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НЕТРАДИЦІЙНІ ВИДИ ТРАНСПОРТУ. МАШИНИ ТА МЕХАНІЗМИ

UDC 621.867.3

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RESEARCH OF INFLUENCING OF PROJECT DISCRIPTIONS OF ELEVATOR ON PARAMETERS OF ITS DRIVE

Purpose. One of basic elements of band bucket elevators is their drive. For determination of power drive it is necessary to conduct calculations on standard by methods, in what it is needed to expend enough time. One of project parameters is productivity of elevator. It is necessary to build parametric dependence of power drive of elevator on its design capacity that takes into account a type and descriptions of load, lifting height, standard sizes and parameters of buckets and tapes. **Methodology.** Using the method of hauling calculation of band buckets elevators, the parametric dependences of power drive of high-speed elevators are built with deep and shallow buckets from their productivity at fixed type of load and height of getting up. **Findings.** It is set on the basis of the built parametric dependences that the change function of a size of elevator power from design capacity (at fixed to the lifting height, load type, rate of tape movement) is piecewise and droningly increasing. The intervals of project values of productivity, which provide the permanent size of elevator power drive are certain in a general view. As the example of application of the recived results the construction process of power drive dependence from design capacity of elevator of shotblasting room, which is intended for transporting of the metallic shot using for consolidating of carriage springs, is considered. For concrete type of load and lifting height of such elevator graphic dependence of power drive on productivity was built. **Originality.** Parametric dependences of elevator power drive on its design capacity were first built, which take into account a type and physical and mechanical descriptions of load, lifting height, standard sizes and parameters of buckets and tapes. **Practical value.** The use of the built dependences enables in relation to rapid determination of approximate value of power drive of vertical high-speed elevators with deep and shallow buckets on the stage of planning and to execute the high-quality selection of its basic elements at concrete project descriptions: type of load, productivity, lifting height.
Keywords: elevator; bucket; drive; power; productivity; load

Introduction

Today it is hard to imagine any industry field without the use of transporting cars. Machines of continuous transport are the basis of complex mechanization of cargo handling and industrial process. They increase the work productivity and production efficiency. The bucket belt elevators are the separate type of continuous transport machines. The elevators are lifts of vertical action

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and used for vertical and high-angle (angle 60−82 °) transportation of bulk and manufactured cargo without intermediate loading and unloading. The use of elevators as an intermediate means of transport makes it possible to have a compact transport scheme, which occupies small space. They are used in the chemical, metallurgical, machine-building industry, production of construction materials, coal preparation plants, food plants and in granaries.

The main publications that describe the structure, design features, operational and design values of the elevators are [3, 4, 5, 6, 7, 9, 10]. It is necessary to calculate the reels, the traction unit (tapes), traction calculation and to perform the selection of the main elements of the driving unit for determination the parameters of elevator drive, and in particular its capacity. The order of performing such calculations are described in detail in [6, 7]. But, the definite part of time is spent during the attraction of such elevator drive calculation methodology. For the process of elevator drive design improvement, it is desirable to have a scheme which allows simplifying calculations to determine the desired value for the drive power depending on design capacity in a particular type of cargo and the height of its ascent.

Purpose

The aim of this work is building of a parametric dependence of the elevator power drive from its design capacity, which takes into account the type and characteristics of the cargo, lifting height, standard dimensions and parameters of the buckets and tapes.

Methodology

The value of the drive power of the elevator depends on many parameters. The main parameters are: type of cargo, design capacity and lifting height. For further study we will define the basic components of the overall calculation of the elevator which in varying degrees depends on design capacity. These include: linear capacity of buckets (capacity and disposed step of the buckets); width, number of strips and linear weight of tape; the required distributed weight of the load; linear load on the working branch; draft force on the drive drum.

Linear capacity of elevator buckets:

$$\frac{i_0}{t} = \frac{P}{3,6v\rho\psi} = \frac{P}{\alpha}, \quad (1)$$

where $\alpha = 3,6v\rho\psi$ – value, that takes into account the properties of the transported cargo, t•m/l•h; ψ – coefficient of bucket charge (according to the physical and mechanical properties of cargo); t – disposed step of buckets, m; ρ – cargo density, t/m3; v – tape speed, m/s.

According to the meaning of linear capacity of the elevator bucket that is calculated by the formula (1) the type and disposed step of buckets are selected by the table 1 [7]. The selection of bucket type depends on the material properties that is transported. The deep buckets are used for easily granular, powdered and small parts of cargoes; shallow – for difficult bulk materials.

With the aim of taking into account the subsequent calculations of the physical and mechanical properties of the cargo that is transported, we'll build a correspondent table of the elevator parameters, defined in table 1, the value of performance, expressed by the formula (1) in parts of the coefficient α. The obtained data will be posted in tables 2 and 3 for elevators with deep and shallow buckets accordingly.

On the basis of design value capacity of the elevator productivity and the type of transported material, parameters of the bucket, the step of their disposition on the tape, and the necessary width of the tape are selected by tables 2 and 3. Characteristics of deep and shallow bucket (width, the bucket outreach, bucket height and capacity) are shown in table 4.

The tapes of State standart 23831-79, State standart 20-85 are used in the bucket elevator as the traction units. The rubber and fabric tapes of State standart 20-85 type BKNL-150 are accepted as a traction units of bucket elevator for the determination of further researches. The actual number of tape strips can be 3, 4, 5, 6.

The thickness of the tape is determined by the formula

$$\delta_s = \delta_r + i\delta_p + \delta_n, \quad (2)$$

where $\delta_r = 3$ mm, $\delta_n = 1,5$ mm is the thickness of the rubber plates with working and non-working sides of the tape; $\delta_p = 1,6$ mm is the thickness of one fabric strip. i is the number of strips.

