ASCERTAINING THE METHODOLOGY FOR APRON FEEDERS CALCULATION

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ABSTRACT

Aim of the present paper is the systematization and the unification of the formulae for calculation, the ascertaning of the values of the coefficients for the calculation, the proposition of new formulae for the determination of some of the apron feeders parameters, and to calculate specific apron feeders. The calculations prove the correctness of the described methodology. The results for the calculated motor power are close to the values of the installed motor power of the apron feeders, although they are manufactured by different companies.

INTRODUCTION

Apron feeders (AF) are widely used in the mining industry for the transportation of heavy and lumpy materials. They are designed for the most hard conditions of exploatation to feed the crushers at quarry and storage bins. They have capacities up to 6000 t/h and are able to transport materials with maximum lump size up to 2000 mm (Das and Sahn, Maton).

The calculation of the AF is similar to that of the apron conveyors, but there are some peculiarities. The large size of material lumps is the cause for the increase of the width of the aprons and the height of the skirts. The presence of fixed skirts cause additional resistances due to skirt friction. The presence of receiving hopper causes additional resistance due to the pressure of the material in it. The hard conditions of exploatation and the great starting resistances are the cause for the introduction of a coefficient of reserve of motor power.

BACKGROUND

The basic formulae for the AF calculation are given in most of the references (Bandov, 1973; Vasiliev, 1991; Deevski 1982, Kuzmanov, 1989; Das and Sahn, Maton). Each company manufacturing AF has it's own methodology for calculation. In the companies prospects, diagrams for the AF selection are usually given (Smidth). A complete methodology for calculation, however, is not given.

For example in (Kuzmanov, 1989) the formulae for the determinaton of the additional resistances are missing. In (Deevski, 1982) there is a formula for the calculation of the resistance from the material pressure, but formula for the values of some of the coefficients is missing, as for example the coefficient of skirt friction (given only in (Vasiliev, 1991)). Formulae for the determination of some of the parameters, as the height of the skirts and the dimensions of the hopper

opening, are not given too. Some of the formulae must be taken from the methodology for the calculation of apron conveyors, for example the formulae for the resistances in the chain sprockets given in (Deevski, 1982) and (Kuzmanov, 1989) and the the formula for the calculation of the skirt friction resistance, given in (Kuzmanov, 1973). The values of some of the coefficients must be taken from other chapters of the books and the manuals, as for example the coefficient of internal friction of the material.

Aim of the present paper is the sistematization and the unification of the formulae for calculation, the ascertaning of the values of the coefficients for the calculation, the proposition of new formulae for the determination of some of the AF parameters, and to calculate specific AF.

DETERMINATION OF THE WIDHT OF THE APRONS, THE HEIGHT OF THE SKIRTS AND THE APRON SPEED

As the transported material is lumpy, it's maximum lump size will determine the apron width B [m]. For the determination of B, the known formula [3,5]: $B = 0,0017.a_{max} + 0,2$ is used, and then the next standart width is assumed. The companies manufacturing AF usually give in tables the apron width B in accordance to a_{max} (Smidth) (Table 1). If the input a_{max} is not in the table, B is chosen for the nearest greater a_{max} .

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a _{max} [mm]	315	400	500	650	800	1000	1250	1600
B [m]	0,8	1	1,25	1,4	1,6	1,8	2	2,5
h [m]	0,5	0,6	0,8	1	1,1	1,2	1,3	1,8

Formula for the determination of the height of the skirts h for the AF is not given in the references. In (Kuzmanov, 1989) is given h for apron conveyors (h = 150-300 mm), but in AF h is

much greater. From table 1 it is seen, that h can be determined approximately by the formula:

$$h = 0,65.B, m$$
 (1)

When the parameters B and h are determined, the apron speed v is determined by the known formula for the capacity (Bandov, 1973; Deevski, 1982; Kuzmanov, 1989):

$$v = \frac{Q_h}{3600.B.h.p.\psi.c}$$
, m/s (2)

where:

Qh [t/h] – capacity of the AF;

 ρ [t/m³] – density of the transported material;

 $\psi = 0.75 - \text{extraction efficiency factor;}$

 $c = \frac{100 - \beta}{100}$ - inclination factor (β [°] – angle of inclination).

