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INTRODUCTION OF A JET PUMP DREDGER EQUIPPED WITH AN INNOVATIVE SUCTION HEAD

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УПРОВАДЖЕННЯ ЕЖЕКТОРНОГО ЗЕМСНАРЯДУ ОБЛАДНАНОГО ІННОВАЦІЙНИМ ҐРУНТОЗАБІРНИМ ПРИСТРОЄМ

The purpose of the article is performing full-scale experimental studies of the JPD 300-120 ejector suction dredger equipped with an innovative soil suction head with a jet disintegrator system.

Methodology. Consists in preparing and conducting field experimental tests of floating production equipment as part of an ejector soil suction head with a jet disintegrator system, developed using the method of calculating the rational parameters of hydraulic disintegrators.

Results. The paper substantiates the parameters of the mining and hydrotransportation system, developed the design of the ejector suction head for the system of jet preparation and hydrotransportation of soils. The main elements of the water supply system of the ejector soil suction head with a jet disintegrator system have been selected. Field experimental studies were prepared and carried out in the conditions of the east-Bug-2 building sand deposit, which is located in the Voznesensk district of the Mykolaiv region. The experiment was carried out in two stages. The first one envisaged the use of a simplified jet disintegrator system for jet preparation of the underwater face, while the cavity of the jet disintegrator nozzle had a direct connection with the pressure cavity of the soil suction head. At the second stage, jet disintegration of the underwater face was carried out by nozzles, in which, by means of throttling, the pressure in front of the nozzle was reduced to the calculated values.

Scientific novelty. For the first time in crisis economic conditions, in order to confirm the reliability of previously obtained analytical dependencies to determine the rational parameters of hydraulic disintegrators and determine the operational characteristics of equipment, full-scale experimental studies of the JPD 300-120 suction dredger equipped with an innovative ejector soil suction head with a jet disintegrator system were carried out.

Practical significance. The use of a soil suction head with a jet disintegrator system as the main equipment of the JPD 300-120 dredger made it possible to effectively develop a gravel layer during the development of the East-Bug-2 building sand deposit. The industrial implementation of the JPD 300-120 suction dredger equipped by a soil suction head with a jet disintegrator system showed the practical feasibility, technological and economic efficiency of using ejector dredgers in the development of flooded and underwater sand and gravel deposits with a significant content of coarse gravel. Controlling the pressure in the pressure cavity of the soil suction head made it possible to rationalize the process of soil disintegration and increased the concentration of the transported pulp by 77,8%.

Keywords*: ejector shallow dredge, working body, hydraulic ripper, model experiment.*

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

The development of such deposits, using traditional suction dredgers based on soil pumps, due to their design features, is associated with a number of difficulties, which mainly consist in the impossibility of mining and hydraulic transportation of large-sized gravel.

Modern mechanisms for the development of flooded sand and gravel ore and non-metallic deposits with a significant content of coarse gravel include airlift and ejector (hydroelevator) dredgers, mechanical multi-bucket dredgers, clamshell dredgers, rod shells dredgers, rope-scraper installations and their combinations [1-3]. Traditionally, for the development of sand and gravel deposits with inclusions of large-sized gravel, mechanical-type mining equipment are used. However, the use of such equipment does not allow the use of hydraulic transport as a most convenient and economically feasible mode of transport in the development of flooded and underwater fields. Thus, the development of a technology that allows the implementation of hydromechanized development of such complex-structured gravel deposits and equipment for its implementation is a promising and relevant scientific and technical problem.

Methodology. The work used a complex research method. At the stage of developing a method for calculating the rational parameters of a jet disintegrator system [4, 5], in the theoretical and experimental study of the processes of interaction of turbulent jet streams with an underwater face of non-cohesive soil, standard methods and criteria of applied hydrodynamics were used [6, 7]. Theoretical study of processes is carried out in the form of physical and mathematical modeling. A complex of laboratory experimental studies of the process of jet disintegrating of the underwater face with granular soil was prepared and carried out using the developed laboratory facilities [4, 5]. The processing and analysis of the experimental data was carried out using the methods of mathematical statistics and experiment planning, and the approximating dependences were obtained by the least squares method. Pilot work was carried out on the operating full-scale installation of the jet pump dredger JPD 300-120 in the conditions of the East-Bug-2 building sand deposit. Measurements of technological and design parameters were carried out using standard metric equipment.

