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Болотських М.С., Болотських М.М. ІНТЕГРАЛЬНІ ОГИНАЮЧІ БЕЗРОЗМІРНІ ВАКУУМНІ ХАРАКТЕРИСТИКИ ВОДОСТРУМИННИХ НАСОСІВ, ВЖИВАНИХ В УСТАНОВКАХ БУДІВЕЛЬНОГО ВОДОЗНИЖЕННЯ. У статті описано особливості робочого режиму водоструминних насосів, використовуваних для створення вакууму в установках будівельного водозниження, виведені аналітичні залежності і побудовані безрозмірні вакуумні характеристики, аналіз яких дозволив отримати інтегральні огинаючі характеристики, що є геометричним місцем точок, що відповідають максимальним значенням ККД водоструминних насосів, дані рекомендації зі застосування них у практиці проектування і експлуатації.

Ключові слова: водоструминний насос, безрозмірна характеристика, вакуум, водозниження.

Bolotskykh N.S., Bolotskykh N.N. INTEGRAL CIRCUMFLEX DIMENSIONLESS VACUUM DESCRIPTIONS OF WATER-JET PUMPS, APPLIED IN OPTIONS OF BUILDING WATER DECREASE. The features of operating condition of the water-jet pumps used for creation of vacuum in the options of building water decrease are described in the article, analytical dependences are shown out and dimensionless vacuum descriptions, the analysis of that allowed to get integral circumflex descriptions, being the geometrical place of points corresponding to the maximal values output-input ratio water-jet pumps, are built, recommendations are given on application of them in practice of planning and exploitation.

Keywords: water-jet pump, dimensionless description, vacuum, water decrease.

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FEATURES OF CREATION OF UNIVERSAL TECHNOLOGICAL SETS OF THE SMALL-SIZED EQUIPMENT FOR CONDITIONS OF A BUILDING SITE

This article describes the equipment patented in Ukraine and appraised under construction conditions as an independent machine and as a part of the universal small-sized equipment. This article provides process flow diagram for manufacture of reinforced concrete shells by wet filling method upon off-form concreting by means of equipment set that uses fiber-concrete mixtures with synthetic elements. Dependencies have been found to determine its productivity and power costs.

Key words: Universal small-sized equipment, processing kit, universal hose-type concrete pump, three-shaft concrete mixer, capacity, power, fiber-concrete mixture.

In modern constructions, monolithic concretizing plays a central role. There are a lot of different types of equipment that are used in these works for preparation and transportation of concrete mixtures [1, 2]. The studies of these machines are represented in these works [3, 4]. Considered structures of machines used in monolithic concreting have disadvantages that relate the quality of prepared mixture and reliability of operation in comparison with machines offered in this work.

The experience of multiple use of sets of universal small-sized equipment at construction facilities of different purpose shows their efficiency and suggests that wide-scale use of these machines is viable. The set content includes new machines and equipment protected by Ukrainian patents. This includes concrete grout pumps of different design, concrete mixers that operate in cascade mode and gunned nozzles with ring tips [5, 6]. Today, new universal non-piston hose concrete pump of original design is at manufacture stage [7].

All machines are developed based on results of multiple studies and wide testing at construction facilities.

Proposed equipment may be used in construction and reconstruction of operated buildings and structures for preparation of structures and items of complex form directly at construction sites up the use of off-form concreting by wet filling method [8].

Unfurnished concrete casting by the wet shotcrete method was used in the manufacture of reinforced concrete shells [9] (Fig. 1a, b).


a)


b)

Fig. 1. Reinforced concrete casings made at construction sites by wet filling method upon off-form concreting.

Concreting by the wet shotcrete method was carried out with the following technological parameters: working pressure p = 0,6 MPa; Distance to the shotcrete surface of the shell L = 0.8...1.0 m. Compressed air consumption for supplying the concrete mixture through the nozzle q_1=7 m^3/min, additional supply of compressed air through the ring nozzle q_2=2 m^3/min; The rate of spraying a fiber-reinforced concrete mixture onto the shotcrete surface of the shell is v = 55...60 m/s.

