Definisanje osnovnih parametara kompleta male opreme za pripremu suvog maltera za različitu namenu

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Na osnovu prikupljenih informacija i pregleda naučne literature, uočena su nerešena pitanja u procesu pripreme suvih građevinskih mešavina neposredno na gradilištu. Razmatrane su konstrukcije postojećih tehnoloških kompleksa za proizvodnju suvih građevinskih mešavina a njihovi glavni nedostaci su identifiktovani neposredno pri primenini gradilištu. Na osnovu izvedenih istraživaanja predloženi su projekti tehnoloških setova male opreme za pripremu suvih građevinskih mešavina na gradilištu. Utvrđeno je da su osnove za kreiranje predloženih tehnoloških kompleta novi projekti betonskih miksera koji rade u kaskadnom načinu rada. Predložena je tehnika za izračunavanje glavnih parametara tehnološke opreme, zavisno od upotrebe osnovne mašine.

Ključne reči: set male opreme, suva mešavina, mikser betona, kaskadni režim, putanja kretanja čestica mešavine.

1. UVODNE NAPOMENE

Moderne suve građevinske smeše su složene kompozicije komponenti, različite u njihovim svojstvima. Mešanje ovih komponenti zajedno i stvaranje homogene smeše je težak zadatak u tehničkom smislu. Stvaranje efikasne opreme za ove svrhe je veliki problem modernog građevničkog procesa. Sa svojim rešenjem, posebnu pažnju treba posvetiti razvoju tehnološke opreme.

Trenutno, u procesu pripreme suvih građevinskih mešavina, postoji niz nerešenih problema: povećana nosivost radnih tela i miksera, dugo vremena za pripremu kompleksnih kompozicija, prisustvo segregacije tokom pripreme smeša i složenost pripreme smeša direktno na gradilištu [1 - 4].

Trenutno se koriste tehnološki kompleksi koji imaju mogućnost proizvodnje mešavina različitih vrsta za pripremu suvih građevinskih mešavina [5 - 7]. Kompleksi su opremljeni visokokvalitetnim uređajima za doziranje i mešačima prisilnog delovanja sa jednim ili dve osovine, na kojima su različiti mešački uređaji [3, 9]. Međutim, savremeni mešači za beton ne dozvoljavaju uvek proizvodnju homogene smeše sa malim faktorom punjenja radne zapremine mašine. Pored toga, postojeći mikseri ne dozvoljavaju stvaranje jednog organizovanog radnog ciklusa na jednom mjestu. Sa ovih pozicija, atraktivniji su tehnološki kompleti koji omogućavaju kombinovanje svih operacija u vremenu.

Produktivnost skupa tehnološke opreme određuje se na osnovu tehničkih performansi bazne mašine koja se koristi u sastavu tehnološkog seta.

Resultati laboratorijskih i industrijskih ispitivanja novih dizajnerskih miksera koji rade u kaskadnom režimu, potvrđuju njihovu efikasnost u pripremi suvih građevinskih mešavina, što omogućava opremanje ovih mašina tehnološkim kompletima i kompleksima [8].

2. GLAVNI MATERIJALI I REZULTATI

Predlaže se izrada i uvođenje malih setova opreme za pripremu suvih građevinskih mešavina na bazi novih miksera koji rade u kaskadnom režimu u proizvodnji malih količina (za pojedinačnu malu izgradnju, izgradnju u poljoprivrednom sektoru, popravku i rekonstrukciju postojećih objekata). Kompleti tehnološke opreme prikazani su na Slici 1. Sva oprema ovih tehnoloških kompleta bazirana je na zajedničkoj osnovi i izabrana je u skladu sa performansom i korištenjem mašina.

Tehnološki set opreme, prikazan na slici 1, uključuje sledeće komponente: 1 - mikser (osnovna mašina); 2 - mašina za punjenje; 3 - bunker za pesak; 4 - silos cementa; 5 - vaga za merenje težine; 6 - rezač vlakana; 7 - transportero-dodavač; 8 - bunker granita; 9 - punilica.

Osnovne mašine tehnološkog seta (slika 1) mogu biti gradski mešači novog konstruktivnog rešenja: mikser sa dve osovine, gravitacioni betonski mešač [5].