Results and discussion. The solution to the problem of developing deposits with a significant content of large-sized gravel can be performed by using suction dredgers with a jet underwater face formation system, pulp preparation and hydrotransportation (ejector dredger).

One of the examples of deposits, which are characterized by the presence of large-sized gravel in a mineral, is the East-Bug-2 deposit of building sands (Mykolaiv region, Ukraine). For the mining of a gravel layer, during the detailed design, the use of an ejector dredger is recommended. For this purpose, a project was developed to modernize the MZ-8 suction dredger by installing a soil suction head with a jet disintegrator system as the main equipment.

When modernizing the mining system of the MZ-8 dredger, the previously developed method for calculating the rational parameters of hydraulic disintegrator and known methods for calculating jet pumps were used [4, 5]. Physical and mathematical models characterizing the developed calculation method are given in the works [6, 7]. The modernization project for the MZ-8 suction dredger [5, 8] provided for the reconstruction and renewal of: the base watercraft, engine room with the installation of new pumping equipment, drive, shut-off and control valves, pipelines, bagermeister cabin with the installation of start-up and control systems for the main electric drive, as well as equipment control systems for working movements of the soil suction head. The work was carried out within the framework of the project № 110025 "Justification of the rational parameters of the suction dredger MZ-8" [8]. After modernization, the suction dredger was named as jet pump dredger JPD 300-120. The project substantiates the parameters of the production and hydrotransportation system, developed the design of the soil suction head with a jet disintegrator system. As a result of the justification of rational parameters, the main elements of the water supply system of the soil suction head with a jet disintegrator system were selected. The soil suction head was named as JSH 300-120. The hydraulic system of the ejector dredger provides for 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.

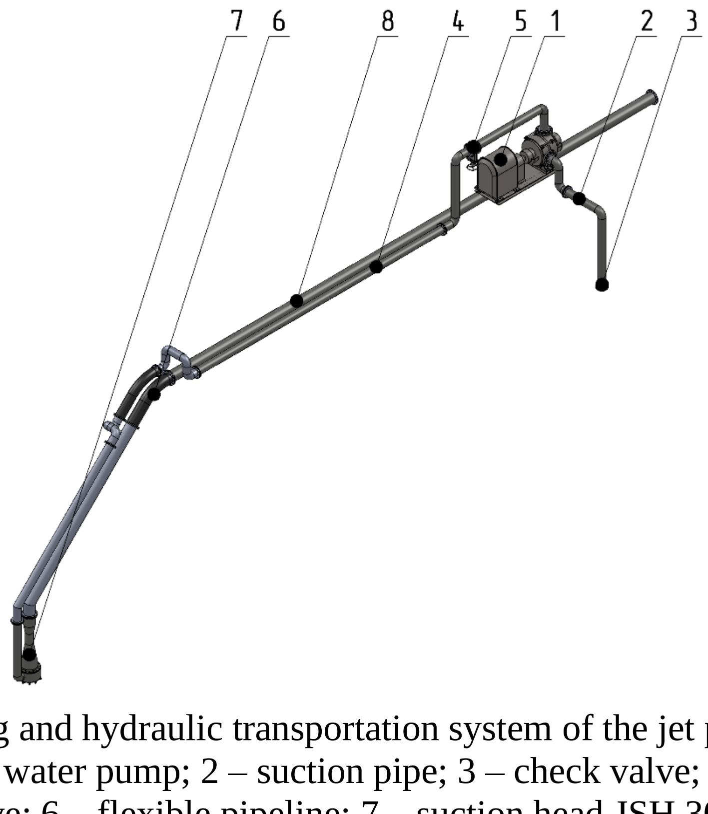
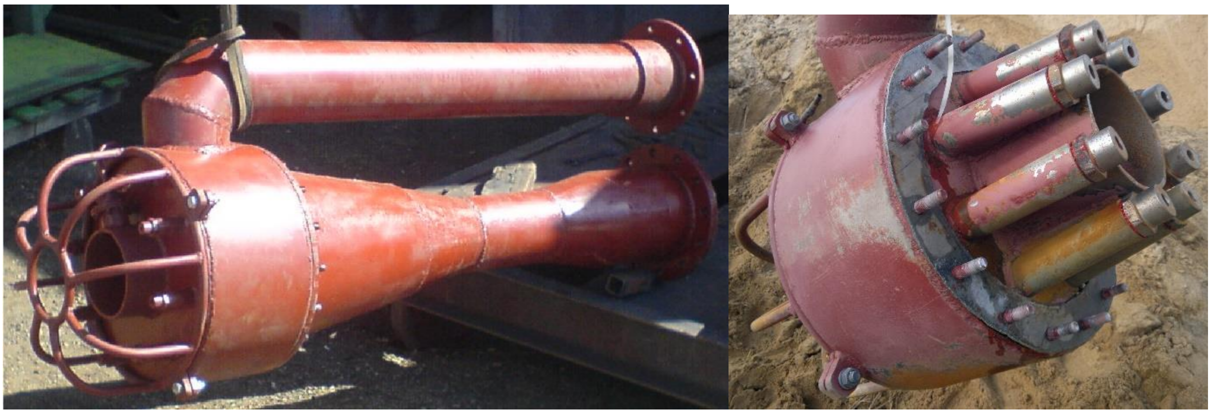


