MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
DNIPRO UNIVERSITY OF TECHNOLOGY

MECHANICAL AND MACHINEBUILDING FACULTY
DEPARTMENT OF ENGINEERING AND DESIGN IN MACHINERY INDUSTRY
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ENGINEERING OF MINING MACHINES AND COMPLEXES FOR UNDERWATER MINING OF MINERALS

MEHODICAL RECOMMENDATIONS FOR LABORATORY CLASSES

"Calculation of the suction dredge hydrotransport system parameters"
for students of the specialty 133 Branch Engineering

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Затверджено до видання науково-методичною комісією спеціальності 133 Галузеве машинобудування (протокол № 1 від 31.08.2021, протокол засідання кафедри ІДМ №1 від 30.08.2021) як методичні рекомендації для бакалаврів ОПП «Комп'ютерний інжиніринг у машинобудуванні»

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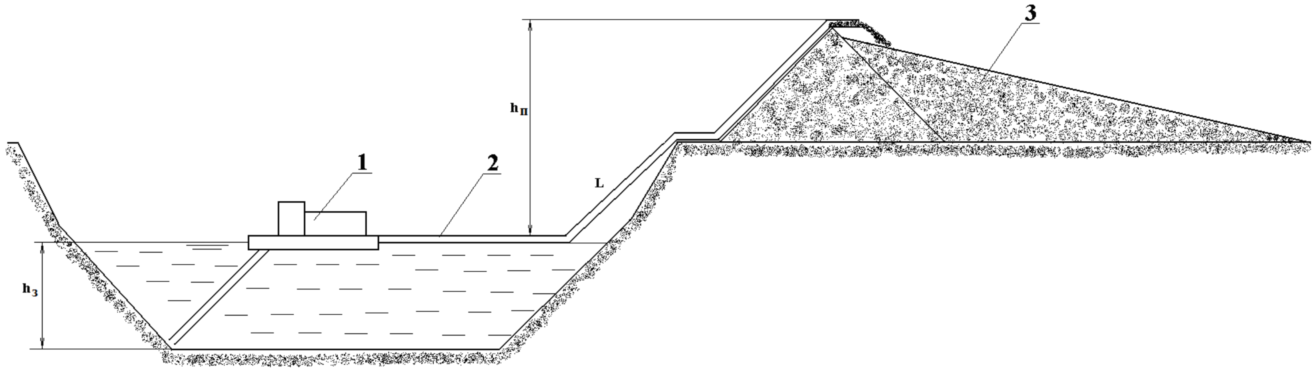
Наведено послідовність розрахунку параметрів гідротранспортної системи землесосного снаряда.

Рекомендації орієнтовано на активацію виконавчого етапу навчальної діяльності студентів.

BACKGROUND DATA

The greatest distance of hydrotransportation , m.

Option	1	2	3	4	5	6	7	8	9	10
Range, m	**90**	**100**	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**
Pipe GOST	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**
Option	11	12	13	14	15	16	17	18	19	20
Range, m	**190**	**200**	**210**	**220**	**230**	**240**	**250**	**260**	**270**	**280**
Pipe GOST	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**



Scheme of the suction dredge work with storage of soil on the hydraulic dump:
1 - suction dredge; 2 - pulp line, 3 - hydraulic dump

Soil - grained, dusty sand:

clay particles is 0,005 mm – up to 3%,

gravel particles 2...40 mm – up to 5%;

Depth of mining of a mineral in one ledge – 12 m;

The geometric elevation of the pulp is – 13 m;

The annual working hours fund of the enterprise is 4048 hours;

Coefficient of soil porosity *m* = 0,5;

Density of soil skeleton $\rho_г$ =2650 kg / m^3.

The code of pipes: 1 – GOST 10704-91; 2 – GOST 8732-78; 3 – GOST 18599-2001

Characteristics of the pump GRU 800-40 for water pumping / for sand pulp pumping

Water productivity, m^3 / h	500	600	700	800	900	1000	1100	1200
Head, meters of water column	44 / 36,4	43 / 35,6	42 / 34,8	40 / 33,1	38 / 31,5	37 / 30,7	35 / 29	33 / 27,3
Power consumed, kW	110 / 122,1	115 / 127,7	125 / 138,8	133 / 147,6	143 / 158,7	151 / 167,6	160 / 177,6	170 / 188,7
Efficiency	58 / 48	60 / 49,7	62 / 51,4	65 / 53,8	67 / 55,5	67 / 55,5	65 / 53,8	63 / 52,2