Karakteristika rada ovih mašina je stvaranje složenog kretanja čestica smeše u telu mašine [9]. Oprema tehnološkog skupa je ujedinjena i ima tradicionalno rešenje izvođenja. Produktivnost skupa tehnološke opreme određuje se na osnovu tehničkih performansi bazne mašine koja se koristi u sastavu tehnološkog seta.

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Slika 1: Tehnološki set opreme za pripremu suve građevinske mešavine: 

a) osnovna mašina i troosovinski mikser; b) osnovna mašina sa gravitacionim mikserom; c) osnovna mašina idvorotorni mikser

Produktivnost tehnološkog seta korišćenjem betonskog miksera sa tri osovine nalazi se prema zavisnosti [10]:

\[
\Pi_{\text{mres}} = \frac{3600 \cdot \frac{\pi}{4} (D^2 - d^2) \cdot b \cdot n \cdot z_2 \cdot \sin \alpha \cdot k_{Y} \cdot k_{Z}}{2} \cdot Z_{II}
\]

gde su:

- \(D\) – prečnik vratila na kraju lopatice, m;
- \(d\) – prečnik prosečnog vratila, m;
- \(b\) – širina lopatice, m;
- \(Z_2\) – broj lopatica srednjeg vratila;
- \(\alpha\) – ugao postavljanja lopatice, °;
- \(K_{Y}\) – faktor opterećenja miksera u odnosu na prosečno vratilo, \(K_{Y} = 0.75\);
- \(n\) – broj obrtaja vratila radnog uređaja;
- \(K_{Z}\) – koeficijent vraćanja betonske mešavine u drugoj zoni.

Određivanje tehničke produktivnosti kompletne opreme, koja uključuje mikser betona gravitacionog dejstva, definisan je kao

\[
\Pi_{\text{mres}} = V_{\text{odm}} \cdot Z_{II} = \frac{1}{2} \left( \pi \cdot L_0 \cdot (R_{II}^2 - k \cdot r_2^2) - \pi \cdot r_1^2 \cdot L_0 \cdot z_2 \cdot z_1 \cdot b_1 \cdot h_1 \cdot c_1 - z_2 \cdot b_2 \cdot h_2 \cdot c_2 \right) \cdot Z_{II}
\]

gde su:

- \(V_{\text{odm}}\) – ukupna zapremina mešavine u mikseru, m³;
- \(Z_{II}\) – broj ciklusa po času \((t_0 - \text{trajanje ciklusa})\), koji se sastoji od zbir vremena potrebnog za utovar komponenata \(t_1\), vremena mešanja \(t_2\) i pražnjenja mešavine \(t_3\) \((t_0 = t_1 + t_2 + t_3)\), s;
- \(L_0\) – dužina miksera, m;
- \(R_{II}\) – poluprečnik miksera, m;
- \(k\) – koeficijent koji uzima u obzir položaj mešavine;
- \(R_{II}\) – poluprečnik vratila, m;
- \(b_1, b_2, h_1, h_2, c_1, c_2\) – dužina, visina i debljina lopatice tela miksera i lopatice vratila, m.

Produktivnost tehnološkog seta sa dvorotornim turbulentnim mikserom data je preko zavisnosti

\[
\Pi_{\text{mres}} = V_{\text{odm}} \cdot Z_{II} \cdot K_{m},
\]

gde su:

- \(V_{\text{odm}}\) – ukupna zapremina mešavine u mikseru, m³;
- \(Z_{II}\) – broj ciklusa mešavanja po času \((t_0 - \text{trajanje jednog ciklusa})\), i jednako je zbiru vremena sipanja komponenti \(t_1\), vremena mešanja \(t_2\) i pražnjenja mešavine \(t_3\) \((t_0 = t_1 + t_2 + t_3)\), c;
- \(K_{m}\) – faktor korišćenja mašine (0.85).

U ovom slučaju, snabdevanje miksera komponentama može se prikazati na sledeći način:

\[
M = \int_{t_0}^{t_1} (Q_{x_{\text{in}}} - Q_{x_{\text{out}}}) \, dt
\]

gde je:

- \(M\) – ukupna masa komponenata;
- \(t\) – vreme za sipanje svih komponenata;
- \(Q_{x_{\text{in}}}\) – protok komponenti nakon skladištenja;
- \(Q_{x_{\text{out}}}\) – protok komponenti posle dodavanja.