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Table 1

Value of linear capacity of buckets

Bucket width B_k, mm	Tape width B, mm	Disposed step of the bucket t, mm	Bucket			
			deep		shallow	
			i_0, l	$\frac{i_0}{t}$, l/m	i_0, l	$\frac{i_0}{t}$, l/m
100	125	200	0,2	1	0,1	0,5
125	150	320	0,4	1,3	0,2	0,66
160	200	320	0,6	2	0,35	1,17
200	250	400	1,3	3,24	0,75	1,87
250	300	400	2,0	5	1,4	3,5
320	400	500	4,0	8	2,7	5,4
400	500	500	6,3	12,6	4,2	8,4
500	650	630	12	19	–	–
650	800	630	18	28,6	–	–
800	1000	800	32	40	–	–
1 000	1 200	800	45	56,25	–	–

Table 2

Dependence of parameters of deep buckets on the productivity to the elevator

Bucket width B_k, mm	Tape width B, mm	Disposed step of buckets t, mm	Bucket capacity i_0, л	Elevator effectiveness, t/h
100	125	200	0,2	α
125	150	320	0,4	1,3α
160	200	320	0,6	2α
200	250	400	1,3	3,24α
250	300	400	2,0	5α
320	400	500	4,0	8α
400	500	500	6,3	12,6α
500	650	630	12	19α
650	800	630	18	28,6α
800	1 000	800	32	40α
1 000	1 200	800	45	56,25α

Table 3

Dependence of parameters of shallow buckets on the productivity to the elevator

Bucket width B_k, mm	Tape width B, mm	Disposed step of buckets t, mm	Bucket capacity i_0, л	Elevator effectiveness, t/h
100	125	200	0,1	0,5α
125	150	320	0,2	0,66α
160	200	320	0,35	1,17α

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End of table 3

Bucket width B_k, mm	Tape width B, mm	Disposed step of buckets t, mm	Bucket capacity i_0, л	Elevator effectiveness, t/h
200	250	400	0,75	1,87α
250	300	400	1,4	3,5α
320	400	500	2,7	5,4α
400	500	500	4,2	8,4α

Table 4

Description of buckets to the elevator

Type of the bucket	Internal sizes of the bucket, mm				Capacity of the bucket, l
	width B_k	departure A_k	hight	R	
Curved deep D	100	50	65	25	0,1
	100	75	80	25	0,2
	125	90	95	30	0,4
	160	105	110	35	0,6
	200	125	135	40	1,3
	250	140	150	45	2,0
	320	175	190	55	4,0
	400	195	210	60	6,3
	500	235	255	75	12
	650	250	275	80	18
	800	285	325	85	32
	1 000	310	355	95	45
Curved shallow S	125	65	85	30	0,2
	160	75	100	35	0,35
	200	95	130	40	0,75
	250	120	160	55	1,4
	320	145	190	70	2,7
	400	170	220	85	4,2

The weight of one meter of tape is determined by the formula

$$q_s = 10^{-6} B\delta_s\rho_s g, \qquad (3)$$

where $\rho_s = 1100$ kg/m3 is a density of the tape.

Using the formula (2) and (3) for calculation, we presented the table of width and linear weight of tape with different number of stripes and its compliance of elevator productivity for deep and shallow buckets.

Distributed weight per 1 m of the tape is determined by the formula:

$$q_v = \frac{Pg}{3{,}6v} = \beta P, \qquad (4)$$

where $\beta = \frac{g}{3,6v}$ is the coefficient, which depends on the speed tape, N•s/kg•m.

The dependence of the distributed weight of the cargo from the design capacity is calculated by the formula (4) and shown in table 7.

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Table 5

Linear weight of ribbons for deep buckets

Width of tape B, mm	Linear weight of tape when $i=3$, N/m	Linear weight of tape when $i=4$, N/m	Linear weight of tape when $i=5$, N/m	Linear weight of tape when $i=6$, N/m	Elevator effectiveness, t/h
125	12,5	14,7	16,8	19,0	α
150	15,0	17,6	20,2	22,8	1,3α
200	20,1	23,5	27,0	30,4	2α
250	25,1	29,4	33,7	38,0	3,24α
300	30,1	35,3	40,4	45,6	5α
400	40,1	47,0	53,9	60,8	8α
500	50,1	58,8	67,4	76,0	12,6α
650	65,2	76,4	87,6	98,8	19α
800	80,2	94,0	107,8	121,6	28,6α
1 000	100,3	117,5	134,8	152,0	40α
1 200	120,3	141,	161,7	182,4	56,25α

Table 6

Linear weight of ribbons for shallow buckets

Width of tape B, mm	Linear weight of tape when $i=3$, N/m	Linear weight of tape when $i=4$, N/m	Linear weight of tape when $i=5$, N/m	Linear weight of tape when $i=6$, N/m	Elevator effectiveness, t/h
125	12,5	14,7	16,8	19,0	0,5α
150	15,0	17,6	20,2	22,8	0,66α
200	20,1	23,5	27,0	30,4	1,17α
250	25,1	29,4	33,7	38,0	1,87α
300	30,1	35,3	40,4	45,6	3,5α
400	40,1	47,0	53,9	60,8	5,4α
500	50,1	58,8	67,4	76,0	8,4α

Linear weight of tape with buckets is determined by the formula

$$q_{\text{h}} = q_{\text{s}} + \frac{m_{\text{k}} g}{t}, \quad (5)$$

where m_{k} is bucket weight, kg (table 8).

Linear load on working branch is given by:

$$q_{\text{r}} = q_{\text{h}} + q_{\text{v}}. \quad (6)$$

Tentative mass of deep and shallow buckets are shown in table 8 [7].

Using the formula (5)-(6) and taking into account the data of table 8, we define the linear dependence of the load on the working branch of the elevator from the performance values in the deep and shallow buckets. The results of the calculations for tapes with different numbers of stripes are shown in tables 9, 10.

Traction calculation of bucket tape elevator is performed by the method of the outline traversing, the basic principle of which is the revelation of the characteristic points of the route where the change in tension of the tape takes place.

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Table 7

Distributed weight of load

Width of tape B_k, mm	Distributed weight during the elevator work with shallow buckets, N/m	Elevator productivity with sallow buckets, N/m	Distributed weight during the elevator work with deep buckets, N/m	Elevator effectiveness with deep buckets, N/m
100	0,5αβ	0,5α	αβ	α
125	0,66αβ	0,66α	1,3αβ	1,3α
160	1,17αβ	1,17α	2αβ	2α
200	1,87αβ	1,87α	3,24αβ	3,24α
250	3,5αβ	3,5α	5αβ	5α
320	5,4αβ	5,4α	8αβ	8α
400	8,4αβ	8,4α	12,6αβ	12,6α
500	–	–	19αβ	19α
650	–	–	28,6αβ	28,6α
800	–	–	40αβ	40α
1 000	–	–	56,25αβ	56,25α