1. SUCTION DREDGE PRODUCTIVITY

The productivity of the suction dredger depends on the physical and mechanical properties of the rocks being developed. The hourly technical productivity of the suction dredger is determined by the formula

$$Q_{\text{Т}} = \frac{Q_{\text{П}} K_{з}}{\left[q_{в} + (1 - m)\right]}, \qquad (1)$$

where $Q_{\text{П}}$ – hourly productivity of the suction dredge ground pump by pulp, m^3 / h; $K_{з}$ = 0,9 – the coefficient taking into account the decrease in the suction dredger technical productivity at a large height of the ledge, is taken at a total ledge height less than that indicated in table 1; $q_{в}$ – specific water consumption for the mining and hydrotransportation of 1 m^3 of rock (table 2), m^3 / m^3.

Table 1

Ledge height for suction dredgers, less of which a reduction factor is applied $K_{з}$

Productivity of suction dredgers by water, m^3 / h	Overall height, m	Maximum mining depth below the water level (permissible), m
Up to 1300	2,4	1,5
1300...2200	3,2	2,5
2200...4000	4,8	3,5
More than 4000	6,4	5,0

The hourly productivity of a suction dredge soil pump by a pulp is determined by the formula

$$Q_{\text{П}} = \frac{Q_{з.\text{В}} \rho_{в}}{\rho_{\text{П}}}, \qquad (2)$$

where $Q_{з.\text{В}}$ – productivity of the suction dredge by water (determined by technical characteristics and corresponds to the optimal mode of the soil pump), m^3 / h; $\rho_{в}$ – density of water, kg / m^3; $\rho_{\text{П}}$ – pulp density, kg / m^3.

Density of pulp can be calculated by the formula

$$\rho_{\text{П}} = \frac{q_{в} \rho_{в} + \rho_{\text{Г}} (1 - m)}{q_{в} + 1 - m}, \qquad (3)$$

$\rho_{\text{Г}}$ – density of the soil skeleton, kg / m^3; *m* – coefficient of rock porosity;

Table 2

Distribution of rocks by groups in their mining by suction dredgers

Group of soils	specific water consumption , m^3 , for mining and hydrotransportation of 1 m^3 of soil	Name of soil	The grading characteristic soils (particles sizes, mm; their amount by weight %)					
			clayey less than 0,005	clayey 0,005...0,05	sandy: small 0,05...0,25	sandy: average 0,25...0,5	sandy: large 0,5...2	gravel 2...40
I	7	Sands: fine-grained	Until 3	Until 15	More than 50	Until 50	Until 10	Until 1
		medium-grained			Until 50	More than 50		
		heterogeneous			Until 50	Until 50		
		dusty		Until 20	Is not regulated			
		Flowing sludge		Is not regulated				
II	9	Sands heterogeneous	Until 3	Until 15	Until 50	Until 50	10...50	Until 5
		Sands dusty		20...50	Is not regulated			
		Sands large -grained		Until 15	Until 50	Until 50	More than 50	
		Sandy loam light	3...6	Until 50	Is not regulated			
III	11	Sands heterogeneous	Until 3	Is not regulated				Until 10
		Sandy loams heavy	6...10	Until 50	Is not regulated			Until 5
IV	14	Sandy-gravel soils	Until 3	Is not regulated				Until 5
		Loams light	10...15					Until 10
V	18	Sandy-gravel soils	Until 5					Until 10
		Loams average	15...20					Until 40
VI	22	Sandy-gravel soils	Until 5					Until 40
		Loams heavy	20...30					Until 10
		Clays flowing	Until 40					

Annual capacity of the suction dredger, m[3] / year

$$Q_{\Gamma} = Q_{T} T_{год} K_{и.з}, \tag{4}$$

where $T_{год}$ – annual fund of calendar time, h; $K_{и.з}$ – the coefficient of the suction dredger use in time (table 3).

Table 3

Characteristics of the suction dredger use in time $K_{и.з}$

Characteristics of working conditions	Number of pumping stations			
	No	1	2	3
When transporting a sand and gravel mixture with gravel content by a suction dredger, %:				
Until 5	0,7	0,67	0,64	0,61
Until 20	0,65	0,62	0,59	0,56
20...40	0,6	0,57	0,54	0,51
40...60	0,55	0,52	0,49	0,47

2 CALCULATION OF THE PIPELINE DIAMETER

The diameter of the pipeline is chosen in accordance with the approximate values of the hydrotransportation speed of grounds and hydrotranspor system productivity by pulp

$$D = 1{,}128 \cdot \sqrt{\frac{Q_n}{V}}, \tag{5}$$

where Q_n – productivity of the dredge by pulp m[3] / s;

V – speed of pulp flow through the pipeline, take 3 m / s.