Odnos ukupne mase i zapremine miksera \(V\) je dat kao:

\[
\frac{M}{V} = \Delta x = \frac{Q}{V} \left( x_{\text{in}} - x_{\text{out}} \right) \, dt
\]

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gde su:

\[ M = \text{ukupna masa komponenti} \]
\[ t = \text{ivreme sipanja svih komponenti;} \]
\[ x_{\text{at}}, x_{\text{aas}}, x = \text{redom, sadržaj komponenti na ulazu, izlazu i unutar miksera;} \]
\[ Q\text{'- kapacitet miksera pri stalnim uslovima rada.} \]

Među glavnim indikatorima performansi malih tehnoških setova opreme za pripremu građevinske mešavine, vredni pomenuti troškove snage.

Troškovi snage za rad tehnoške opreme namenjeni za pripremu mešavina vlakno-beton se sastoji od sume troškova snage pojedinih vrsta opreme koja je uključena u komplet (slika 1, c): mašina- alat vlakna, osnovna mašina (mikser za beton), dodavači i dozatori. Stoga, zavisnost za određivanje snage tehnoškog skupa opreme ima oblik [7]

\[ N_{\text{TRO}} = N_{\text{ed}} + N_{\text{p}} + N_{\text{H}} + N_{\text{s}}, \]  

(6)
gde su:

\[ N_{\text{TRO}} = \text{ukupna potrošnja energije za rad tehnoškog seta opreme, kW;} \]
\[ N_{\text{ed}} = \text{potrošnja energije osnovne mašine, kW;} \]
\[ N_{\text{p}} = \text{potrošnja energije rezača vlakana, kW;} \]
\[ N_{\text{H}} = \text{potrošnja energije dodavača, kW;} \]
\[ N_{\text{s}} = \text{potrošnja energije dozatora, kW.} \]

Uzimajući u obzir projektovane karakteristike osnovne mašine za beton sa tri osvine (slika 1), prilikom rada na svim građevinskim mešavinama, \( N_{\text{os}} \) treba definisati kao za mikser sa tri osvine \( N_{\text{ed}} \) uzimajući u obzir rad mašina na svim građevinskim mešavinama

\[ N_{\text{ed}} = \frac{N_{\text{1}} + N_{\text{2}} + N_{\text{s}}}{1000 \cdot \eta}, \]  

(7)
gde su:

\[ N_{\text{1}} = \text{potrošnja energije za mešanje sa gornjim vratilom;} \]
\[ N_{\text{2}} = \text{potrošnja energije za mešanje komponenti mešavine betona i transport u deo za pražnjenje sa srednjim vratilom;} \]
\[ N_{\text{3}} = \text{potrošnja energije za mešanje komponenti sa donjim vratilom;} \]
\[ \eta = \text{stepen koristnosti pogonskog mehanizma.} \]

\[ N_{\text{i}} = N_{\text{i}}^{1} + N_{\text{i}}^{2}. \]  

(8)
gde su:

\[ N_{\text{i}}^{1} = \text{potrošnja energija mešanja u prvoj zoni;} \]
\[ N_{\text{i}}^{1} = \text{potrošnja energija mešanja u drugoj zoni;} \]
\[ N_{\text{i}}^{2} = \omega \cdot F_{i} \cdot C_{i} \cdot f \cdot (R_{i}^{3} - r_{i}^{3}) \cdot Z_{i}^{3} \cdot k_{i}^{3} \cdot \rho_{i}, \]  

(9)

\[ N_{\text{1}} = \text{omega - ugaona brzina vratila, s}^{-1}; \]
\[ F_{i} = \text{površina lopatica, m}^{2}; \]
\[ C_{i} = \text{koeficijent otpora kretanju čestica suve mešavine betona duž lopatica u prvoj zoni, } C_{i} = 9; \]
\[ f = \text{koeficijent trenja suve mešavine na lopatici, } f = 0,4; \]
\[ R = \text{spoljni poluprečnik obrtanja lopatici, m;} \]
\[ r = \text{unutrašnji poluprečnik obrtanja lopatici, m;} \]
\[ Z_{i} = \text{broj lopatica na gornjem vratilu u prvoj zoni mešanja;} \]
\[ \kappa_{i} = \text{faktor opterećenja koji se odnosi na gornje vratilo;} \]
\[ \rho_{l} = \text{prosečna gustina mešavine, kg/m}^{3}. \]