Subsequently, the manufactured reinforced concrete shells by the wet shotcrete method were tested.

The purpose of full-scale tests was to determine the stress-strain state of reinforced concrete shells of the new «Monophant» construction system using a hydrostatic method [9, 10].

The object of the study was reinforced concrete cylindrical and spherical shells with dimensions in the plan of 2200×2200 mm, made in the form of lightweight structures consisting of external and internal concrete cladding 50 mm thick, between which there are liners of expanded polystyrene 160 mm thick. The reinforcement of the shells is made with a grid with a cell of 200×200 mm and d = 6 mm. On the diagonal directions of the shells there are internal ribs with a width of 50 mm, ensuring the joint operation of the shells, which are reinforced with a flat frame with fittings d = 10 mm.

Given the complexity of the configuration of the loaded surface of the shells, reservoirs in the form of a cellular system consisting of 11 cells with dimensions of 200×200 mm and a height of 1200 mm were constructed above the shells for the uniform distribution of pressure from the water column (Fig. 2).

During the experiment, the loading of the shells was carried out by a uniformly distributed load over the entire surface of the shells, 1/2, 1/3 of the cylindrical shell, and 1/2, 1/4, 1/8 of the spherical shell [11, 12]. The tests were non-destructive. The measured deformations in reinforced concrete casings were recorded at 25 points using indicators (Table 1, Fig. 3).

a) b)

Fig. 2. Bench tests of shells: a) - water supply to the tank; b) - tank design

Table 1 - Average data of indicators of vertical displacements of a spherical shell

Indicator No.	Vertical movements, mm							
	Full	Δ	1/2	Δ	1/4	Δ	1/8	Δ
1	0,275	0,021	0,117	0,004	0,044	0,026	0,016	0,006
2	0,382	0,009	0,136	0,000	0,055	0,024	0,023	0,006
3	0,419	0,082	0,153	0,021	0,068	0,013	0,027	0,007
4	0,377	0,013	0,133	0,003	0,051	0,003	0,020	0,009
5	0,264	0,030	0,115	0,006	0,039	0,031	0,015	0,007
6	0,383	0,008	0,157	0,023	0,142	-0,021	0,042	0,001
7	0,597	-0,021	0,195	0,004	0,149	-0,018	0,054	0,000
8	0,496	0,026	0,197	0,011	0,159	-0,003	0,063	-0,004
9	0,590	-0,014	0,185	0,014	0,093	0,003	0,049	0,005
10	0,387	0,004	0,153	0,027	0,050	0,004	0,039	0,003
11	0,417	0,084	0,231	0,020	0,208	0,014	0,077	-0,009
12	0,490	0,031	0,257	0,031	0,231	-0,014	0,091	0,000
13	0,686	-0,054	0,281	0,022	0,178	-0,026	0,096	-0,001
14	0,495	0,026	0,265	0,023	0,156	-0,005	0,095	-0,004
15	0,420	0,081	0,241	0,010	0,064	0,019	0,080	-0,012
16	0,384	0,007	0,295	0,005	0,233	-0,016	0,108	-0,016
17	0,595	-0,019	0,331	-0,010	0,237	0,011	0,130	-0,008
18	0,498	0,021	0,349	0,012	0,227	-0,018	0,184	-0,015
19	0,593	-0,017	0,335	-0,006	0,151	-0,020	0,127	-0,005
20	0,381	0,010	0,308	-0,008	0,059	0,020	0,103	-0,012
21	0,268	0,026	0,238	-0,039	0,178	0,021	0,120	-0,017
22	0,386	0,004	0,349	-0,008	0,236	-0,013	0,138	-0,011
23	0,413	0,088	0,405	-0,007	0,211	0,011	0,223	0,003
24	0,380	0,010	0,358	-0,017	0,144	-0,023	0,135	-0,008
25	0,275	0,021	0,246	-0,047	0,047	0,019	0,118	-0,015