Table 8

Tentative mass of buckets to the elevator

Bucket weight, mm	Wall thickness, mm	The weight of one bucket, kg	
		Deep	Shallow
100	2	0,5	0,4
125	2	0,7	0,6
160	2	0,9	0,7
200	3	2	1,5
250	3	3	2
320	3	5	5
400	4	11	10
500	5	18	–
650	5	23	–
800	6	28	–
1 000	6	33	–

Table 9

The linear loading on a working branch at deep bucket

Bucket width B_k, mm	Distributed cargo weight q_v, N/m	Linear load on the working branch in tape with $i = 3$ q_r, N/m	Linear load on the working branch in tape with $i = 4$ q_r, N/m	Linear load on the working branch in tape with $i = 5$ q_r, N/m	Linear load on the working branch in tape with $i = 6$ q_r, N/m	Elevator effective-ness, t/h
100	αβ	37+αβ	39,2+αβ	41,3+αβ	43,5+αβ	α
125	1,3αβ	36,4+1,3αβ	39+1,3αβ	41,6+1,3αβ	44,2+1,3αβ	1,3α
160	2αβ	47,7+2αβ	51,1+2αβ	54,6+2αβ	58+2αβ	2α

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End of table 9

Bucket width B_k, mm	Distributed cargo weight q_v, N/m	Linear load on the working branch in tape with $i=3$ q_r, N/m	Linear load on the working branch in tape with $i=4$ q_r, N/m	Linear load on the working branch in tape with $i=5$ q_r, N/m	Linear load on the working branch in tape with $i=6$ q_r, N/m	Elevator effective-ness, t/h
200	3,24αβ	74,1+3,24αβ	78,4+3,24αβ	82,7+3,24αβ	87+3,24αβ	3,24α
250	5αβ	103,6+5αβ	108,8+5αβ	113,9+5αβ	119,1+5αβ	5α
320	8αβ	138,1+8αβ	145+8αβ	151,1+8αβ	158+8αβ	8α
400	12,6αβ	265,7+12,6αβ	274,4+12,6αβ	283+12,6αβ	291,6+12,6αβ	12,6α
500	19αβ	345,2+19αβ	356,4+19αβ	367,6+19αβ	378,8+19αβ	19α
650	28,6αβ	438+28,6αβ	451,8+28,6αβ	465,6+28,6αβ	479,4+28,6αβ	28,6α
800	40αβ	443,3+40αβ	460,5+40αβ	477,8+40αβ	495+40αβ	40α
1 000	56,25αβ	524,6+56,3αβ	545,3+56,3αβ	566+56,3αβ	586,7+56,3αβ	56,25α

Table 10

The linear loading on a working branch at shallow bucket

Bucket width B_k, mm	Distributed cargo weight q_v, N/m	Linear load on the working branch in tape with $i=3$ q_r, N/m	Linear load on the working branch in tape with $i=4$ q_r, N/m	Linear load on the working branch in tape with $i=5$ q_r, N/m	Linear load on the working branch in tape with $i=6$ q_r, N/m	Elevator effective-ness, t/h
100	0,5αβ	32,1+0,5αβ	34,3+0,5αβ	36,4+0,5αβ	38,6+0,5αβ	0,5α
125	0,66αβ	33,4+0,66αβ	36+0,66αβ	37,8+0,66αβ	40,4+0,66αβ	0,66α
160	1,17αβ	41,5+1,17αβ	44,9+1,17αβ	48,4+1,17αβ	51,8+1,17αβ	1,17α
200	1,87αβ	61,9+1,87αβ	66,2+1,87αβ	70,5+1,87αβ	74,8+1,87αβ	1,87α
250	3,5αβ	79,1+3,5αβ	84,3+3,5αβ	89,4+3,5αβ	94,6+3,5αβ	3,5α
320	5,4αβ	138,1+5,4αβ	145+5,4αβ	151,1+5,4αβ	158+5,4αβ	5,4α
400	8,4αβ	246,1+8,4αβ	254,8+8,4αβ	263,4+8,4αβ	272+8,4αβ	8,4α

In addition the tension in the next point ($i+1$) is the sum of the tape tension in the point (i) and the resistance of the tape movement on the section between these points:

$$S_{i+1} = S_i + W_{i,i+1}. \quad (7)$$

In case of a drum drive speed (Fig. 1) by clockwise the minimum tension will be at the point 2 – S_2. Such tension in the tape at normal material scooping satisfies the condition:

$$S_2 = S_{\min} \geq 5q_v. \quad (8)$$

The strength of the tension at the point 3 consists of a resistance force on the drum and resistance of cargo scooping W_{2-3}:

$$S_3 = kS_2 + W_{2-3}, \quad (9)$$

where $k = 1,08$ is the coefficient of tension increase in the tape with buckets during the drum rounding .

Resistance of scooping material is determined by the formula

$$W_{2\text{-}3} = \frac{k_z q_v}{g}, \quad (10)$$

where k_z is the coefficient of scooping (Nm/kg), which is determined by the specific work, that is expended on scooping of 1 kg material. When the speed of buckets is $v = 1,0...1,25$ m/s, $k_z = 12,5...25$ Nm/kg for pulverous and small pieces materials and $k_z = 20...40$ N/m for middle pieces materials.

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Thus, substituting the formulas (8) and (10) in (9) we have:

$$S_3 = q_v \left(5,4 + \frac{k_z}{g} \right). \quad (11)$$

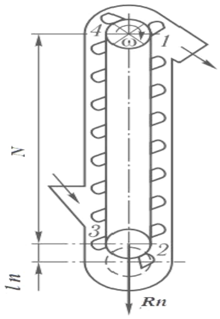

Fig. 1. Chart tape bucket of the elevator

Choosing the meaning $k_z = 25$ Nm/kg (it satisfies all cargoes) we have:

$$S_3 = 7,95 q_v . \quad (12)$$

The tension forces in the points 1 and 4 are determined by the formulas:

$$S_4 = S_{nb} = S_3 + W_{3-4} = 7,95 q_v + q_r H , \quad (13)$$

$$S_1 = S_{zb} = S_2 + W_{2-1} = 5 q_v + q_h H , \quad (14)$$

where H – height of cargo lifting, m.