Potrošena energija na mešanje komponenti betonske smese transport do izlaza sa srednjim vratilom

\[ N_{i} = N_{i}^{1} + N_{i}^{2}, \]  

(10)
gde je:

\[ N_{i}^{1} = \frac{N_{\text{os}} \cdot \eta \cdot g \cdot W \cdot \omega \cdot R_{\text{a}}}{1000}; \]  

(11)

\[ g = \text{gravitaciono ubrzanje;} \]
\[ R_{\text{a}} = \text{pupunčki zavojnic, m;} \]
\[ W = \text{koeficijent prevlašćenja (kada se telo kreće u nepovoljnim uslovima } W = 4); \]
\[ \omega = \text{ugaona brzina vratila, s}^{-1}; \]
\[ \eta = \text{stepen koristnosti pogonskog mehanizma.} \]

\[ Z_{i}^{3} = \text{broj lopatica na srednjem vratilu u drugoj zoni.} \]

Potrebna snaga za mešanje komponenti sa donjim vratilom je

\[ N_{i} = N_{i}^{1} + N_{i}^{3}, \]  

(12)

\[ N_{i}^{1} = \frac{N_{\text{os}} \cdot \eta \cdot g \cdot W \cdot \omega \cdot R_{\text{a}}}{1000}; \]  

(13)

\[ g = \text{gravitaciono ubrzanje;} \]
\[ R_{\text{a}} = \text{pupunčki zavojnic, m;} \]
\[ W = \text{koeficijent prevlašćenja (kada se telo kreće u nepovoljnim uslovima } W = 4); \]
\[ \omega = \text{ugaona brzina vratila, s}^{-1}; \]
\[ \eta = \text{stepen koristnosti pogonskog mehanizma.} \]

\[ Z_{i}^{3} = \text{broj lopatica na srednjem vratilu u drugoj zoni.} \]

Potrebna snaga za mešanje komponenti sa donjim vratilom je

\[ N_{i} = N_{i}^{1} + N_{i}^{3}, \]  

(14)

\[ N_{i}^{1} = \frac{N_{\text{os}} \cdot \eta \cdot g \cdot W \cdot \omega \cdot R_{\text{a}}}{1000}; \]  

(15)

\[ g = \text{gravitaciono ubrzanje;} \]
\[ R_{\text{a}} = \text{pupunčki zavojnic, m;} \]
\[ W = \text{koeficijent prevlašćenja (kada se telo kreće u nepovoljnim uslovima } W = 4); \]
\[ \omega = \text{ugaona brzina vratila, s}^{-1}; \]
\[ \eta = \text{stepen koristnosti pogonskog mehanizma.} \]

\[ Z_{i}^{3} = \text{broj lopatica na srednjem vratilu u drugoj zoni.} \]
$N_f$ i $N_i$ – definišu se na isti način kao i za gornje vratilo.

Za mikser sa gravitacionim dejstvom [5], snaga $N_{a,u}$ utrošena za proces pripreme mešavine suve smeše, sastoji se od snage potrebne za okretanje tela miksera i snage potrebne za okretanje vrata lopatica.

$$N_{a,u} = N_k + N_b, \text{ kBm},$$

gde je:

$N_k$ - snaga potrebna za okretanje tela miksera.

$$N_k = N_k^{(1)} + N_k^{(2)} = \frac{\omega_k \cdot M_k}{\eta_k \cdot 1000} + \frac{F_{mp,a} \cdot V_{adc,a} \cdot z_2}{1000 \cdot \eta_a},$$

(16)

pri čemu su:

$G_{cu}$ – težina komponenti, $\text{N}$;
$\eta$ – količina vratila u telu, $\text{m}$;
$Z$ – broj mešanja u telu mašine $\text{e}$;
$\omega_k$ – ugaona brzina obrtanja tela miksera, $\text{s}^{-1}$;
$\eta_k$ – efikasnost pogona vratila;
$F_{mp,a}$ – sila trenja koja se povećava kada se čestice mešavine pomeraju duž površinu lopatica tela miksera, $\text{N}$;
$V_{adc,a}$ – apsolutna brzina čestica smeše duž tela lopatica, $\text{m} / \text{s}$. ;
$z_2$ – broj lopatica na unutrašnjoj površini tela.