The coefficient c must be taken into account, because the AF feeding the cushers are inclined (usually $\beta = 15 \div 25^{\circ}$) (Das and Sahn; Maton; The PHB Weserhutte). The reason for the inclination is the facilitation of truck discharge and the protection of the crusher from the material direct fall into it.

The apron speed is limited to 0,25 m/s (Das and Sahn), and in some cases – to 0,4 m/s (Deevski, 1982). The reasons for the limitation are the great dynamic loads in the track chains and the high abrasion wear of the aprons. If the calculated speed is greater than the limited, the skirt height *h* must be increased. The contemporary drives of the AF allow variation of the speed in the work diapason v = 0,03-0,16 m/s (Das and Sahn, Smidth, The PHB Weserhutte ...) for different capacities. This is realized with the use of variable speed DC, AC and hydraulic motors.

There are AF, which are used to feed the belt conveyor after the crusher (Kuzmanov, 1973; The PHB Weserhutte ...). They transport material with small lump size and with angle of inclination - 0° . For them the apron width B must be determined by the formula (2), and the coefficient c=1.

DETERMINATION OF THE TRACK RESISTANCES AND THE MOTOR POWER

The track resistances are classified in three groups (Bandov, 1973; Vasiliev, 1991; Maton): resistance from the apron movement and the lift of the material W₁, resistance from the skirt friction of the material W₂ and resistance from the internal friction of the material, as a result of the material's pressure in the hopper – W₃. The resistance W₁ [N] is a sum of the resistances in the loaded strand W_{1s}, in the bottom strand W_{bs}, in the drive chain sprockets W_{dcs} and in the return chain sprockets W_{rcs}. They are determined by the known formulae (Vasiliev, 1991; Deevski, 1982; Kuzmanov, 1989):

$$\begin{split} & W_{1} = W_{IS} + W_{bS} + W_{dCS} + W_{rCS} \\ & W_{IS} = L.(q_{0} + q_{m})(w_{0}.\cos\beta + \sin\beta) \\ & W_{bS} = L.q_{0}.(w_{0}.\cos\beta - \sin\beta) \\ & W_{rCS} = k_{1}.S_{2} \\ & W_{dCS} = k_{2}.(S_{1} + S_{4}) \end{split}$$

where:

L [m] – feeder length;

 $q_0 = (A + 60.B)g$ [N/m] – linear weight of the aprons;

A = 150 – coefficient for heavy duty work (Vasiliev, 1991; Kuzmanov, 1989);

$$\begin{split} q_{m} &= \frac{Q_{h}.g}{3,6.v} \quad [\text{N/m}] - \text{linear weight of the material}; \\ w_{o} &= 0,03 \div 0,04 - \text{apron movement loss factor}; \\ S_{1}, S_{2}, S_{3} \text{ is } S_{4} \quad [\text{N}] - \text{tensile forces in the chains}; \\ S_{2} &= S_{min} = 3000 \text{ N}; \\ S_{3} &= S_{2} + k_{1}.S_{2}; \\ S_{4} &= S_{3} + W_{IS}; \\ S_{1} &= S_{2} - W_{bs}; \\ k_{1} &= 0,07 - \text{traction loss factor in the drive chain sprockets}; \\ \kappa_{2} &= 0,05 - \text{traction loss factor in the return chain sprockets}. \end{split}$$

The resistance W₂ is determined by the formula (Kuzmanov, 1973):

$$W_{2} = \frac{k_{m}.\rho.g.L.h^{2}.f.1000}{\cos^{2}\beta}$$
 [N] (4)

where:

$$\kappa_{m} = \frac{1 - \sin(\phi_{O})}{1 + \sin(\phi_{O})}$$
 - coefficient of paticles mobility;

 $\phi_{O} = arctg(\mu_{O})$ [°] – angle of the intenal friction of the material;

 μ_0 – coefficient of the internal friction of the material (μ_0 = 0,7÷0,75 for ore and μ_0 = 0,5 ÷ 0,1 for coal (Kuzmanov, 1989); f - coefficient of skirt friction of the material (f = 0,7 for ore, f = 0,56 for rock and f = 0,5 ÷0,9 for coal [2]);

The resistance W₃ is determined by the formula (Deevski, 1982):

$$W_3 = P \cdot \mu_0 [N] \tag{5}$$

where:

 $P = \frac{F_0.R_X.\rho.g.1000}{k_{\Pi}.\mu_0} \quad [N] - \text{ force from the material}$

pressure in the hopper;

 $F_0 = C.D.10^{-6}$ [m²] –effective section of the hopper opening;

 $R_{X} = \frac{(C - a_{max})(D - a_{max})}{2.(C + D - 2.a_{max}) \cdot 1000} \quad [m] - hydraulic radius$

of the hopper opening;

C, D [mm] – dimensions of the hopper opening.

