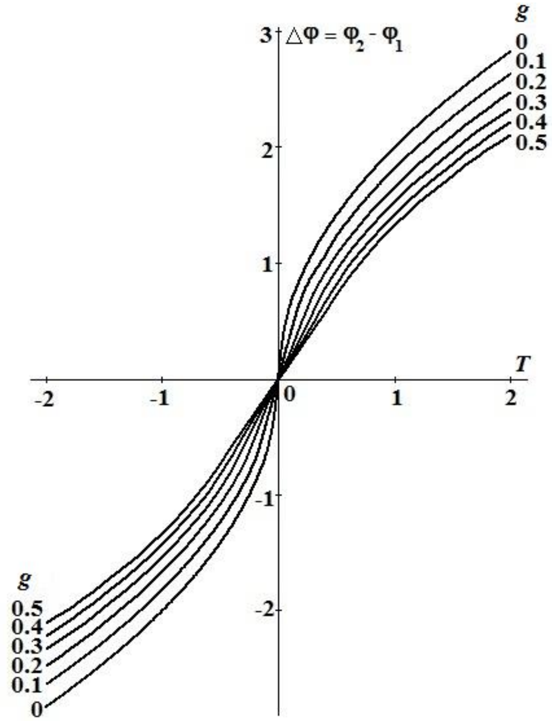

Figure 4: Changes in relative flow rate of air transferred through bucket elevator enclosures (at $t_1 = t_2 = t$, $g_1 = g_2 = g$)

In this case the difference between airflows

$$Q_2 - Q_1 = (\varphi_2 - \varphi_1) v_e S \tag{52}$$

will be either positive (at $t > 0$) or negative (at $t < 0$) and will increase in its absolute value with increasing parameter t .

Tables 1 and 2 summarize calculated values of relative air flow rates inside bucket elevator enclosures. These values have been determined using formulas (26–28) and (46–48).

These findings reveal that, within the range of low available pressures (at $t < 1$), flow rate of ascending air inside the return run enclosure declines both with increasing parameter t_2 and decreasing parameter g_2 . Within the range of high available pressures (at $t_2 > g_2$), air velocity $u_2 > v_e$. In this case the ejecting capacity of empty buckets poses additional resistance and therefore relative flow air φ_2 would decrease with increasing M_2 at unchanged Δp (and decreasing t_2).

The relative flow rate of ascending air decreases with increasing Δp inside the enclosure of the carrying run of the conveyor, and a downward airflow arises at $t_1 > 1$ (φ_1 is negative). Higher values of M_1 (decreasing t_1) result in decreased flow rate φ_1 .

Table 1: Relative air flow rate φ_2 inside the enclosure of bucket elevator return run