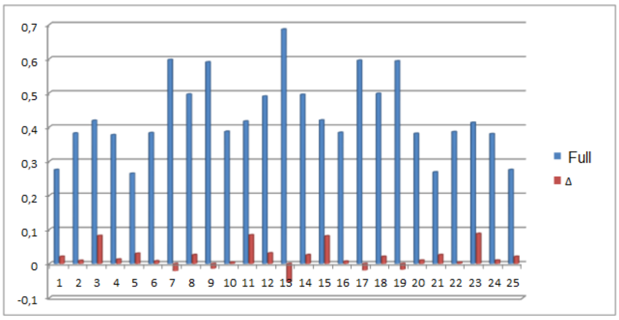
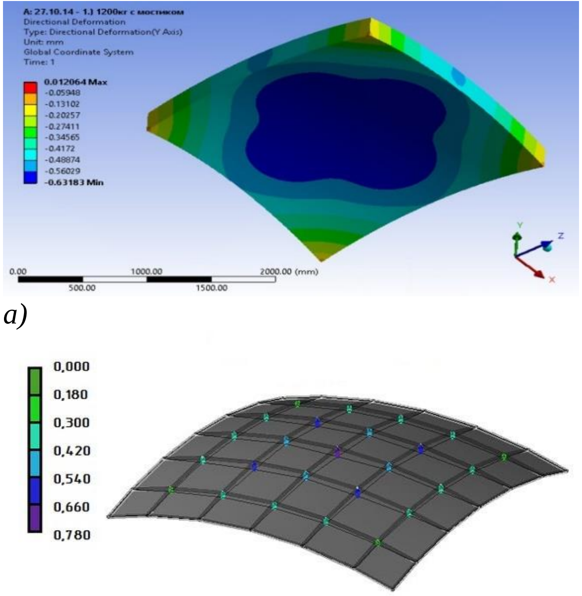


Fig. 3. Graphical representation of vertical displacements of a spherical shell from a uniformly distributed load of 10 kN/m^2 over the entire surface of the structure

The tests were carried out sequentially, to obtain statistical data, each loading and unloading scheme was performed 6 times.

Comparison of the experimental data with the theoretical data clearly demonstrates the correctness of the calculated model of the spherical and cylindrical shell, as well as the purity of the experiment (Fig. 4).



a)

b)

Fig. 4. Comparison of theoretical and experimental data of spherical shell studies (loading of the entire shell surface): a) The theoretical displacement field; b) The experimental displacement field

Thus, the load system, the measurement system, the developed and patented method for testing the shells of different Gaussian curvature in the complex made it possible to solve the following tasks in the process of testing: to confirm the theoretical data obtained experimentally and to evaluate the deformed state of reinforced concrete shells.

On the basis of the full-scale experiment of reinforced concrete structures, the maximum displacement from the load of 10 kN/m^2 was established, which amounted to 0.686 mm for spherical and 0.242 mm for a cylindrical shell.

It follows from the studies carried out that the reinforced concrete lightweight structures of the «Monophant» system, having a reduced thickness of 40-50% less than that of solid structures due to the use of unrecoverable hollow-core inserts made from expanded polystyrene, possess all the necessary strength and rigidity characteristics of load-bearing elements of buildings and structures from monolithic reinforced concrete and open up fundamentally new opportunities in the formless monolithic construction with the use of concrete laying by wet-shotcrete.

Manufacture of reinforced concrete shells was carried out with the help of a technological set of equipment, which was made according to the scheme "two-piston mortar pump with poppet valves - three-shaft concrete mixer operating in cascade mode - working nozzle with a ring nozzle" [5, 6].

It is offered subsequently in the specified scheme of a technological complete set to use universal non-piston hose concrete pump which will allow to increase term of service of the specified technological complete set of the equipment. The proposed new design of the concrete pump is shown in Fig. 5 [7].

