7. **Christine Rosenberger**. Ukraine's Energy Policy [Electronic resource].Konrad Adenauer Stiftung. Access mode: http://www.kas.de/ukraine.

8. **MalanchukZ.., MalanchukE., IgnatyukI., MalanchukL., MoshchichS**. Strategic framework for the development of rational subsoil use in Ukraine. Australian and New Zeland Journal of Fundamental and Applied Studies. – Sydney University Press, **1 (15)**, V. 3. 126–132. (2015)

9. **Yakymchuk A.Y., Navrotskyi R.L., Kovshun N. E.** Natural resources potential as innovative and investment development prospect.Polesie Scientific Bulletin. **3 (11)**. V. 1. 179–186. (2017)

10. **Kovshun N.** Basis for the realization of sustainable development strategy in Ukraine. Economics of Sustainable Development: methodological approaches and practical solutions: collective monograph / by general edition of O. Kendikhov. – Kyiv : Center of educational literature,. 25–30.(2016)

DESIGN AND IMPLEMENTATION OF A JET PUMP DREDGE

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Purpose. Experimental confirmation of mathematical models obtained in previous studies, testing and industrial implementation of a jet pump dredger.

Methodology. Standard methods of experimentation with experimental and industrial mining of construction sand applied with different settings of the jet suction member.

Findings. The method for calculating the rational parameters of hydraulic ripper was introduced in the design of a jet suction member with a hydraulic ripper. The use of a jet working member as the main equipment of a jet pump dredger made it possible to efficiently mining a gravel bed during the development of the East-Bugsky-2 construction sand deposit. The industrial implementation of the jet pump installation using the example of an ejector dredger project showed the practical feasibility, technological and economic efficiency of the use of ejector dredgers in the mining of flooded and underwater sand and gravel deposits with a significant content of coarse gravel. To confirm the reliability of the previously obtained analytical dependencies and determine the operational characteristics of the equipment, field experimental studies of the jet suction member were carried out.. An ejector dredger is used in the development of the East-Bugsky-2 sand deposit.

Conclusion. The use of a jet dredging member as the main equipment of a jet pump dredger made it possible to efficiently mining a gravel bed during the development of the East-Bugsky-2 field of construction sands.

Keywords: The jet pump dredger, jet suction member, hydraulic ripper, full-scale experiment.

Introduction

The existing variety of mining equipment for the mining of flooded and underwater sand and gravel deposits, domestic and imported, available on the market, allows you to choose equipment for the vast majority of options for the layout of mining complexes. At the same time, on the domestic market there are no offers of mining and transportation complexes applicable for the development of specific complex structural deposits, which include river, lake, flooded sand and gravel ore and non-ore deposits with a significant content of coarse gravel.

The development of such deposits, using traditional design suction dredges based on slurry pumps, due to their design features, is associated with a number of difficulties, which are mainly the impossibility of mining and hydrotransporting coarse gravel.

Objectives. The purpose of the work is **e**xperimental confirmation of mathematical models obtained in previous studies, testing and industrial implementation of a jet pump dredger.

Description of the research methodology. Is applied standard methods of experimentation with a full-scale and industrial mining of construction sand with different settings of the jet suction member.

Presentation of the main research. The solution to the problem of mining deposits with a significant content of coarse gravel can be accomplished by using pump dredgers with a jet system for forming a face, preparing pulp and hydrotransport (ejector dredger).

East-Bugsky-2 field of construction sands (Nikolaev region, Ukraine), is characterized by the presence of coarse gravel in minerals. For the mining of a gravel formation, during the detailed design, it is recommended to use an ejector dredger, which was designed by modernizing the melioration dredger MZ-8.

When modernizing the mining system of the MZ-8 dredger, the developed method for calculating the rational parameters of hydraulic disintegrants and the known methods for calculating jet pumps were applied [1, 2]. The project for the modernization of the MZ-8 dredger [3] provides for reconstruction and updating of: base vessel; engine room with the installation of a new pumping equipment, drive, stop valves, pipelines; cabs of the bagermaster with installation of start-up and control systems for the main electric drive, as well as equipment control systems for working movements of the working member. The work was carried out as part of the project №110025 «Justification of the rational parameters of the dredger MZ-8», 2009. After modernization, the dredger was named jet pump dredger. The work substantiates the parameters of the mining and hydrotransport systems, developed the design of the working member of the jet preparation system and hydrotransport of mined minerals. As a result of the rationale for rational parameters, the main elements of the water supply system of the jet suction member were chosen. The hydraulic system of the ejector dredger assumes the presence of a high-pressure water pump 1 with suction 2 and pressure 4 pipes (Fig. 1). To protect the suction pipe, a check valve 3 with a protective mesh is provided.

A valve 5 was used to start the pump and regulate the water supply. To control the pressure, pressure gauges are installed in the water supply system, directly behind the pump, and in the slurry pipeline. Pressure gauges are duplicated on the control panel in the cabin of the bagmeister. Working member with a jet pump and hydraulic ripper 7 is connected to the ship's water supply 4 and the slurry pipeline using flexible pipelines 6. The monitoring of the production process is carried out by means of a vacuum gauge, the sensor of which is installed on the suction pipe of the working member, and the device - on the control panel in the cabin of the bagmeister.