Actual diameter of the pipeline $D_ф$ chosen by grade pipes with a conformity of GOST, the closest to the calculated D. Range of pipes, used for hydromechanization are shown in tables 4 – 6. Rational hydrotransport mode is provided in excess of the actual hydrotransportation speed above the critical within 10-30%.

3 DETERMINATION OF PULP MOVEMENT CRITICAL SPEED

The actual flow rate of the pulp by pipeline is:

$$V_ф = \frac{4 \cdot Q_{п}}{\pi D_ф^2}, \text{ m / s.} \tag{6}$$

The chosen diameter of the pipeline should provide the pupl hydrotransport with a speed greater than or equal to the critical speed.

Table 4

The assortment for steel electric welded pipes according to GOST 10704-91

Outside diameter, mm	Weight of 1 m of pipes, kg, with wall thickness, mm											
	4	4,5	5	5,5	6	7	8	9	10	11	12	14
114	10,85	12,15	13,44	14,72	-	-	-	-	-	-	-	-
127	12,13	13,59	15,04	16,48	-	-	-	-	-	-	-	-
133	12,73	14,26	15,78	17,29	-	-	-	-	-	-	-	-
140	13,42	15,04	16,65	18,24	-	-	-	-	-	-	-	-
152	14,60	16,37	18,13	19,87	-	-	-	-	-	-	-	-
159	15,29	17,15	18,99	20,82	22,64	26,24	-	-	-	-	-	-
168	16,18	18,14	20,10	22,04	23,97	27,79	31,57	-	-	-	-	-
177,8	17,14	19,23	21,31	23,37	25,42	29,49	33,5	-	-	-	-	-
180	17,36	-	21,58	-	-	-	-	-	-	-	-	-
193,7	18,71	21,00	23,27	25,53	27,77	32,23	36,64	-	-	-	-	-
219	21,21	23,80	26,39	28,96	31,52	36,60	41,63	46,61	-	-	-	-
244,5	23,72	26,63	29,53	32,42	35,42	41,00	46,66	52,27	-	-	-	-
273	26,54	29,80	23,05	36,28	39,51	45,92	52,28	58,60	-	-	-	-
325	31,67	35,57	39,46	43,34	47,20	54,90	62,54	70,14	-	-	-	-
355,6	34,68	38,96	43,23	47,49	51,73	60,18	68,58	76,93	85,23	-	-	-
377	36,79	41,34	45,87	50,39	54,90	63,87	72,80	81,67	90,51	-	-	-
406,4	39,70	44,60	49,50	54,38	59,25	68,95	78,60	88,20	97,76	107,26	116,72	-
426	41,63	46,78	51,91	57,04	62,15	72,33	82,47	92,55	102,59	112,58	122,52	-
530	-	-	64,74	71,14	77,54	90,29	102,99	115,64	128,24	140,79	153,30	165,75