Potrebna snaga za rad vesla vrata tokom mešanja data je izrazom

$$N_b = N_b^{(1)} + N_b^{(2)} = \frac{\omega_a \cdot M_a}{\eta_a \cdot 1000} + \frac{F_{mp,a} \cdot V_{adc,a} \cdot z_2}{1000 \cdot \eta_a},$$

(17)

gde je:

$\omega_a$ – ugaona brzina obrtanja vrata lopatica miksera, $\text{s}^{-1}$;
$M_b$ – uvijanje vrata lopatica, $\text{N} \cdot \text{m}$;
$\eta_a$ – efikasnost pogona vrata;
$F_{mp,a}$ – sila trenja koja nastaje prilikom kretanja čestica smeše površini lopatica, $\text{N}$;
$V_{adc,a}$ – apsolutna brzina čestica duž lopatica, $\text{m} / \text{s}$;
$z_2$ – broj lopatica.

Instalacijom dvorotornog turbulentnog miksera, važi izraz:

$$N_{s,a} = \omega_{p,a} \cdot F_z \cdot q_{av} \cdot f \cdot (R - r) \cdot \text{Cos} \beta \cdot Z_s \cdot \kappa_i \cdot \rho_i,$$

(18)

gde je:

$\omega_{p,a}$ – ugaona brzina obrtanja vratila lopatica miksera, $\text{s}^{-1}$;
$F_z$ – površina lopatica, $\text{m}^2$;
$q_{av}$ – pritisak na lopatice na strani mešanja, $\text{Pa}$;
$f = 0,4$;
$R$ – spoljašnji poluprečnik rotacije lopatica, $\text{m}$;
$r$ – unutrašnji poluprečnik rotacije lopatica, $\text{m}$;
$Z_s$ – broj lopatica na gornjem vratilu u prvoj zoni mešanja;
$\kappa_i$ – faktor opterećenja mešalice betona;
$\rho_i$ – prosečna gustina suve mešavine, $\text{kg} / \text{m}^3$;
$\beta$ – ugao lopatica.

Dakle, predloženi tehnološki setovi malih dimenzija mogu se uspešno koristiti za direktni rad na gradilištu.

3. ZAKLJUČAK

1. Predloženi su tehnološki skupovi malih dimenzija nove konfiguracije i novog projektovanog rešenja za izvođenje malih količina rada u uslovima gradilišta.
2. Takode, date su zavisnosti koje omogućavaju utvrđivanje pokazatelja performansi novih setova tehnološke opreme za pripremu suvih građevinskih smeša na gradilištu.

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The Definition of Basic Parameters of the Set of Small-sized Equipment for Preparation of Dry Mortar for Various Applications

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Based on the conducted information retrieval and review of the scientific literature, unsolved issues have been identified in the process of preparation of dry construction mixtures in the conditions of a construction site. The constructions of existing technological complexes for the production of dry construction mixtures are considered and their main drawbacks are identified in terms of application in the conditions of the construction site. On the basis of the conducted research, the designs of technological sets of small-sized equipment for the preparation of dry construction mixtures in the construction site are proposed. It is found out that the basis for creating the proposed technological kits are new designs of concrete mixers operating in cascade mode. A technique for calculating the main parameters of technological sets of equipment is proposed, depending on the use of the base machine of the kit.

Keywords: a set of small-sized equipment, a dry construction mix, a concrete mixer, a cascade regime, the motion trajectory of the mixture particles.

1. INTRODUCTION

Modern dry building mixtures are complex compositions of components, different in their properties. Mixing these components together and creating a homogeneous mixture is a difficult task in a technical sense. Creation of effective equipment for these purposes is an urgent problem of modern construction. With its solution, special attention should be paid to the development of technological kits.