Fig. 1. The hydraulic system of the ejector dredger: *1* – water pump; *2* – suction pipe; *3* – check valve; *4* – pressure water supply system; *5* – valve; *6* – flexible pipeline; *7* – jet suction member; *8* – pressure slurry pipe

The hydraulic system of the ejector dredger works as follows: with a water pump 1 pressurized water is supplied by a water pipe 4 to a working member 7. The water pump is started after filling the system with water using the auxiliary pump with the valve closed 5. A protective mesh is provided to protect the system from large contaminants. Working member 7 implements the process of jet preparation of the minerals in the underwater bottom face and hydrotransport of the obtained slurry by the hydrotransport system 8 to the place of storage or processing. The recommended technology for the application of the developed working member, in which it is possible to achieve its maximum efficiency, has become pit mining technology.

The main element of the ejector dredger is a working member with a jet pump (Fig. 2). The design is developed using specialized computer programs (SolidWorks, MathCad).

In the summer of 2011, work on the manufacture, installation and completion of equipment was completed. Full-scale tests of the jet pump dredger took place in the conditions of the East-Bugsky-2 field of construction sands, which is located in the Voznesensk district of the Nikolaev region. Total area of the field – 32,25 hectare [4]. The territory of the quarry field is divided into four blocks. Approved mineral reserves amount to 3977 thousand m^3. According to the peculiarities of the geological structure, the field belongs to the 1st group, such as reservoir, sustained in structure, capacity and quality of the mineral. Within the limits of calculating reserves, the ineral is watered, the water level is at around 16,000 m. Mining and geological conditions of the field contribute to the development of open pit using floating dredgers. Overburden is represented by a soil-plant layer, loams, partially - by sandy loam. The average thickness of the soil-plant layer is 0,64 m, the loam layer is 1,26 m. Average minerals layer power in the overwater part is 8,13 m, and in the underwater part is 4,4 m.

During the tests, such mining and technical parameters were controlled:

H_B - pressure in a pressurized water pipeline, MPa;

H_B - vacuum in the suction pipe (the gauge is installed in the suction pipe of the working member), kPa;

$L_П$ - slurry pipeline length, m;

$h_П$ - geometric elevation of slurry above water level, m;

$h_З$ - geometric height of the slurry suction, m;

$d_Э$ – diameter of ejector nozzles, m;

d_p – diameter of erosion nozzles, m;

$n_Э$ – number of ejector nozzles, pieces;

n_p – number of erosion nozzles, pieces;

T – production equipment turning on time, min.

a

b

Fig. 2. Jet suction working member:a - general view; b - jet pump

To confirm the reliability of the developed analytical dependencies [1] and determine the operational characteristics of the equipment, full-scale field experimental studies were carried out. The full-scale experiment was carried out with a slurry pipe length $L_П$ of 80 m, mining depth $h_З$ of 2 m, geometric elevation of slurry above water level $h_П$ of 5 m. During the experiment, the volume concentration of the slurry was measured during discharge to the alluvium map. Productivity by slurry and minerals were determined by the volumetric method. The obtained experimental data of the full-scale experiment performed during pilot tests of the ejector dredger are shown in tables 1, 2 [5, 6].

The experiment was performed in two stages. The first envisaged the use of a simplified washout system for face jet preparation, while the cavity of the erosion nozzle had a direct connection with the pressure cavity of the working member, i.e., the pressure in the pressure cavity of the working member was 1,02-1,06 MPa (Table 1).

Table 1

The experimental data of a full-scale experiment. Pressure in the pressure cavity of the working member is – 1,02-1,06 MPa

Level in a measured capacity, mm		Slurry volume concentration, C_o	Pressure gauge, H_B, MPa	Vacuum Gauge H_B, kPa
slurry	sand			
1	2	3	4	5
The experimental data for: $d_Э$ – 19 mm, d_p – 7 mm, $n_Э$ – 8 pieces, n_p – 1 pieces.				
182	20	0,11	1,06	18-20
180	18	0,1	1,06	16-18
175	15	0,09	1,04	16-18
181	12	0,07	1,04	16-18
		C_o average – 0,09		
The experimental data for: $d_э$ - 19 mm, d_p - 7 mm, n - 8 pieces, n_p - 2 pieces.				
slurry	sand			
180	19	0,11	1,04	16-18
185	15	0,08	1,04	16-18
182	13	0,07	1,04	16-18
180	14	0,08	1,04	16-18
178	12	0,07	1,04	16-18
174	13	0,07	1,04	16-18
183	10	0,05	1,04	16-18
		C_o average – 0,08		

At the second stage, erosion of the soil in the face was performed by nozzles, in which, by throttling, the pressure in front of the nozzle was reduced to the calculated values, i.e., the pressure in the pressure cavity of the working member was 0,5-0,6 MPa. The obtained experimental data are shown in table 2Table 2

The experimental data of a full-scale experiment. Pressure in the pressure cavity of the working member is 0,5-0,6 MPa