The dependence of the tension forces values at the point 4, calculated by the formula (13), from the value of design capacity, the type of bucket and the number of strips of tape are summarized in tables 11−12:

Table 11

The strength of tension in a point 4 at deep buckets

Bucket width B_k, mm	The strength of tension in the tape with $i = 3$ S_4, N	The strength of tension in the tape with $i = 4$ S_4, N	Elevator effectiveness, t/h
100	37N+αβ(7,95+N)	39,2N+αβ(7,95+N)	α
125	36,4N+1,3αβ(7,95+N)	39N+1,3αβ(7,95+N)	1,3α
160	47,7N+2αβ(7,95+N)	51,1N+2αβ(7,95+N)	2α
200	74,1N+3,24αβ(7,95+N)	78,4N+3,24αβ(7,95+N)	3,24α
250	103,6N+5αβ(7,95+N)	108,8N+5αβ(7,95+N)	5α
320	138,1N+8αβ(7,95+N)	145N+8αβ(7,95+N)	8α
400	265,7N+12,6αβ(7,95+N)	274,4N+12,6αβ(7,95+N)	12,6α
500	345,2N+19αβ(7,95+N)	356,4N+19αβ(7,95+N)	19α
650	438N+28,6αβ(7,95+N)	451,8N+28,6αβ(7,95+N)	28,6α
800	443,3N+40αβ(7,95+N)	460,5N+40αβ(7,95+N)	40α
1 000	524,6N+56,3αβ(7,95+N)	545,3N+56,3αβ(7,95+N)	56,25α

Continuation of table 11

The strength of tension in a point 4 at deep buckets

Bucket width B_k, mm	The strength of tension in the tape with $i = 5$ S_4, N	The strength of tension in the tape with $i = 6$ S_4, N	Elevator effectiveness, t/h
100	41,3N+αβ(7,95+N)	43,5N+αβ(7,95+N)	α
125	41,6N+1,3αβ(7,95+N)	44,2N+1,3αβ(7,95+N)	1,3α
160	54,6N+2αβ(7,95+N)	58N+2αβ(7,95+N)	2α
200	82,7N+3,24αβ(7,95+N)	87N+3,24αβ(7,95+N)	3,24α
250	113,9N+5αβ(7,95+N)	119,1N+5αβ(7,95+N)	5α
320	151,1N+8αβ(7,95+N)	158N+8αβ(7,95+N)	8α
400	283N+12,6αβ(7,95+N)	291,6N+12,6αβ(7,95+N)	12,6α

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End of table 11

Bucket width B_k, mm	The strength of tension in the tape with $i=5$ S_4, N	The strength of tension in the tape with $i=6$ S_4, N	Elevator effectiveness, t/h
500	367,6N+19αβ(7,95+N)	378,8N+19αβ(7,95+N)	19α
650	465,6N+28,6αβ(7,95+N)	479,4N+28,6αβ(7,95+N)	28,6α
800	477,8N+40αβ(7,95+N)	495N+40αβ(7,95+N)	40α
1000	566N+56,3αβ(7,95+N)	586,7N+56,3αβ(7,95+N)	56,25α

Table 12

The strength of tension in a point 4 at shallow buckets

Bucket width B_k, mm	The strength of tension in the tape with $i=3$ S_4, N	The strength of tension in the tape with $i=4$ S_4, N	Elevator effectiveness, t/h
100	32,1N+0,5αβ(7,95+N)	34,3N+0,5αβ(7,95+N)	0,5α
125	33,4N+0,66αβ(7,95+N)	36N+0,66αβ(7,95+N)	0,66α
160	41,5N+1,17αβ(7,95+N)	44,9N+1,17αβ(7,95+N)	1,17α
200	61,9N+1,87αβ(7,95+N)	66,2N+1,87αβ(7,95+N)	1,87α
250	79,1N+3,5αβ(7,95+N)	84,3N+3,5αβ(7,95+N)	3,5α
320	138,1N+5,4αβ(7,95+N)	145N+5,4αβ(7,95+N)	5,4α
400	246,1N+8,4αβ(7,95+N)	254,8N+8,4αβ(7,95+N)	8,4α

End of table 12

The strength of tension in a point 4 at shallow buckets

Bucket width B_k, mm	The strength of tension in the tape with $i=5$ S_4, N	The strength of tension in the tape with $i=6$ S_4, N	Elevator effectiveness, t/h
100	36,4N+0,5αβ(7,95+N)	38,6N+0,5αβ(7,95+N)	0,5α
125	37,8N+0,66αβ(7,95+N)	40,4N+0,66αβ(7,95+N)	0,66α
160	48,4N+1,17αβ(7,95+N)	51,8N+1,17αβ(7,95+N)	1,17α
200	70,5N+1,87αβ(7,95+N)	74,8N1,87αβ(7,95+N)	1,87α
250	89,4N+3,5αβ(7,95+N)	94,6N+3,5αβ(7,95+N)	3,5α
320	151,1N+5,4αβ(7,95+N)	158N+5,4αβ(7,95+N)	5,4α
400	263,4N+8,4αβ(7,95+N)	272N+8,4αβ(7,95+N)	8,4α

The dependence of the values of the tension forces at the point 1 is calculated by the formula (14) the value of design capacity, the type of bucket and the number of strips of tape are summarized in tables 13-14.

Table 13

The strength of tension in a point 1 at deep buckets

Bucket width B_k, mm	The strength of tension in the tape with $i=3$ S_1, N	The strength of tension in the tape with $i=4$ S_1, N	The strength of tension in the tape with $i=5$ S_1, N	The strength of tension in the tape with $i=6$ S_1, N	Elevator effectiveness, t/h
100	37N+5αβ	39,2N+5αβ	41,3N+5αβ	43,5N+5αβ	α
125	36,4N+6,5αβ	39N+6,5αβ	41,6N+6,5αβ	44,2N+6,5αβ	1,3α
160	47,7N+10αβ	51,1N+10αβ	54,6N+10αβ	58N+10αβ	2α
200	74,1N+16,2αβ	78,4N+16,2αβ	82,7N+16,2αβ	87N+16,2αβ	3,24α

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End of table 13

Bucket width B_k, mm	The strength of tension in the tape with $i=3$ S_1, N	The strength of tension in the tape with $i=4$ S_1, N	The strength of tension in the tape with $i=5$ S_1, N	The strength of tension in the tape with $i=6$ S_1, N	Elevator effectiveness, t/h
250	103,6N+25αβ	108,8N+25αβ	113,9N+25αβ	119,1N+25αβ	5α
320	138,1N+40αβ	145N+40αβ	151,1N+40αβ	158N+40αβ	8α
400	265,7N+63αβ	274,4N+63αβ	283N+63αβ	291,6N+63αβ	12,6α
500	345,2N+95αβ	356,4N+95αβ	367,6N+95αβ	378,8N+95αβ	19α
650	438N+143αβ	451,8N+143αβ	465,6N+143αβ	479,4N+143αβ	28,6α
800	443,3N+200αβ	460,5N+200αβ	477,8N+200αβ	495N+200αβ	40α
1 000	524,6N+281,5αβ	545,3N+281,5αβ	566N+281,5αβ	586,7N+281,5αβ	56,25α