Fig. 1. Mining and hydraulic transportation system of the jet pump dredger JPD 300-120: 1 – water pump; 2 – suction pipe; 3 – check valve; 4 – pressure pipe; 5 – hydraulic valve; 6 – flexible pipeline; 7 – suction head JSH 300-120; 8 – slurry pipeline

Hydraulic valve 5 is used to start the pump and adjust 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 bagermeister cabin. The soil suction head with a jet pump and a hydraulic disintegrator 7 is connected to the pressure pipe 4 and the slurry pipeline 8 using flexible pipelines 6. The control of the mining process is carried out by means of a vacuum gauge, the sensor of which is installed on the suction pipe of the soil suction head, and the device is on the control panel in the bagermeister cabin.

The hydraulic system of the ejector dredger works as follows: water pump 1 is supplied with water by pressure pipe 4, to the soil suction head 7. The water pump is started after filling the system with water using an auxiliary pump with the hydraulic valve 5 closed. A protective grid is provided to protect the system from the ingress of large contaminants. The soil suction head with a jet pump and a hydraulic disintegrator 7 implements the process of jet preparation of the underwater face and hydrotransportation of the obtained pulp by the slurry pipeline 8 to the place of storage or processing. The recommended technology for the use of the developed soil suction head with a jet pump and a hydraulic disintegrator, in which it is possible to achieve its maximum efficiency, was the pit mining technology.

The main element of the ejector dredger JPD 300-120 is a soil suction head with a jet disintegration system JSH 300-120 (Fig. 2). The design was developed using specialized computer programs (SolidWorks, MathCad).



a *b*

Fig. 2. The soil suction head with a jet disintegrator system JSH 300-120:
a – general view; *b* – jet pump

At the preparatory stage for carrying out full-scale experimental studies on the use of an ejector soil suction head with a jet disintegrator system, work was carried out on the manufacture, installation and refinement of the design of machines and units installed as the main equipment of the jet pump dredger JPD 300-120. Field experimental studies and tests of the JPD 300-120 dredger (Fig. 3) were carried out in the conditions of the East-Bug-2 building sand deposit, which is located in the Voznesensk district of the Mykolaiv region. The deposit has a total area of – 32,25 hectare [9]. The territory of the quarry field is divided into four blocks. Approved mineral reserves are 3977 thousand m^3. According to the features of the geological structure, the deposit belongs to the 1st group, the type of reservoir deposit, sustained in structure, thickness and quality of the mineral. Within the limits of the reserves calculation, the mineral is flooded, the water level is at the mark 16,000 m. Mining and geological conditions of the deposit favor open pit mining using floating suction dredgers. Overburden rocks are represented by a soil-vegetative layer, loams, and partly by sandy loams. Average thickness of soil-vegetation layer – 0,64 m, loam layer – 1,26 m. The average power of a mineral: in the surface part is 8,13 m, and in the lower underwater – 4,4 m. The mineral is characterized by the presence of large-sized gravel.