Table 5

The assortment for steel pipes seamlessly deformed according to GOST 8732-78

Outside diameter, mm	Weight of 1 m of pipes, kg, with wall thickness, mm											
	4	4,5	5	5,5	6	7	8	9	10	11	12	14
114	10,85	12,15	13,44	14,72	15,98	18,47	20,91	23,31	25,65	27,94	30,19	34,53
121	11,54	12,93	14,30	15,67	17,02	19,68	22,29	24,86	27,37	29,84	32,26	36,94
127	12,13	13,60	15,04	16,48	17,90	20,72	23,48	26,19	28,85	31,47	34,03	39,01
133	12,73	14,26	15,78	17,29	18,79	21,75	24,66	27,52	30,33	33,10	35,81	41,09
140	-	15,04	16,65	18,24	19,83	22,96	26,04	29,08	32,06	35,00	37,88	43,50
146	-	15,70	17,39	19,06	20,72	24,00	27,23	30,41	33,54	36,62	39,66	45,57
152	-	16,37	18,13	19,87	21,60	25,03	28,41	31,74	35,02	38,25	41,43	47,65
159	-	17,15	18,99	20,82	22,64	26,24	29,79	33,29	36,75	40,15	43,50	50,06
168	-	-	20,10	22,04	23,97	27,79	31,57	35,29	38,97	42,59	46,17	53,17
180	-	-	21,58	23,67	25,75	29,87	33,93	37,95	41,93	45,85	49,72	57,31
194	-	-	23,31	25,57	27,82	32,28	36,70	41,06	45,38	49,64	53,86	62,15
203	-	-	-	-	29,15	33,84	38,47	43,06	47,60	52,09	56,52	65,25
219	-	-	-	-	31,52	36,60	41,63	46,61	51,54	56,43	61,26	70,78
245	-	-	-	-	-	41,09	46,76	52,38	57,95	63,48	68,95	79,76
273	-	-	-	-	-	45,92	52,28	58,60	64,86	71,07	77,24	89,42
299	-	-	-	-	-	-	57,41	64,37	71,27	78,13	84,93	98,40
325	-	-	-	-	-	-	62,54	70,14	77,68	85,18	92,63	107,38
351	-	-	-	-	-	-	67,67	75,91	84,10	92,23	100,32	116,35
377	-	-	-	-	-	-	-	81,68	90,51	99,29	108,02	125,33
402	-	-	-	-	-	-	-	87,23	96,67	106,07	115,42	133,96
426	-	-	-	-	-	-	-	92,56	102,59	112,58	122,52	142,25
450	-	-	-	-	-	-	-	97,88	108,51	119,09	129,62	150,53
480	-	-	-	-	-	-	-	104,54	115,91	127,23	138,50	160,89
500	-	-	-	-	-	-	-	108,98	120,84	132,65	144,42	167,80

Table 6

The assortment for polyethylene PE-63 pipes according to GOST 18599-2001

Average outer diameter, mm		*SDR 41* S20		*SDR 26* S12,5		*SDR* 17,6 *S* 8,3		*SDR 11* *S5*	
		Maximum operating water pressure at 20 ºC, MPa							
		0,25		0,4		0,6		1	
		Wall thickness							
nom.	deviation	nom.	deviation	nom.	deviation	nom.	deviation	nom.	deviation
90	+0,9	2,2	+0,5	3,5	+0,6	5.1	+0,8	8,2	+1,3
110	+1,0	2.7	+0,5	4,2	+0,7	6,3	+1,0	10,0	+1.5
125	+1,2	3,1	+0,6	4.8	+0,8	7,1	+1.1	11,4	+1.8
140	+1,3	3,5	+0,6	5,4	+0,9	8,0	+1,2	12,7	+2,0
160	+1.5	4,0	+0,6	6,2	+1,0	9.1	+1.4	14,6	+2,2
180	+1,7	4,4	+0,7	6,9	+1.1	10.2	+1,6	16,4	+2.5
200	+1,8	4,9	+0,8	7,7	+1.2	11,4	+1.8	18,2	+2.8
225	+2,1	5,5	+0,9	8.6	+1,3	12,8	+2,0	20,5	+3,1
250	+2,3	6,2	+1,0	9,6	+1.5	14.2	+2,2	22.7	+3,5
280	+2.6	6,9	+1,1	10,7	+1,7	15,9	+2,4	25,4	+3,9
315	+2.9	7,7	+1.2	12,1	+1,9	17,9	+2,7	28.6	+4,3
355	+3.2	8.7	+1,4	13,6	+2,1	20,1	+3,1	32,2	+4,9
400	+3,6	9,8	+1,5	15,3	+2,3	22,7	+3,5	36,3	+5,5
450	+4,1	11,0	+1,7	17,2	+2,6	25.5	+3,9	40,9	+6,2
500	+4,5	12.3	+1,9	19,1	+2,9	28,3	+4,3	45,4	+6,9
560	+5,0	13,7	+2,1	21.4	+3,3	31,7	+4,8	50,8	+7,7
630	+5,7	15.4	+2,4	24,1	+3,7	35,7	+5,4	57,2	+8,6
710	+6.4	17,4	+2,7	27,2	+4,1	40,2	+6,1	–	–
800	+7,2	19,6	+3,0	30,6	+4.6	45.3	+6,8	–	–
900	+8,1	22,0	+3,3	34,4	+5,2	51,0	+7,7	–	–
1000	+9,0	24,5	+3,7	38,2	+5,8	56,6	+8.5	–	–
1200	+10,0	29,4	+4,5	45,9	+6,9	–	–	–	–

The critical speed of the pulp, it can be determined from the following dependent and

$$V_{кр} = 2{,}8 \cdot \frac{\sqrt[6]{P} \cdot \sqrt{q_в \cdot D_ф}}{\sqrt[4]{C_\varphi}}, \qquad (7)$$

where P – bulk consistency of the soil in the pulp; $q_в$ – specific water consumption, taken according to Table 2 , m^3 / m^3; $D_ф$ – the actual diameter of the pulp pipeline, m; C_φ – the average coefficient of frontal resistance (table 7).