Table 14

The strength of tension in a point 1 at shallow buckets

Bucket width B_k, mm	The strength of tension in the tape with $i=3$ S_1, N	The strength of tension in the tape with $i=4$ S_1, N	The strength of tension in the tape with $i=5$ S_1, N	The strength of tension in the tape with $i=6$ S_1, N	Elevator effectiveness, t/h
100	32,1N+2,5αβ	34,3N+2,5αβ	36,4N+2,5αβ	38,6N+2,5αβ	0,5α
125	33,4N+3,3αβ	36N+3,3αβ	37,8N+3,3αβ	40,4N+3,3αβ	0,66α
160	41,5N+5,85αβ	44,9N+5,85αβ	48,4N+5,85αβ	51,8N+5,85αβ	1,17α
200	61,9N+9,35αβ	66,2N+9,35αβ	70,5N+9,35αβ	74,8N+9,35αβ	1,87α
250	79,1N+17,5αβ	84,3N+17,5αβ	89,4N+17,5αβ	94,6N+17,5αβ	3,5α
320	138,1N+27αβ	145N+27αβ	151,1N+27αβ	158N+27αβ	5,4α
400	246,1N+42αβ	254,8N+42αβ	263,4N+42αβ	272N+42αβ	8,4α

Traction force with regard to the resistance to rotation of the drive drum is determined by the formula

$$F_0 = S_4 - S_1 + (k'-1)(S_4 + S_1), \qquad (15)$$

where $k' = 1,08$ is the coefficient of resistance to the drive drum rotation.

After the algebraic transformations in formula (15) we have:

$$F_0 = 1,08S_4 - 0,92S_1. \qquad (16)$$

The value of traction force with regard to the resistance to rotation of the drive drum depending on the values of the design capacity, the type of bucket (deep and shallow) and the number of tape strips are summarized in table 15-16:

Table 15

Traction force on a drive drum at deep bucket

Bucket width B_k, mm	Traction force of the tape with $i=3$ F, N	Traction force of the tape with $i=4$ F, N	Elevator effectiveness, t/h
100	5,9N+αβ(4+1,08N)	6,3N+αβ(4+1,08N)	α
125	5,82N+1,3αβ(4+1,08N)	6,2N+1,3αβ(4+1,08N)	1,3α
160	7,63N+2αβ(4+1,08N)	8,2N+2αβ(4+1,08N)	2α
200	11,9N+3,24αβ(4+1,08N)	12,5N+3,24αβ(4+1,08N)	3,24α
250	16,6N+5αβ(4+1,08N)	17,4N+5αβ(4+1,08N)	5α
320	22,1N+8αβ(4+1,08N)	23,2N+8αβ(4+1,08N)	8α
400	42,5N+12,6αβ(4+1,08N)	43,9N+12,6αβ(4+1,08N)	12,6α

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End of table 15

Traction force on a drive drum at deep buckets

Bucket width B_k, mm	Traction force of the tape with $i=3$ F, N	Traction force of the tape with $i=4$ F, N	Elevator effectiveness, t/h
500	55,2N+19αβ(4+1,08N)	57N+19αβ(4+1,08N)	19α
650	70,1N+28,6αβ(4+1,08N)	72,3N+28,6αβ(4+1,08N)	28,6α
800	70,9N+40αβ(4+1,08N)	73,7N+40αβ(4+1,08N)	40α
1 000	83,9N+56,3αβ(4+1,08N)	87,2N+56,3αβ(4+1,08N)	56,25α
Bucket width B_k, mm	Traction force of the tape with $i=5$ F, N	Traction force of the tape with $i=6$ F, N	Elevator effectiveness, t/h
100	6,6N+αβ(4+1,08N)	7N+αβ(4+1,08N)	α
125	6,7N+1,3αβ(4+1,08N)	7,1N+1,3αβ(4+1,08N)	1,3α
160	8,7N+2αβ(4+1,08N)	9,3N+2αβ(4+1,08N)	2α
200	13,2N+3,24αβ(4+1,08N)	13,9N+3,24αβ(4+1,08N)	3,24α
250	18,2N+5αβ(4+1,08N)	19,1N+5αβ(4+1,08N)	5α
320	24,2N+8αβ(4+1,08N)	25,3N+8αβ(4+1,08N)	8α
400	45,3N+12,6αβ(4+1,08N)	46,7N+12,6αβ(4+1,08N)	12,6α
500	58,8N+19αβ(4+1,08N)	60,6N+19αβ(4+1,08N)	19α
650	74,5N+28,6αβ(4+1,08N)	76,7N+28,6αβ(4+1,08N)	28,6α
800	76,4N+40αβ(4+1,08N)	79,2N+40αβ(4+1,08N)	40α
1 000	90,6N+56,3αβ(4+1,08N)	93,9N+56,3αβ(4+1,08N)	56,25α

Table 16

Traction force on a drive drum at shallow buckets

Bucket width B_k, mm	Traction force of the tape with $i=3$ F, N	Traction force of the tape with $i=4$ F, N	Elevator effectiveness, t/h
100	5,1N+αβ(4+1,08N)	5,5N+αβ(4+1,08N)	0,5α
125	5,3N+1,3αβ(4+1,08N)	5,8N+1,3αβ(4+1,08N)	0,66α
160	6,6N+2αβ(4+1,08N)	7,2N+2αβ(4+1,08N)	1,17α
200	9,9N+3,24αβ(4+1,08N)	10,6N+3,24αβ(4+1,08N)	1,87α
250	12,7N+5αβ(4+1,08N)	13,5N+5αβ(4+1,08N)	3,5α
320	22,1N+8αβ(4+1,08N)	23,2N+8αβ(4+1,08N)	5,4α
400	39,4N+12,6αβ(4+1,08N)	40,8N+12,6αβ(4+1,08N)	8,4α