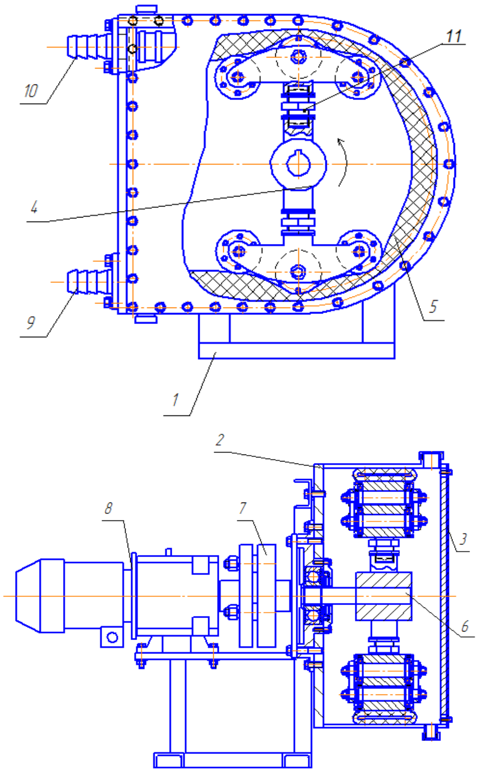


Fig. 5. Universal non-piston hose concrete pump of a new design solution.
1 - frame; 2 - pump housing; 3 - the cover of the pump casing; 4 - rotor with rollers; 5 - a working part of a hose in the case of the pump; 6 - central rotor drive shaft; 7 - coupling; 8 - the electric motor; 9 - the suction hose connection; 10 - the union of a delivery part of a hose; 11 - threaded device.

A distinctive feature of the design of the proposed concrete pump is the installation on the rotor at an angle of 180° of two traverses with three rollers of the same diameter. Two lateral rollers in relation to the central one in each of the two traverses are installed relative to the central axis of the rotor at different radii. This allows the rotor to deform the hose inside the pump casing gradually under the influence of the rollers both during the suction of the concrete mix and during its injection. This design of the rotor with rollers allows smoothly returning the hose to its original state. The specified features of the concrete pump construction contribute to the extension of its reliable operation. In addition, the presence of threaded devices on the rotor allows, if necessary, to adjust the operation of the pump to different capacities, which is possible with its operation on hoses of different diameters (d = 32 mm, 50 mm, 75 mm). For this purpose, the traverses with the rollers are connected to the rotor by special threading devices. Also, the devices allow the use of a new pump to work on hoses of different diameters.

When transferring a concrete pump to a hydraulic drive, its capabilities expand. Continuous smooth switching of the working speeds of the concrete pump also helps to increase the service life of the concrete pump. A concrete pump with a previously presented schematic diagram and a mechanical drive (Fig. 4) in the variant of its transfer to a hydraulic drive is shown in Fig. 6.

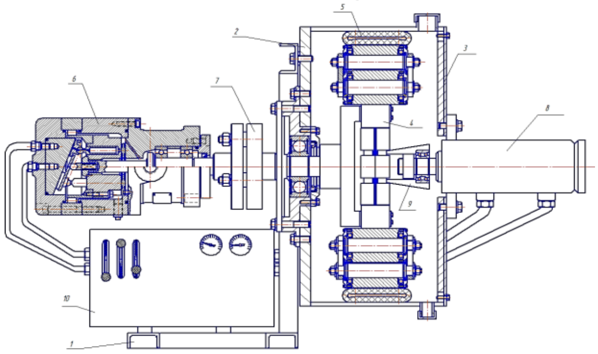


Fig. 6. Universal non-piston hose type concrete pump with hydraulic drive
1 - frame; 2 - pump housing; 3 - the cover of the case; 4 - rotor with rollers; 5 - flexible hose; 6 - the hydraulic motor; 7 - coupling; 8 - the hydrocylinder; 9 - conical tip; 10 - hydraulic distribution unit.