Fig. 3. Installation of equipment of the jet pump dredger JPD 300-120

Full-scale experimental studies were planned to confirm the reliability of the previously obtained analytical dependencies to determine the rational parameters of hydraulic disintegrators [6, 7] and determine the operational characteristics of the jet pump dredger JPD 300-120, based on the soil suction head with a jet disintegrator system JSH 300-120.

In the course of full-scale experiments and tests, such mining and technical parameters were controlled:

$H_в$ – pressure in the pressure water supply pipe, mPa;

$H_{вп}$ – vacuum in the suction pipe (the vacuum gauge sensor is installed in the suction pipe of the soil suction head), kPa;

$L_п$ – pipeline length, m;

h_n – geometric height of the slurry lift above the water level, m;

h_3 – geometric slurry suction head, m;

$d_э$ – diameter of ejection nozzles in operation, m;

d_p – diameter of jet disintegrator nozzles in operation, m;

$n_э$ – number of ejection nozzles in operation, pcs.;

n_p – number of jet disintegrator nozzles in operation, pcs.;

T – turn-on time of mining equipment, min.

The full-scale experiment was carried out with the length of the slurry pipeline $L_П$ = 80 m, the depth of mining h_3 = 2 m, the geometric height of the slurry lift above the water level h_n = 5 m. During the experiment, the volume concentration of the slurry was measured when draining onto the hydraulic warehouse (Fig. 4). Productivity for slurry and minerals was determined by the volumetric method. The obtained experimental data of a full-scale experiment performed during pilot tests of the jet pump dredger JPD 300-120 are shown in tables 1, 2.

Fig. 4. The jet pump dredger JPD 300-120 in the face

The experiment was carried out in two stages. The first one provided for the use of a simplified jet disintegrator system for jet disintegration of the underwater face, while the cavity of the disintegrator nozzle had a direct connection with the pressure cavity of the soil suction head, that is, the pressure in the pressure cavity of the soil suction head was 1,02…1,06 mPa (Table 1).

Table 1

Experimental data of natural experiment. The pressure in the pressure cavity of the soil suction head – 1,02…1,06 мПа

Level in measuring container, mm		Slurry volume concentration, C_o	Pressure gauge readings, $H_в$, mPa	Vacuum gauge readings $H_в$, kPa
slurry	sand			
1	2	3	4	5
Experimental data at: $d_э$ – 19 mm, d_p – 7 mm, $n_э$ – 8 pcs., n_p – 1 pcs.				
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		
Experimental data at: $d_э$ – 19 mm, d_p – 7 mm, $n_э$ – 8 pcs., n_p – 2 pcs.				
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, soil disintegration in the underwater face was carried out by nozzles, in which, by means of throttling, the pressure in front of the nozzles was reduced to the calculated values, that is, the pressure in the pressure cavity of the soil suction head was 0,5…0,6 м mPa. The obtained experimental data are given in the table 2Comparison of experimental data indicates the effectiveness of the developed calculation method for the design of jet disintegrator system for preparing the jet pump dredgers underwater face [4, 6, 7]. The maximum average value of the slurry volume concentration for the first stage was C_o = 0,09, for the second stage C_o = 0,16. Thus, pressure control in the pressure cavity of the soil suction head makes it possible to rationalize the process of soil disintegration and increase the concentration of the transported slurry by 77,8%, which is quite significant.

Table 2

Experimental data of natural experiment. The pressure in the pressure cavity of the soil suction head – 0,5…0,6 mPa

Level in measuring container, mm		Slurry volume concentration, C_o	Pressure gauge readings, $H_в$, mPa	Vacuum gauge readings $H_в$, kPa
slurry	sand			
1	2	3	4	5
Experimental data at: $d_э$ – 19 mm, d_p – 7 mm, $n_э$ – 8 pcs., n_p –0 pcs.				
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 – 0,06		
Experimental data at: $d_э$ – 19 mm, d_p – 7 mm, $n_э$ – 8 pcs., n_p – 1 pcs.				
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 – 0,12		
Experimental data at: $d_э$ – 19 mm, d_p – 7 mm, $n_э$ – 8 pcs., n_p – 2 pcs.				
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		

Table 2 continued

1	2	3	4	5
Experimental data at: $d_э$ – 19 mm, d_p – 7 mm, $n_э$ – 8 pcs., n_p – 3 pcs.				
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		

It is characteristic that the complete absence of the action of the jet disintegrator system nozzles during the preparation of the soil for mining showed the minimum concentration of the slurry C_o= 0,06. That is, the use of underwater face jet disintegration technology for subsequent development allows increasing the slurry concentration by 166,7%.