Continuation of table 16

Traction force on a drive drum at shallow buckets

Bucket width B_k, mm	Traction force of the tape with $i=5$ F, N	Traction force of the tape with $i=6$ F, N	Elevator effectiveness, t/h
100	5,8N+αβ(4+1,08N)	6,2N+αβ(4+1,08N)	0,5α
125	6,0N+1,3αβ(4+1,08N)	6,5N+1,3αβ(4+1,08N)	0,66α
160	7,7N+2αβ(4+1,08N)	8,3N+2αβ(4+1,08N)	1,17α
200	11,3N+3,24αβ(4+1,08N)	12N+3,24αβ(4+1,08N)	1,87α

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End of table 16

Bucket width B_k, mm	Traction force of the tape with $i=5$ F, N	Traction force of the tape with $i=6$ F, N	Elevator effectiveness, t/h
250	14,3N+5αβ(4+1,08N)	15,1N+5αβ(4+1,08N)	3,5α
320	24,2N+8αβ(4+1,08N)	25,3N+8αβ(4+1,08N)	5,4α
400	42,1N+12,6αβ(4+1,08N)	43,5N+12,6αβ(4+1,08N)	8,4α

Kinematic chart of the elevator drive is shown in Fig. 2.

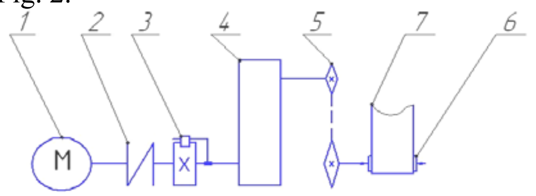

Fig. 2. Chart of the elevator drive:
1 – engine; *2* – elastic clutch; *3* – stopping device (arresting); *4* – reducing gear; *5* – chain transmission; *6* – drive drum; *7* – tape

The coefficient of the drive useful effect performance duty is determined by the formula:

$$\eta = \eta_r \eta_l \eta_m , \qquad (17)$$

where $\eta_r = 0{,}96$ – coefficient of the reducing gear useful effect performance duty; $\eta_l = 0{,}95$ – coefficient of the chain transmission useful effect performance duty; $\eta_m = 0{,}98$ – coefficient of the sleeve useful effect performance duty.

Therefore

$$\eta = \eta_r \eta_l \eta_m = 0{,}96 \cdot 0{,}95 \cdot 0{,}98 = 0{,}89 .$$

The power of the engine is determined by the formula

$$P = \frac{F_o v}{1\,000\eta} . \qquad (18)$$

Design power of the engine is determined by the formula

$$P_r = n_u P , \qquad (19)$$

where $n_u = 1{,}1...1{,}2$ – margin of power coefficient.

As far as $\eta = 0{,}89$ and $n_u = 1{,}1$, then from the formula (18) and (19) we receive:

$$P_r = \frac{F_o v}{1\,000\eta} = 0{,}001 F_o v . \qquad (20)$$

The dependence of the calculated engine power from the values of the design capacity, the type of bucket, the number of tape strips , the speed of belt movement and the lifting height of the load is calculated by the formula (20) that based on the data tables 15-16 are summarized in tables 17-18:

Table 17

Design engine power at deep buckets

Bucket width B_k, mm	Engine power when the tape is $i=3$ P, W	Engine power when the tape is $i=4$ P, W	Elevator effectiveness, t/h
100	(5,9N+αβ(4+1,08N))v	(6,3N+αβ(4+1,08N))v	α
125	(5,82N+1,3αβ(4+1,08N))v	(6,2N+1,3αβ(4+1,08N))v	1,3α
160	(7,63N+2αβ(4+1,08N))v	(8,2N+2αβ(4+1,08N))v	2α
200	(11,9N+3,24αβ(4+1,08N))v	(12,5N+3,24αβ(4+1,08N))v	3,24α
250	(16,6N+5αβ(4+1,08N))v	(17,4N+5αβ(4+1,08N))v	5α
320	(22,1N+8αβ(4+1,08N))v	(23,2N+8αβ(4+1,08N))v	8α
400	(42,5N+12,6αβ(4+1,08N))v	(43,9N+12,6αβ(4+1,08N))v	12,6α
500	(55,2N+19αβ(4+1,08N))v	(57N+19αβ(4+1,08N))v	19α
650	(70,1N+28,6αβ(4+1,08N))v	(72,3N+28,6αβ(4+1,08N))v	28,6α
800	(70,9N+40αβ(4+1,08N))v	(73,7N+40αβ(4+1,08N))v	40α
1 000	(83,9N+56,3αβ(4+1,08N))v	(87,2N+56,3αβ(4+1,08N))v	56,25α

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End of table 17

Design engine power at deep buckets

Bucket width B_k, mm	Engine power when the tape is $i = 5$ P, W	Engine power when the tape is $i = 6$ P, W	Elevator effective-ness, t/h
100	(6,6N+αβ(4+1,08N))v	(7N+αβ(4+1,08N))v	α
125	(6,7N+1,3αβ(4+1,08N))v	(7,1N+1,3αβ(4+1,08N))v	1,3α
160	(8,7N+2αβ(4+1,08N))v	(9,3N+2αβ(4+1,08N))v	2α
200	(13,2N+3,24αβ(4+1,08N))v	(13,9N+3,24αβ(4+1,08N))v	3,24α
250	(18,2N+5αβ(4+1,08N))v	(19,1N+5αβ(4+1,08N))v	5α
320	(24,2N+8αβ(4+1,08N))v	(25,3N+8αβ(4+1,08N))v	8α
400	(45,3N+12,6αβ(4+1,08N))v	(46,7N+12,6αβ(4+1,08N))v	12,6α
500	(58,8N+19αβ(4+1,08N))v	(60,6N+19αβ(4+1,08N))v	19α
650	(74,5N+28,6αβ(4+1,08N))v	(76,7N+28,6αβ(4+1,08N))v	28,6α
800	(76,4N+40αβ(4+1,08N))v	(79,2N+40αβ(4+1,08N))v	40α
1 000	(90,6N+56,3αβ(4+1,08N))v	(93,9N+56,3αβ(4+1,08N))v	56,25α