One of the variants of the technological scheme with the use of a new universal small-sized equipment, which can be recommended for the formless concreting of architectural forms of various design solutions, is presented in Fig.6. The basic machines in this scheme are the three-shaft concrete mixer 6 and the universal non-piston hose concrete pump 8. The above technological scheme attracts primarily by the fact that all operations of the working cycle, including, if necessary, cutting of synthetic fiber fibers, are carried out directly on the construction site and are combined in time. Such an organization of the robot cycle excludes the possibility of clumping of fiber fibers, since they, when the mixer is operating, are cut by the automatic cutter installed on its body.

All equipment included in the proposed scheme is patented in Ukraine. It is of interest to design a robotic nozzle 10, which minimizes the rebound, as shown in Fig. 7.

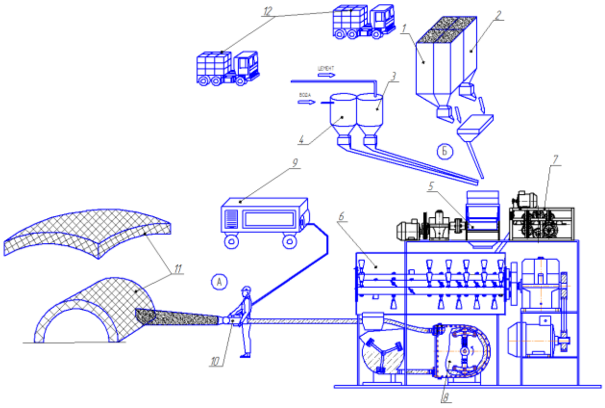


Fig. 7. Technological scheme of works by wet-shotcrete directly on the construction site.
1 - bunker with sand; 2 - bunker with rubble; 3 - bunker with cement; 4 - water tank; 5 - belt feeder; 6 - three-shaft concrete mixer; 7 - a machine-cutter of a fiber; 8 - universal hose concrete pump; 9 - the compressor; 10 - shotcrete nozzle; 11 - shotcrete shells; 12 - truck for transportation of materials; A - the area of shotcrete works; B - concrete mixing unit.

High performance indexes of small-sized equipment sets are reached mainly due to creation of reliable structure of basic machines that ensure their stable operation.

Thus, for process set that uses fiber-concrete mixture (fig. 6), the number of cycles of discharge of fiber concrete mixture to consumer through transport pipeline mostly depends on reliability of hose section that interacts with rollers of rotating rotor inside concrete pump and the length of transport pipeline, through which the mortar is fed to consumer.

$$N_{ц} = t_{resource}/t_{ц}, \quad (1)$$

where $t_{resource}$ is a time resource , for which the length of operating part of the hose of concrete pump and transport pipeline of respective diameter considering the reliability of material, from which it is made, hours ; $t_{ц}$ is full operation cycle time of concrete pump reduced to hourly output , hours.

$$t_{ц} = V/\Pi_{tech} \quad , \quad (2)$$

where V is required volume of concrete mortar to be pumped by available hose-type concrete pump, m^3; Π_{tech} is hourly output of the pump, m^3/h.

$$\Pi_{tech} = 60S \cdot V_{cp} \cdot z \cdot k_1 \cdot k_2 \cdot k_3, \quad (3)$$

where S is cross-section area of the hose in concrete pump, m^2; V_{mean} is a mean speed of fiber-concrete mortar that is transported through flexible pipeline, m/min.; z is a number of rollers of pump rotor ; k_1 is a factor that considers gradual build-up of force created by rotor rollers that press the hose in working part of the pump ($k_1 = 1{,}36$); k_2 is a factor that considers the reliability of work of the hose part of the pump considering respective strains; k_3 is a factor that considers the conditions for feeding mortars by concrete pump through transport flexible pipeline taking into account its physical and mechanical properties.

$$k_2 = \sigma_{eql}/[\sigma]_{\text{p}}, \quad (4)$$

where σ_{eql} is total multi-sided tension that affects the hose in pump house upon movement of the portion of concrete mortar under the effect of pressing rotor rollers , MPa; $[\sigma]_{\text{p}}$ is acceptable rapture tension of the hose, MPa;

$$k_3 = p_{ouput\ action}/p_{output\ calc.}, \quad (5)$$

where $p_{output\ action}$ is actual pressure at the output from main transport line of universal hose-type concrete pump; $p_{\ output\ calc.}$ is a calculated value of the pressure at the output of main transport line of universal hose-type concrete pump [13].