t_2 \ g_2	0	0.1	0.2	0.3	0.4	0.5
-2.0	-0.4142	-0.4083	-0.4027	-0.3974	-0.3923	-0.3874
-1.9	-0.3784	-0.3733	-0.3685	-0.3639	-0.3595	-0.3553
-1.8	-0.3416	-0.3374	-0.3333	-0.3295	-0.3257	-0.3222
-1.7	-0.3036	-0.3004	-0.3971	-0.2939	-0.2908	-0.2879
-1.6	-0.2649	-0.2622	-0.2596	-0.2571	-0.2546	-0.2523
-1.5	-0.2247	-0.2227	-0.2208	-0.2189	-0.2170	-0.2153
-1.4	-0.1832	-0.1818	-0.1805	-0.1791	-0.1779	-0.1766
-1.3	-0.1402	-0.1393	-0.1385	-0.1377	-0.1369	-0.1361
-1.2	-0.0954	-0.0950	-0.0946	-0.0942	-0.0938	-0.0935
-1.1	-0.0488	-0.0487	-0.0486	-0.0485	-0.0484	-0.0483
-1.0	0.000	0.000	0.000	0.000	0.000	0.000
-0.9	0.0513	0.0512	0.0510	0.0509	0.0508	0.0506
-0.8	0.1056	0.1050	0.1044	0.1038	0.1032	0.1026
-0.7	0.1633	0.1618	0.1603	0.1588	0.1574	0.1561
-0.6	0.2254	0.2222	0.2192	0.2164	0.2137	0.211
-0.5	0.2929	0.2871	0.2818	0.2768	0.3722	0.2679
-0.4	0.3675	0.3575	0.3486	0.3406	0.3333	0.3267
-0.3	0.4523	0.4352	0.4208	0.4084	0.3974	0.3875
-0.2	0.5528	0.5232	0.5000	0.4810	0.4648	0.4508
-0.1	0.6838	0.6268	0.5886	0.5596	0.5363	0.5168
0	1.000	0.7597	0.6910	0.6461	0.6126	0.5858
0.1	1.3162	1.000	0.8170	0.7435	0.6948	0.6584
0.2	1.4472	1.2240	1.000	0.8511	0.7847	0.7351
0.3	1.5477	1.3451	1.1667	1.000	0.8849	0.8168
0.4	1.6325	1.4392	1.2743	1.1300	1.000	0.9046
0.5	1.7071	1.5189	1.3604	1.2243	1.1055	1.000
0.6	1.7746	1.5894	1.4343	1.3022	1.1881	1.0883
0.7	1.8367	1.6535	1.5000	1.3700	1.2583	1.1611
0.8	1.8944	1.7120	1.5598	1.4309	1.3204	1.2244
0.9	1.9487	1.7667	1.6151	1.4867	1.3767	1.2813
1.0	2.0000	1.8182	1.5667	1.5385	1.4286	1.3333
1.1	2.0488	1.8669	1.7153	1.5869	1.4769	1.3816
1.2	2.0954	1.9132	1.7613	1.6357	1.5224	1.4268
1.3	2.1402	1.9575	1.8052	1.66761	1.5655	1.4694
1.4	2.1832	2.0000	1.8471	1.7176	1.6064	1.5099
1.5	2.2247	2.0409	1.8874	1.7573	1.6456	1.5486
1.6	2.2649	2.0804	1.9262	1.7955	1.6832	1.5856
1.7	2.3038	2.1186	1.9637	1.8323	1.7194	1.6212
1.8	2.3416	2.1556	2.0000	1.8679	1.7543	1.6555
1.9	2.3784	2.1915	2.0354	1.9024	1.7881	1.6886
2	2.4142	2.2265	2.0694	1.9358	1.8209	1.7208

Table 2: Relative air flow rate φ_1 inside the enclosure of bucket elevator carrying run

t_1 \ g_1	0	0.1	0.2	0.3	0.4	0.5
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-1.8	2.3416	2.1556	2.0000	1.8679	1.7543	1.6555
-1.7	2.3038	2.1186	1.9637	1.8323	1.7194	1.6212
-1.6	2.2649	2.0804	1.9262	1.7955	1.6832	1.5856
-1.5	2.2247	2.0409	1.8874	1.7573	1.6456	1.5486
-1.4	2.1832	2.0000	1.8471	1.7176	1.6064	1.5099
-1.3	2.1402	1.9575	1.8052	1.6761	1.5655	1.4694
-1.2	2.0954	1.9132	1.7613	1.6357	1.5224	1.4268
-1.1	2.0488	1.8669	1.7153	1.5869	1.4769	1.3816
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-0.3	1.5477	1.3451	1.1667	1.000	0.8849	0.8168
-0.2	1.4472	1.2240	1.000	0.8511	0.7847	0.7351
-0.1	1.3162	1.000	0.8170	0.7435	0.6948	0.6584
0	1.000	0.7597	0.6910	0.6461	0.6126	0.5858
0.1	0.6838	0.6268	0.5886	0.5596	0.5363	0.5168
0.2	0.5528	0.5232	0.5000	0.4810	0.4648	0.4508
0.3	0.4523	0.4352	0.4208	0.4084	0.3974	0.3875
0.4	0.3675	0.3775	0.3486	0.3406	0.3333	0.3267
0.5	0.2929	0.2871	0.2818	0.2768	0.3722	0.2679
0.6	0.2254	0.2222	0.2192	0.2164	0.2137	0.2111
0.7	0.1633	0.1618	0.1603	0.1588	0.1574	0.1561
0.8	0.1056	0.1050	0.1044	0.1038	0.1032	0.1026
0.9	0.0513	0.0512	0.0510	0.0509	0.0508	0.0506
1.0	0.000	0.000	0.000	0.000	0.000	0.000
1.1	-0.0488	-0.0487	-0.0486	-0.0485	-0.0484	-0.0483
1.2	-0.0954	-0.0950	-0.0946	-0.0942	-0.0938	-0.0935
1.3	-0.1402	-0.1393	-0.1385	-0.1377	-0.1369	-0.1361
1.4	-0.1832	-0.1818	-0.1805	-0.1791	-0.1779	-0.1766
1.5	-0.2247	-0.2227	-0.2208	-0.2189	-0.2170	-0.2153
1.6	-0.2649	-0.2622	-0.2596	-0.2571	-0.2546	-0.2523
1.7	-0.3036	-0.3004	-0.3971	-0.2939	-0.2908	-0.2879
1.8	-0.3416	-0.3374	-0.3333	-0.3295	-0.3257	-0.3222
1.9	-0.3784	-0.3733	-0.3685	-0.3639	-0.3595	-0.3553
2	-0.4142	-0.4083	-0.4027	-0.3974	-0.3923	-0.3874