Level in a measured capacity, mm		Slurry volume concentration, C_o	Pressure gauge, H_B, MPa	Vacuum Gauge H_B, kPa
slurry	sand			
1	2	3	4	5
The experimental data for: $d_Э$ – 19 mm, d_p – 7 mm, $n_Э$ – 8 pieces, n_p – 1 pieces.				
180	3	0,02	1	22
180	7	0,04	1	20
180	15	0,08	1,06	18
180	17	0,09	1,06	18
180	13	0,07	1,06	18
185	5	0,03	1,06	18
		C_o average average – 0,06		
The experimental data for: $d_Э$ – 19 mm, d_p – 7 mm, $n_Э$ – 8 pieces, n_p – 1 pieces.				
185	25	0,14	1,06	16-20
185	20	0,11	1,04	16
170	15	0,09	1,04	18-20
170	17	0,10	1,04	18-20
170	26	0,15	1,04	15-18
180	30	0,17	1,04	14-16
185	27	0,15	1,04	14-16
185	25	0,14	1,04	14-16
180	25	0,14	1,04	14-16
170	12	0,07	1,04	14-16
		C_o average average – 0,12		
The experimental data for: $d_Э$ – 19 mm, d_p – 7 mm, $n_Э$ – 8 pieces, n_p – 2 piece				
180	33	0,18	1,02	10
180	31	0,17	1,02	12
185	29	0,16	1,02	12
175	26	0,15	1,02	10-12
170	28	0,16	1,02	10-12
180	29	0,16	1,02	11
180	29	0,16	1,02	11
180	27	0,15	1,02	11
		C_o average – 0,16		

Continuation of table 2

The experimental data for: $d_Э$ – 19 mm, d_p – 7 mm, $n_Э$ – 8 pieces, n_p – 3 pieces				
180	26	0,14	1,04	12

180	33	0,18	1,04	13
185	36	0,19	1,04	13
185	27	0,15	1,04	13
150	16	0,11	1,04	12
180	19	0,11	1,04	14
135	17	0,13	1,04	14
160	26	0,16	1,04	14
175	27	0,15	1,04	14
180	32	0,18	1,04	14
165	29	0,18	1,04	14
175	24	0,14	1,04	14
175	38	0,22	1,04	14
180	24	0,13	1,04	12
190	33	0,17	1,04	12
160	24	0,15	1,04	12
185	33	0,18	1,04	12
		C_o average – 0,16		

Comparison of experimental data indicates the effectiveness of the application of the developed calculation method for the design of jet systems for the minerals slurry preparation in the underwater bottom face of jet pump dredgers. The maximum average volumetric concentration of slurry for the first stage was C_o=0,09, for the second stage C_o=0,16. It is characteristic that the complete absence of the action of the erosion nozzles during the mineral slurry preparation for mining showed a minimum concentration of the slurry C_o=0,06 [7, 8].

Based on the results of full-scale tests of an ejector dredger, its operational characteristics were determined [9]:

- soil type - loose sand, gravel up to 120 mm;
- mining depth up to 6 m;
- horizontal transportation range - up to 250 m;
- pump drive - 160 kW;
- slurry productivity – 500 m^3/h.

The ejector dredger manufactured on the basis of the MZ-8 dredger, since 2011, has been used in the development of the East-Bugsky-2 sand deposit.

Conclusions. The developed method for calculating the rational parameters of hydraulic disintegrants was introduced in the design of the jet pump suction member with a hydraulic disintegrant. The use of a jet dredging member as the main equipment of a jet pump dredger made it possible to efficiently mining a gravel bed during the development of the East-Bugsky-2 field of construction sands.

Referens

1. **Bondarenko, A. O.** (2012). Improving the erosion systems of pump dredgers: monograph. Dnipro. National Mining University, 105 p.

2. **Bondarenko, A. O.** (2012). Mining machines for underwater mining: textbook. Dnipro. National Mining University, 90 p.

3. **Bondarenko, A. O.** (2009). Justification of the rational parameters of the MZ-8 pump dredge: report on research. Dnipro. National Mining University.

4. **Bondarenko, A. O.** (2010). Quarry reconstruction for the development of East-Bugsky-2 sand deposit: working draft Dnipro. National Mining University.

5. **Bondarenko, A. O.** (2012). Mathematical modeling of soil dredger absorption processes in the underwater bottomhole. Metallurgical and Mining Industry, 3, pp. 79–81.

6. **Bondarenko, A. O.** (2012). Laws of determination of fine materials suction limits in submarine suction dredge face. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, 4, pp. 59–64.

7. **Bondarenko, A.O.** (2018). Theoretical bases of pulp suction process in the shallow dredge underwater face, Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 3, pp. 22–29. DOI: 10.29202/nvngu/2018-3/4.

8. **Bondarenko, A.O.** (2018). Modeling of interaction of inclined surfaces of a hydraulic classifier with a flow of solid particles, Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 4, pp. 13–20. DOI: 10.29202/nvngu/2018-4/5.

9. **Bondarenko, A.O., Naumenko, R.P.** (2019). Comprehensive solution of recycling waste from stone processing industry, Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 4, pp. 96–101. DOI: 10.29202/nvngu/2019-4/14.