The hourly productivity of the new hose concrete pump has been studied taking into account the technological parameters that determine the operation of the machine.

In this case, the productivity of the concrete pump (Π_{tech}, m^3/h) was considered as a function of Y, depending on the following factors:

X_1 - diameter of the hose in the casing of the concrete pump (d, m);

X_2 - rotor speed (n, min^{-1});

X_3 - is the mobility of a concrete mixture (П, cm).

The function (productivity), depending on three independent factors Y = f (X_1, X_2, X_3) was investigated using the central orthogonal composition plan of the second order.

The regression equation obtained on the basis of the processing of the experimental data in the final version has the form:

$$y = 8{,}547 + 8{,}86x_1 + 5{,}154x_2 + 2{,}584x_3 + 2{,}352x_1^2 + 4{,}43x_1x_2 + 2{,}215\, x_1x_3 \quad (6)$$

The obtained regression equation allowed to construct the dependences of the performance of the hose concrete pump on each of the indicated technological parameters and to analyze their influence on the function under study.

Fig. 8 shows the dependence of the pump performance on the diameter of the hose used in it.

The nature of this dependence indicates that in the accepted range of variation, productivity increases with increasing diameter of the hose. Therefore, this conclusion should be taken into account when using a concrete pump to work on hoses of different diameters.

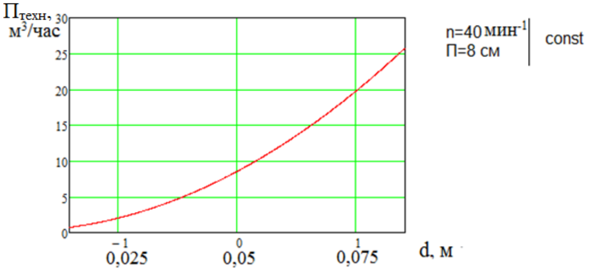


Fig. 8. Dependence of the pump performance on the diameter of the hose used in it.

Fig. 8 shows the dependence of the performance of the concrete pump on the rotor speed.

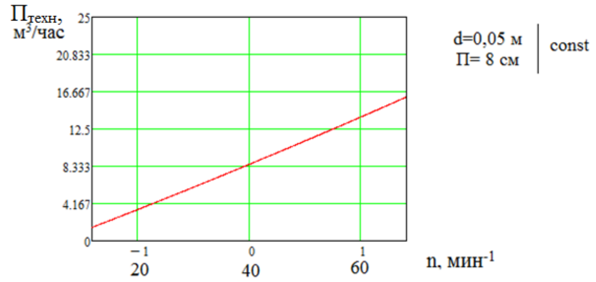


Fig. 9. Dependence of the performance of the concrete pump on the rotor speed

The nature of this dependence indicates a direct proportionality between the performance of the concrete pump and the rotor speed.

The graphical dependence of the concrete pump performance on the mobility of the mixture transported by it is shown in Fig. 9.