Table 18

Design engine power at shallow buckets

Bucket width B_k, mm	Engine power when the tape is $i = 3$ P, W	Engine power when the tape is $i = 4$ P, W	Elevator effectiveness, t/h
100	(5,1N+αβ(4+1,08N))v	(5,5N+αβ(4+1,08N))v	0,5α
125	(5,3N+1,3αβ(4+1,08N))v	(5,8N+1,3αβ(4+1,08N))v	0,66α
160	(6,6N+2αβ(4+1,08N))v	(7,2N+2αβ(4+1,08N))v	1,17α
200	(9,9N+3,24αβ(4+1,08N))v	(10,6N+3,24αβ(4+1,08N))v	1,87α
250	(12,7N+5αβ(4+1,08N))v	(13,5N+5αβ(4+1,08N))v	3,5α
320	(22,1N+8αβ(4+1,08N))v	(23,2N+8αβ(4+1,08N))v	5,4α
400	(39,4N+12,6αβ(4+1,08N))v	(40,8N+12,6αβ(4+1,08N))v	8,4α

End of table 18

Design engine power at shallow buckets

Bucket width B_k, mm	Engine power when the tape is $i = 5$ P, W	Engine power when the tape is $i = 6$ P, W	Elevator effectiveness, t/h
100	(5,8N+αβ(4+1,08N))v	(6,2N+αβ(4+1,08N))v	0,5α
125	(6,0N+1,3αβ(4+1,08N))v	(6,5N+1,3αβ(4+1,08N))v	0,66α
160	(7,7N+2αβ(4+1,08N))v	(8,3N+2αβ(4+1,08N))v	1,17α
200	(11,3N+3,24αβ(4+1,08N))v	(12N+3,24αβ(4+1,08N))v	1,87α
250	(14,3N+5αβ(4+1,08N))v	(15,1N+5αβ(4+1,08N))v	3,5α
320	(24,2N+8αβ(4+1,08N))v	(25,3N+8αβ(4+1,08N))v	5,4α
400	(42,1N+12,6αβ(4+1,08N))v	(43,5N+12,6αβ(4+1,08N))v	8,4α

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Findings

Analyse the impact of the design capacity of the elevator shotblasting room to the power of necessary drive should be conducted. Shotblasting room is used to strengthen the metal springs of car by the method of shot peening. For automation work of such room the elevator is used, that transports the spent shot in feed hopper of shotblasting machine of the rotary type. The steel shot of State standart 3184-95 with diameter of 1,2-1,4 mm is used for the strengthen of the springs. Given the physical and mechanical properties of steel shot (can be attributed to hard-running granular bulk cargo), the tape elevator with disposed buckets and centrifugal unloading was selected. The speed of the tape is $v = 1,45$ m/s; the fill factor bucket $\psi = 0,6$; $\rho = 7,2$ t/m3 is the shot density in accordance with State standart 3184–95; lifting height of the load $H = 4,5$ m.

Under these conditions, the coefficients are equal to:

$$\alpha = 3,$$

$$6v\rho\psi = 3,6 \cdot 1,45 \cdot 7,2 \cdot 0,6$$

$$= 22,55 \text{ t} \cdot \text{m/l per h};$$

$$\alpha\beta = 3,6v\rho\psi \frac{g}{3,6v} = \rho\psi g .$$

$$= 7,2 \cdot 0,6 \cdot 9,8 = 42,34 \text{ N/m}^3$$

The dependence of the design power of the electric drive motor of an elevator from the design capacity are shown in table 19.

Given the standard values of three-phase asynchronous briefly closed motors power of 4A series with synchronous rotation speed of 1000 rpm, table of design capacity and necessary engine power correspondence was built for the elevator drive of shotblasting room.

Table 19

Design engine power at deep buckets

Bucket width B_k, mm	Engine power when the tape is $i = 3$ P, W	Engine power when the tape is $i = 4$ P, W	Engine power when the tape is $i = 5$ P, W	Engine power when the tape is $i = 6$ P, W	Elevator effectiveness, t/h
100	5 382,0	585,0	587,0	589,6	22,55
125	745,0	747,6	750,8	753,4	29,31
160	1 137,7	1 141,4	1 144,6	1 148,6	45,1
200	1 840,0	1 843,9	1 848,5	1 853,1	73,1
250	2 828,0	2 833,2	2 838,4	2 844,3	112,75
320	4 495,7	4 502,9	4 509,4	4 516,6	180,4
400	7 130,9	7 140,1	7 149,2	7 158,3	284,1
500	10 695,0	10 706,8	10 718,5	10 730,2	428,45
650	16 014,0	16 028,4	16 042,8	16 057,1	644,9
800	22 220,2	22 238,4	22 256,1	22 274,3	902
1 000	31 171,2	31 192,7	31 214,9	31 236,4	1 268,4

Table 20

Engine power at deep buckets

Bucket width B_k, mm	Engine power P, kW	Type of engine	Elevator effectiveness, t/h
100	0,75	4A80A6U3	22,55
125	1,1	4A80B6U3	29,31
160	1,5	4A90L6U3	45,1

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End of table 20

Bucket width B_k , mm	Engine power P , kW	Type of engine	Elevator effectiveness, t/h
200	2,2	4A100L6U3	73,1
250	3,0	4A112MA6U3	112,75
320	5,5	4A132S6U3	180,4
500	11,0	4A160S6U3	428,45
650	18,5	4A180M6U3	644,9
800	30	4A200M6U3	902
1 000	37	4A225M6U3	1 268,4

Analyzing the results of calculations presented in table 20, we conclude that the dependence of the power drive of the elevator from its design capacity (at fixed lifting height, type of cargo, the speed of movement of the tape) in general is a piecewise continuous monotonically increasing function that is continuous on the left side at the point of rupture. In this case values effectiveness given in the last column of the table 20 should be considered where the power value changes and equals to the corresponding value given in the second column of the table 20. But to the value 29,31 t/h capacity is equal to 0,75 kW due to the minimality of such power in a number of engines of this class. The graph of the capacity of the elevator drive shotblasting room on the value of design capacity was built according to the results of calculations (Fig. 3).