The bulk consistency of the soil in the pulp is determined by the formula

$$P = \frac{\rho_{П} - \rho_{в}}{\rho_{Г} - \rho_{в}}, \qquad (8)$$

where $\rho_{П}$ – pulp density, kg / m^3; $\rho_{в}$ – density of water, kg / m^3; $\rho_{Г}$ – density of the soil skeleton, kg / m^3.

Table 7

Coefficient of frontal resistance

Name the soil	Loose-like loam	Sands heterogeneous dusty	Sands large - grained	Sands gravel	Sands Gravel-pebble
The gravel content, %	0	until 1	until 10	20...45	more than 45
d_{cp}, мм	0,12	0,12...0,4	0,89	2,2	8,8
C_{φ}	17,8	3,9	1,9	0,95	0,6

4 CALCULATION OF THE PIPELINE PRESSURE CHARACTERISTIC

Calculation of the pipeline pressure characteristic is carried out according to the formula

$$H = h_n \frac{\rho_n}{\rho_в} + h_3 \frac{\rho_n}{\rho_в} + h_d + h_м + h_{вс} + H_O, \qquad (9)$$

where h_n – geometric height of pulp lifting, m;

h_3 – geometric suction height of pulp, m;

ρ_n – pulp density, kg / m^3;

$\rho_в$ – density of water – 1000 kg / m^3;

h_d – loss of pressure on friction in the pipeline, meters of water column;

$h_м$ – local head loss, meters of water column;

$h_{вс}$ – loss of pressure in the suction line, $h_{вс}$=2 meters of water column;

H_0 – residual pressure for pouring pulp –1,0 meters of water column

Loss of head in the pipeline (h_d) are determined by the formula:

$$h_d = i_n \cdot L \cdot K, \text{ meters of water column,} \qquad (10)$$

where К – coefficient = 1,015;

L – the greatest distance of hydrotransportation , m;

i_n – specific losses of head for pulp, meters of water column

$$i_n = i_0 \cdot \left(1 + 6 \cdot \sqrt{P}\right), \qquad (11)$$

where i_0 - specific losses of the head for water at speeds corresponding to critical, meters of water column

$$i_0 = \frac{\lambda \cdot V_ф^2}{2 \cdot g \cdot D_ф}, \tag{12}$$

where λ - coefficient of resistance of the pipeline, is determined by the formula:

$$\lambda = \frac{0,31}{(\lg \mathrm{Re} - 1)^2}. \tag{13}$$

Reynolds number

$$\mathrm{Re} = \frac{V_ф \cdot D_ф}{\nu}, \tag{14}$$

where $V_ф$ - actual water speed in the pipeline, м/s;

$D_ф$ - the pipeline diameter, м;

ν=1,01·10^{-6} м^2/s – kinematic speed of water.