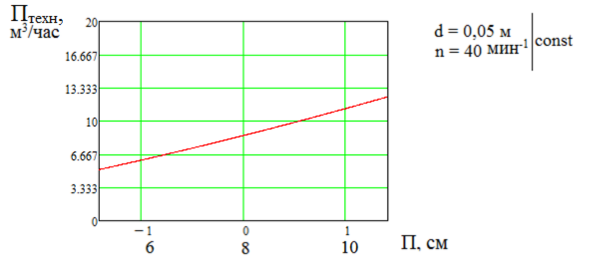


Fig. 9. Graphical dependence of the concrete pump performance on the mobility of the mixture transported

Based on the analysis of Fig. 9, it should be noted that the range of variation of the mobility of the mixture under study allows us to make the following conclusion:

1. In the selected range of variation, the parameters increase the productivity of the concrete pump;

2. The most characteristic increase in the productivity of a concrete pump is observed with an increase in the diameter of the hose;

3. The initial technological parameters of the process of transportation of concrete mixes by a hose pump affect its productivity and can be subjected to longer-term studies.

Thus, when determining the productivity of a concrete pump as a basic indicator of the operation of a technological set, the results of the studies carried out to study the effect on the performance of a concrete pump of the above factors are taken into account.

So, the number of cycles of discharge of fiber-concrete mortar to the consumer through flexible transport pipeline by means of universal non-piston hose type concrete pump per hour is calculated as follows:

$$N_{\text{ц}} = \frac{60 \cdot t_{resource} \cdot S \cdot V_{mean} \cdot z \cdot k_1 \cdot k_2 \cdot k_3}{V}. \quad (7)$$

If this set of equipment is used only for preparation of fiber-concrete mortar excluding the feeding finished mortar to consumer, the basic machine is three-shaft mixer that operates in cascade mode.

The productivity of a technological equipment set is determined on the basis of the technical performance of the base machine used in the composition of the technological set [14].

The productivity of the technological set with the use of a three-shaft concrete mixer is found according to the dependence:

$$\Pi_{tech'} = 3600 \cdot \frac{\pi}{4} \cdot (D^2 - d^2) \cdot b \cdot n \cdot z_b \cdot \sin\alpha \cdot k_1^{aver} \cdot k_r^{II}, \quad (8)$$

where D – is the diameter of the shaft along the end of the blade, m; d – is the diameter of the average shaft, m; b – blade width, m; Z_b – there is number of blades of the middle shaft; α – is the angle of installation of the blades, deg; k_l^{aver} – load factor of the mixer relative to the average shaft, $k_l = 0.75$; n – frequency of rotation of the shaft of the working element; k_r^{II} – coefficient of return of the concrete mixture of the second zone.

Power costs are considered using the example of the proposed technological kit for small-size equipment for the preparation of fiber-reinforced concrete mixtures in the construction site [15]:

$$P_{tes} = P_{b.m} + P_{a.c} + P_{feed} \quad (9)$$

where P_{tes} – is total power consumptions for operation of process set of the equipment, kW; $P_{b.m}$ – is power consumptions for operation; $P_{a.c}$ – is power consumptions for operation of automatic cutter, P_{feed} – is power consumptions for operation of dosing feeder.

Thus, total power required for operation of process set of the equipment in preparation of fiber-concrete mortars with synthetic fiber should be calculated through the following dependency:

$$P_{tes} = \left[\frac{\lambda(P_1 + P_2 + P_3)}{1000\eta}\right] + \left[\frac{F_T \cdot V_r \cdot Z_1 \cdot Z_2}{\eta_1 \cdot 4\eta_2} + \pi \cdot d_f^2 \cdot Z_2 \cdot r_{sh} \cdot \tau_c \cdot \omega_{s.h} \cdot k_c \cdot \sin\alpha\right] + \left[(0{,}003 \cdot \Pi_{feed} + 0{,}00015 \cdot \Pi_{feed} \cdot l + 0{,}03 \cdot B_t \cdot V_t. \cdot l) \cdot К1\right] \quad (10)$$