CONCLUSIONS

- Both the direction and the flow rate of ejected air in bucket elevator enclosures that feature a separate arrangement of carrying and idle conveyor runs would depend on the ratio between ejection heads and the difference between static pressures inside the enclosures of elevator head and elevator boot. A forward motion of air (along the bucket travel direction) arises inside the enclosure of the carrying run when ejection forces prevail (at $\Delta\overline{p} < M_1$, $t_1 < 1$ and $\Delta\overline{p} < M_2$) and inside the return run enclosure at any ejection forces differential pressures (at $\Delta\overline{p} > -M_2$, $t_2 > -1$). A counterflow of air is only possible in a single enclosure: within the carrying run enclosure at $\Delta\overline{p} > M_1$ or within the return run enclosure at $\Delta\overline{p} < -M_2$. The other enclosure would experience a forward flow of air in this case.

- Relative velocities and flow rates of air inside the elevator enclosures depend on two parameters, t and g (14) and (35), representing the ratio of differential pressures and resistances of enclosures to ejection forces. Single-valued variables φ_1 and φ_2 within a wide range of differential pressures ($-\infty < t_1 < \infty$; $-\infty < t_2 < \infty$) can be determined using formulas (46 … 48) and (26 … 28).

When pressures inside the upper and lower elevator enclosures are equal, relative velocities reach their maxima determined by relations (50) and (32). With ejection forces large enough ($M_1 >> \sum\zeta_1$ and $M_2 >> \sum\zeta_2$) air velocities become equal to the velocity of traveling elevator buckets.

Absolute velocities of airflows inside enclosures are dependent not only on the velocity of moving buckets but also on the differential pressure, head resistance of elevator buckets and aerodynamic drag of enclosures, as well as spillage of particles.

- In the case of a forward flow pattern, air flow rate inside the return run enclosure is greater than the one inside the carrying run enclosure of the elevator conveyor. The explanation is that ejection forces arise in an opposite direction to forces caused by differential pressure inside the carrying run enclosure (both forces act in the same direction inside the return run, thus intensifying the air ejection process and boosting additional ejection forces which occur when buckets are unloaded, producing streams of spilled particles), as well as different values of the drag coefficient for empty and laden buckets.

When air moves in a counterflow pattern, ejection forces of buckets create additional drag and therefore the absolute flow rate of ascending air inside the return run enclosure, as well as descending air inside the carrying run enclosure, increase less markedly than in the forward flow case (Tables 1 and 2).

The work has been carried out with the financial support of the Grant Council of the President of the Russian Federation (project MD-95.2017.8) and RFBR (research project No. 16-08-00074a).

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