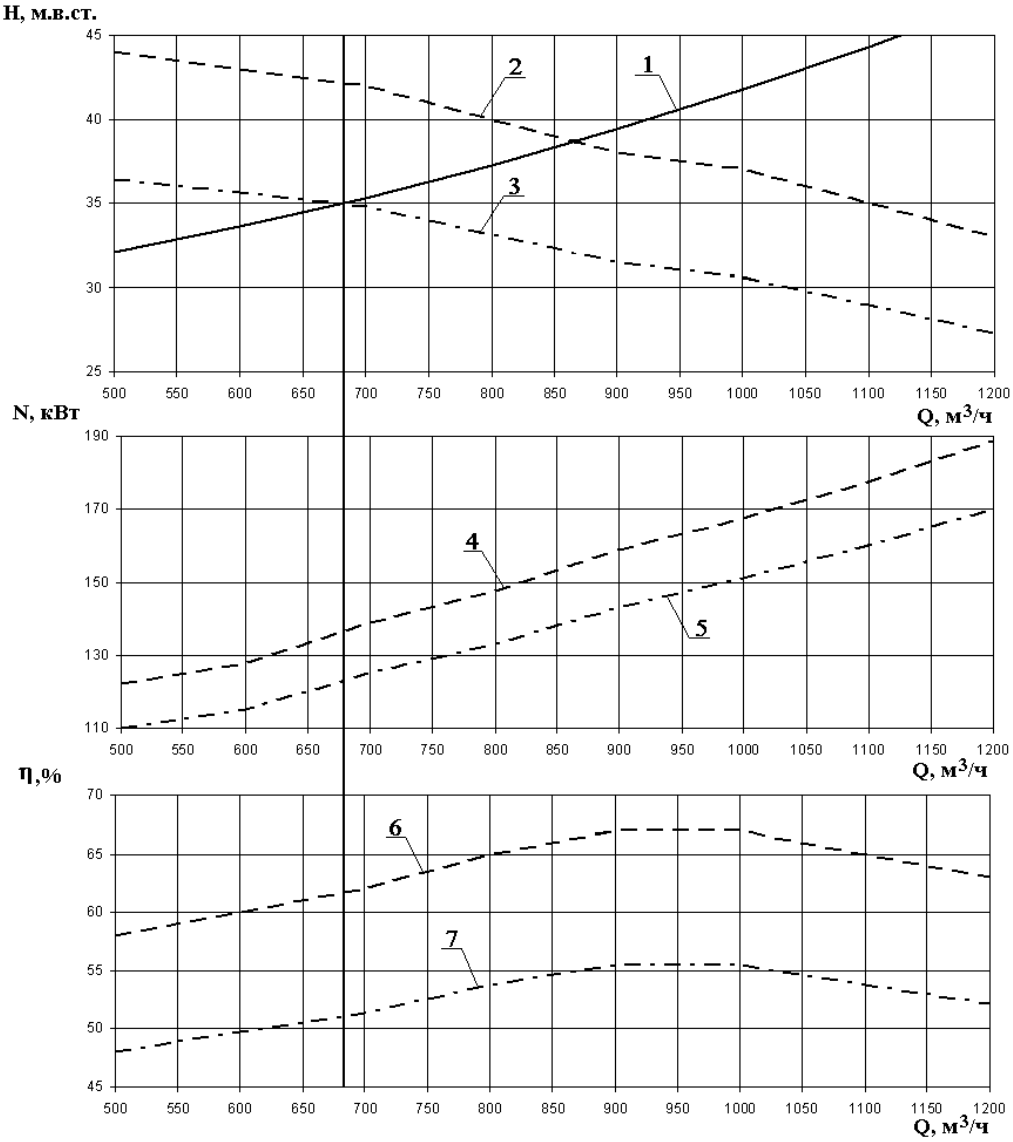
Loss of pressure on local hydraulic resistance in the pipeline $h_м$ with a high degree of reliability is determined according to the formula

$$h_м = 0,1 h_д$$

5 CONSTRUCTION OF THE PIPELINE CONSUMPTION -PRESSURE CHARACTERISTIC AND A GROUND PUMP.

The pipeline consumption-pressure characteristics and a ground pump construct to determine actual operating characteristics of the suction dredge basic hydraulic system " ground pump – pipeline". As a result of the characteristic construction, the values of the head, the power consumed and the pump efficiency when it is operating on this pipeline are determined. The construction of the consumption-pressure characteristic will be considered using the example of the ground pump GRU 800/40 characteristic for pumping the pulp through a pipeline with an internal diameter of 309 mm (GOST 10704-91) and a length of 170 m (Fig.).

Conclusion: it is determined that for underwater mining of heterogeneous and dusty sand with a clay content of less than 0,005 mm - up to 3%, gravel 2 ... 40 mm - up to 5% from a depth of 12 m by a ground pump GRU 800/40 at a distance of 170 m pipeline with internal diameter of 309 mm is required (GOST 10704-91). The estimated parameters of the mining system will take the following values: pulp productivity 600 m^3 / h, required drive motor power 134 kW, efficiency of the pump is 51%.



1 – characteristic of the pipeline with internal diameter 309 мм and length 200 m;
2 – characteristic for pump GRU 800/40 when pumping water;
3 – characteristic for pump GRU 800/40 when pumping pulp;
4 – power consumed for pump GRU 800/40 when pumping pulp;
5 – power consumed for pump GRU 800/40 when pumping water;
6 – efficiency for pump GRU 800/40 when pumping water;
7 – efficiency for pump GRU 800/40 when pumping pulp;
Consumption-pressure characteristic of a transport pulp pipeline with an internal diameter 309 mm (GOST 10704-91), length 200 m, and ground pump GRU 800/40

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В редакції автора

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