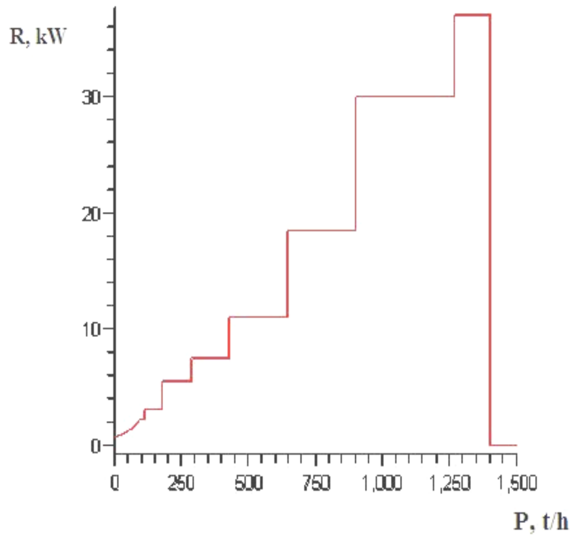

Fig. 3. Dependence of the elevator drive power from the productivity

Originality and Practical value

A parametric dependence of the elevator power drive from its design capacity was built, and it takes into account the type and characteristics of the load, the lifting height, standard dimensions and parameters of the buckets and tapes.

Using the built dependencies enables relatively fast to determine an approximate value of power over the vertical speed elevators with deep and shallow buckets and perform the high-quality selection of its key elements by specific design characteristics: type of load, productivity, lifting height.

On the bases of the proposed approach the impact of the design capacity of the elevator shotblasting room to the required drive was analysed.

Conclusions

The parametric dependence of the values of drive power from its design capacity was built for the bucket tapes elevators. It gives the opportunity to obtain the necessary value of drive power based on the type and physical and mechanical properties of cargoes, the value of the lifting height and design capacity, using only one formula for calculation. The obtained results of the power drive generation process from the expected capacity of the elevator shotblasting room, which is designed to strengthen the car springs are used as an example of attracting. According to the standard of bucket parameters and characteristics of electric motors, the parametric and graphic dependences of drive power from the design capacity was built for

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such type of elevators. It is proved that the function changes of the elevator capacity value from design capacity (at fixed lift height, type of cargo and the speed of the tape) are piecewise continuous and monotonically increasing.

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ДОСЛІДЖЕННЯ ВПЛИВУ ПРОЕКТНОЇ ПРОДУКТИВНОСТІ ЕЛЕВАТОРУ НА ПОТУЖНІСТЬ ЙОГО ПРИВОДУ

Мета. Одним із основних елементів стрічкових ковшових елеваторів є їх привід. Для визначення потужності приводу необхідно провести розрахунки за стандартними методиками, для чого потрібно витратити достатньо часу. Одним із проектних параметрів є продуктивність елеватору. В статті необхідно побудувати параметричну залежність потужності приводу елеватору від його проектної продуктивності, яка

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враховує тип та характеристики вантажу, висоту підйому, стандартні розміри і параметри ковшів та стрічок. **Методика.** Використовуючи методику тягового розрахунку стрічкових ківшевих елеваторів, побудовані параметричні залежності потужності приводу швидкохідних елеваторів із глибокими та мілкими ковшами від їх продуктивності при фіксованому типі вантажу та висоті підйому. **Результати.** На основі побудованих параметричних залежностей встановлено, що функція зміни величини потужності елеватору від проектної продуктивності (при фіксованих висоті підйому, типу вантажу, швидкості руху стрічки) є кусково-сталою та монотонно зростаючою. Визначені в загальному вигляді інтервали проектних значень продуктивності, які забезпечують постійну величину потужності приводу елеватору. В якості прикладу залучення отриманих результатів розглянуто процес побудови залежності потужності приводу від проектної продуктивності елеватору дробометної камери, який призначений для транспортування металевого дробу, що використовується при зміцненні вагонних пружин. Для конкретних типу вантажу та висоти підйому такого елеватору побудовано графічну залежність потужності його приводу від продуктивності. **Наукова новизна.** Вперше виведені параметричні залежності потужності приводу елеватору від його проектної продуктивності, які враховують тип та фізико-механічні характеристики вантажу, висоту підйому, стандартні розміри та параметри ковшів і стрічок. **Практична значимість.** Використання побудованих залежностей дає можливість відносно швидкого визначення приблизного значення потужності приводу вертикальних швидкохідних елеваторів із глибокими та мілкими ковшами на стадії проектування. Також можливим є виконання якісного підбору його основних елементів при конкретних проектних характеристиках: тип вантажу, продуктивність, висота підйому.

Ключові слова: елеватор; ківш; привід; потужність; продуктивність; вантаж

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ИССЛЕДОВАНИЕ ВЛИЯНИЯ ПРОЕКТНЫХ ХАРАКТЕРИСТИК ЭЛЕВАТОРА НА ПАРАМЕТРЫ ЕГО ПРИВОДА

Цель. Одним из основных элементов ленточных ковшовых элеваторов является их привод. Для определения мощности привода необходимо провести расчеты по стандартным методиками, для чего нужно потратить достаточно времени. Одним из проектных параметров является производительность элеватора. Необходимо построить параметрическую зависимость мощности привода элеватора от его проектной производительности, которая учитывает тип и характеристики груза, высоту подъема, стандартные размеры и параметры ковшей и лент. **Методика.** Используя методику тягового расчета ленточных ковшевых элеваторов, построены параметрические зависимости мощности привода быстроходных элеваторов с глубокими и мелкими ковшами от их производительности при фиксированных типе груза и высоте подъема. **Результаты.** На основе построенных параметрических зависимостей установлено, что функция изменения величины мощности элеватора от проектной производительности (при фиксированных высоте подъема, типе груза, скорости движения ленты) является кусочно-постоянной и монотонно возрастающей. Определены в общем виде интервалы проектных значений производительности, которые обеспечивают постоянную величину мощности привода элеватора. В качестве примера применения полученных результатов рассмотрен процесс построения зависимости мощности привода от проектной производительности элеватора дробометной камеры, которая предназначена для транспортировки металлической дроби, используемой при упрочнении вагонных пружин. Для конкретного типа груза и высоты подъема такого элеватора построена графическая зависимость мощности его привода от производительности. **Научная новизна.** Впервые выведены параметрические зависимости мощности привода элеватора от его проектной производительности, которые учитывают тип и физико-механические характеристики груза, высоту подъема, стандартные размеры и параметры ков-

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шей и лент. **Практическая значимость.** Использование построенных зависимостей дает возможность относительно быстрого определения приблизительного значения мощности привода вертикальных быстроходных элеваторов с глубокими и мелкими ковшами на стадии проектирования. Также возможным является выполнение качественного подбора его основных элементов при конкретных проектных характеристиках: тип груза, производительность, высота подъема.

Ключевые слова: элеватор; ковш; привод; мощность; производительность; груз

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