where P_1 – is a power consumed in the process of mixing of concrete mortar components by means of upper shaft of the mixer, kW; P_2 – is a power consumed for mixing components and their transportation to discharge hole by means of middle shaft of the mixer, kW; P_3 – is a power consumed in mixing of mortar components by lower shaft of the mixer, kW; $K^{'}$ – is a factor that considers additional power consumptions for mixing mortar components with synthetic fiber elements upon their feeding by automatic cutter to concrete mixer; F_T – is a draft force created by synthetic fiber feeding mechanism, H; V_r – is a linear rotation speed of feeding rollers; Z_1 – is a number of fibers in harness that is stretched by rollers; Z_2 – is a number of the points where the fiber contacts with roller surfaces (Z_2= 2); $Z_{s.h}$ – is shearing head radius, m; d_f – is fiber element diameter; τ_c – is acceptable strength of fiber elements per cutoff, mPa; $\omega_{s.h}$ – is a spin rate of shearing head, sec^{-1}; k_c – is cycle factor; λ – is cutting angle of the harness made of synthetic fiber; Π_{feed} – is a technical performance of dosing feeder; 1 – is a length of working part of dosing feeder; B_t – is dosing feeder belt; K_1 – is factor that considers resistance force at driving and tensioning drums.

Thus, it is necessary to consider the specific features of machine structures included into sets of small-sized equipment as shown in example above upon analysis of the operation of these process sets.

Conclusions:

1. Reinforced concrete casings made in the conditions of a construction site are shown at use of the new universal small-sized equipment in the form of the technological complete set of the equipment by a method of wet shotcrete.

2. The expediency of using the technological set of small-sized equipment for manufacturing of reinforced concrete curvilinear products with bottomless concreting in the conditions of a construction site by the wet shotcrete method is substantiated.

3. For the example of the schematic diagram of the proposed technological set, based on the results of the studies, dependences were obtained to determine its productivity and the power costs for preparing a fiber-reinforced concrete mixture.

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Емельянова И.А., Блажко В.В., Шатохин В.М., Чайка Д.О., Кабанец Д.С. ОСОБЕННОСТИ СОЗДАНИЯ УНИВЕРСАЛЬНЫХ ТЕХНОЛОГИЧЕСКИХ КОМПЛЕКТОВ МАЛОГАБАРИТНОГО ОБОРУДОВАНИЯ ДЛЯ УСЛОВИЙ СТРОИТЕЛЬНОЙ ПЛОЩАДКИ. Рассматривается оборудование, запатентованное в Украине, которое апробировано в условиях строительства как в качестве самостоятельных машин, так и в составе комплектов универсального малогабаритного оборудования. Рассмотрена технологическая схема изготовления железобетонных оболочек способом мокрого торкретирования при безопалубочном бетонировании с помощью комплекта оборудования, работающего на фибробетонных смесях с синтетическими элементами. Найдены зависимости для определения его производительности и затрат мощности.

Ключевые слова: универсальное малогабаритное оборудование, технологический комплект, универсальный шланговый бетононасос, трехвальный бетоносмеситель производительность, мощность, фибробетонная смесь.

Ємельянова І.А., Блажко В.В., Шатохін В.М., Чайка Д.О., Кабанець Д.С. ОСОБЛИВОСТІ СТВОРЕННЯ УНІВЕРСАЛЬНИХ ТЕХНОЛОГІЧНИХ КОМПЛЕКТІВ МАЛОГАБАРИТНОГО ОБЛАДНАННЯ ДЛЯ УМОВ БУДІВЕЛЬНОГО МАЙДАНЧИКА. Розглядається обладнання, що запатентовано в Україні, яке апробовано в умовах будівництва як в якості самостійних машин, так і в складі комплектів універсального малогабаритного обладнання. Розглянуто технологічну схему виготовлення залізобетонних оболонок способом мокрого торкретування при безопалубковому бетонуванні за допомогою комплекту обладнання, що працює на фібробетонних сумішах з синтетичними елементами. Знайдено залежності для визначення його продуктивності і витрат потужності.

Ключові слова: універсальне малогабаритне обладнання, технологічний комплект, універсальний шланговий бетононасос, тривальний бетонозмішувач продуктивність, потужність, фібробетонна суміш.