Folmulae for the determination of the dimensions C and D are not given in the literature. But from the data for the manufactured AF, the following formulae can be written:

$$C = (B - 0.05).1000$$
 [mm]
 $D = n.C$ [mm] (6)

where:

 $n = 1,2 \div 1,5 - ratio of the hopper opening dimensions.$

From the three resistances the corresponding powers N₁, N₂, N₃ and the total motor power N are determined:

$$N_1 = \frac{W_1, v}{1000.\eta}$$
$$N_2 = \frac{W_2, v}{1000.\eta}$$

$$N_3 = \frac{VV_3, V}{1000.\eta} \ [kW] \tag{7}$$

 $N = N_1 + N_2 + N_3 \ [kW] \tag{8}$

where:

 η = 0,8 - drive efficiency (Kuzmanov, 1989).

CHECK OF THE PROPOSED FORMULAE FOR THE CALCULATION OF SPECIFIC AF

With data from (Deevski, 1982; Das and Sahn; Maton; Smidth; The PHB Weserhutte), calculations for AF are made. The results are given in Table 2. For the calculations, the coefficients are assumed: μ_0 = 0,7, f = 0,7, w₀ = 0,03 and n=1,2

Table.2

		-	-		-	-
Nº	1	2	3	4	5	6
a _{max} [mm]	500	700	1200	1500	1500	1500
B [m]	1,2	1,5	2	2,4	2,4	2,6
Q _h [t/h]	780	800	450	2700	6000	1500
v [m/s]	0,4	0,13	0,055	0,12	0,32	0,04
β [°]	25	22	23	26	22	15
h [m]	0,6	1	1,4	1,8	1,8	2,2
ρ [t/m ³]	1,4	1,9	1,4	2,6	2	2,8
L [m]	7	3,8	10,2	23,6	21	15
N1 [kW]	10	5	7	108	184	24
N ₂ [kW]	4	2	4	68	117	20
N ₃ [kW]	7	6	4	24	50	12
N [kW]	21	13	15	200	351	56
N _i [kW]	30	29	17	180	530	65
kp	1,4	2,2	1,4		1,4	1,2
reference	(Deevski, 1982)	(Das and Sahn)	(Smidth)	(The PHB Weser- hutte)	(Maton)	(Maton)

The power of the installed motor N_i is greater than the calculated power N by formula (8) (Table 2). The ratio $k_r = \frac{N_i}{N}$ is the coefficient of reserve, which is in the range 1,2 - 2,2 (only for the forth AF, N > N_i). The three calculated motor powers (formulae (7)) are related as: N1 > N2 > N3. Only for the short AF (the first and the second from Table 2), N3 > N2.

INFLUENCE OF THE APRON SPEED AND THE VALUES OF SOME OF THE COEFFICIENTS ON THE MOTOR POPWER

The calculations how, that with he increse of the apron speed v (at constant apron width B and decrease of the skirt height h), the necessary motor power N is almost not changed. For the sixth Af from Table 2, when the speed is increaed two tmes (from 0,04 to 0,08 m/s) and the skirt height is dereased two times (from 2,2 to 1,1 m), for the total power N is obtained N=58 kW (N₁ = 23 kW, N₂ = 25 kW and N₃ = 10 kW), or the increase is only 2 kW.

The influence of the coefficients μ_0 , f, n and w_0 for the same AF is shown in Tables 3-6. From Tables 4,5 and 6 it is seen, that when f, n and w_0 are increased – N is increased, and from Table 3 - when μ_0 is increased – N is decreased. The variation of the power N however is small, when different coefficients are used.

Table.3

μο	0,6	0,7	0,8
N [kW]	58	56	55

able.4				
f	0,6	0,7	0,8	0,9
N [kW]	53	56	58	62

Table.5

n	1,2	1,3	1,5
N [kW]	56	58	62

Table.6

Wo	0,03	0,04
N [kW]	56	57

CONCLUSIONS

The calculations prove the correctness of the described methodology. The results for the calculated motor power are close to the values of the installed motor power of the AF, although they are manufactured by different companies.

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