The results of full-scale experimental studies carried out at a real field indicate the significant possibilities of the mining technology for jet disintegration of the underwater face, including for the development of gravel and complex structure deposits.

According to the results of pilot tests of the jet pump dredger JPD 300-120, its operational characteristics were determined:

– type of soil - non-cohesive sand, gravel with a particle size of up to 120 mm;
– depth of mining – up to 6 m;
– distance of transportation horizontally – up to 250 m;
– working pump – ЦНС 300-120;
– pump drive power – 160 kWt;
– slurry productivity – 500 m^3/h.

The jet pump dredger JPD 300-120, manufactured on the basis of the MZ-8 dredger, was recommended for use in the development of the East-Bug-2 sand deposit.

In accordance with the Working Design "Reconstruction of a quarry for the development of East-Bug-2 deposit of sand", the modernized dredger MZ-8 is provided for the processing of clay sands [9, 10].

Conclusions. The use of the soil suction head with a jet disintegrator system JSH 300-120 as the main equipment of the jet pump dredger JPD 300-120 made it possible to effectively mining of a gravel layer during the development of the East-Bug-2 building sand deposit. Thus, pressure control in the pressure cavity of the soil suction head makes it possible to rationalize the process of soil disintegration and increase the concentration of the transported slurry by 77,8%, which is quite significant.

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АНОТАЦІЯ

Метою даної роботи є виконання натурних експериментальних досліджень ежекторного землесосного снаряду ЗНС 300-120, обладнаного інноваційним ґрунтозабірним пристроєм з струминним розпушувачем.

Методологія. Полягає у підготовці і проведенні натурних експериментальних тестів плавучого видобувного обладнання у складі ежекторного ґрунтозабірного пристрою з гідравлічним розпушувачем, розробленого із застосуванням методу розрахунку раціональних параметрів гідравлічних розпушувачів.

Результати. В роботі обґрунтовані параметри системи видобутку й гідротранспортування, розроблена конструкція ґрунтозабірного пристрою системи струминної підготовки і гідротранспортування ґрунтів. Вибрані основні елементи системи водопостачання ґрунтозабірного при-

строю. Натурні експериментальні дослідження підготовлені і виконані в умовах Східно-Бузького-2 родовища будівельних пісків, яке розташоване у Вознесенському районі Миколаївської області. Есперимент виконаний в два етапи. Перший передбачав застосування для струминної підготовки вибою спрощеної системи розмиву, при цьому порожнина розмивної форсунки мала пряме сполучення з напірною порожниною ґрунтозабірного пристрою. На другому етапі розмив ґрунту у вибої виконували форсунками, у яких за допомогою дроселювання, тиск перед соплом зменшували до розрахункових значень.

Наукова новизна. Уперше в кризових економічних умовах з метою підтвердження достовірності отриманих раніше аналітичних залежностей для розрахунку раціональних параметрів гідравлічних розпушувачів й визначення експлуатаційних характеристик обладнання проведені натурні експериментальні дослідження землесосного снаряду ЗНС 300-120, обладнаного інноваційним ежекторним ґрунтозабірним пристроєм з струминним розпушувачем.

Практичне значення. Застосування ґрунтозабірного пристрою у якості основного обладнання земснаряду ЗНС 300-120 дозволило ефективно розробляти гравійний пласт при освоєнні Східно-Бузького-2 родовища будівельних пісків. Промислове упровадження струминнонасосної установки на прикладі землесосного снаряду ЗНС 300-120 показало практичну можливість реалізації, технологічну і економічну ефективність застосування ежекторних земснарядів при освоєнні обводнених і підводних піщано-гравійних родовищ зі значним вмістом крупного гравію. Керування тиском у напірній порожнині ґрунтозабірного пристрою дозволило раціоналізувати процес розмиву ґрунту і підвищило концентрацію транспортуємої пульпи на 77,8%.

Ключові слова: *ежекторний землесосний снаряд, робочий орган, гідравлічний розмив, натурний експеримент.*