At present, in the process of preparation of dry construction mixtures, there is a number of unresolved issues: increased wear of the working bodies and mixer bodies, long time for the preparation of complex compositions, the presence of segregation during the mixture preparation and the complexity of preparing the mixtures directly at the construction site [1 - 4].

At present, technological complexes, which have the ability to produce mixtures of different types, are used for the preparation of dry construction mixtures [5 - 7].

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.

2. MAIN MATERIALS AND RESULTS

It is proposed to develop and introduce small-size sets of equipment for the preparation of dry construction mixtures on the basis of new mixers operating in a cascade mode in the production of small amounts of work (with individual low-rise construction, construction in the agricultural sector, repair and reconstruction of existing buildings).

Technological equipment kits are shown in Figure 1. All equipment of these technological kits is based on a common base and is selected according to the performance of the base machine-mixer.

The technological set of equipment, presented in Figure 1, includes the following components: 1 - mixer (basic machine); 2 - filling machine; 3 - sand bunker; 4 - silo of cement; 5 - weighing batcher; 6 - fiber cutter; 7 - auger feeder; 8 - bunker of granite grains; 9 - filler hopper.

The basic machines of the technological set (Fig. 1) can be concrete mixers of a new constructive solution: a three-shaft concrete mixer, gravity-forced concrete mixer, a two-side turbulent mixer [5]. A feature of the work of these machines is the creation of a complex multi-path motion of the particles of the mixture in the body of the machine [9]. The adjacent equipment of the technological set is unified and has a traditional design solution.

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Figure 1: Technological sets of equipment for the preparation of dry building mixtures:
a) the base machine is a three-shaft mixer; b) the basic machine is a mixer of gravitational-forced action; c) basic machine - two-rotor turbulent mixer

The productivity of the technological set with the use of a three-shaft concrete mixer is found according to the dependence [10]:

\[
\Pi_{т3} = \frac{\pi}{4} \left( D^2 - d^2 \right) \cdot b \cdot n \cdot z_1 \cdot \sin \alpha \cdot k_2 \cdot k_z \cdot z_2
\]  

(1)

where are:
- \( D \) - 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;
- \( z_1 \) - number of blades of the middle shaft;
- \( \alpha \) - is the angle of installation of the blades, deg;
- \( k_2 \) - load factor of the mixer relative to the average shaft, \( k_2 = 0.75 \);
- \( n \) - frequency of rotation of the shaft of the working element;
- \( K_{z2} \) - coefficient of return of the concrete mixture of the second zone.

Determination of the technical productivity of the equipment set, which includes a concrete mixer of gravitational-forced action, is defined as

\[
\Pi_{тг} = \frac{1}{2} \frac{1}{\pi} L \cdot (R^2 \cdot k - r^2) - \pi \cdot r^2 \cdot L \cdot z_2 \cdot z_1 \cdot b_1 \cdot h_1 \cdot c_1 - z_2 \cdot b_2 \cdot h_2 \cdot c_2 \cdot \frac{1}{Z_{ц2}}
\]  

(2)

where are:
- \( V_{полт} \) - is the total volume of the mixture in the mixer, m³;
- \( Z_{ц2} = 3600/t_г \) - number of cycles of machine operation per hour (\( t_г \) - is the duration of one cycle, which consists of the sum of the time for loading components \( t_1 \), mixing them \( t_2 \) and unloading the finished mixture \( t_3 \) (\( t_г = t_1 + t_2 + t_3 \)), c);
- \( L_к \) - length of the mixer body, m;
- \( R_к \) - is the radius of the mixer body, m;
- \( k \) - is a coefficient that takes into account the position of the mixture in the body;
- \( R_m \), \( \ell_m \), \( z_m \), \( r_\alpha \) - radius, length, number of legs of shaft blades and shaft radius, m;
- \( b_1 \), \( b_2 \), \( h_1 \), \( h_2 \), \( c_1 \), \( c_2 \) - length, height and thickness of blades of the body and blades of the mixer shaft, m.

The productivity of the technological set when using a two-rotor turbulent mixer is found according to the dependence

\[
\Pi_{т2} = V_{полт} \cdot Z_{ц2} \cdot k_m
\]  

(3)

where are:
- \( V_{полт} \) - the total volume of the mixture in the mixer, m³;
- \( Z_{ц2} = 3600/t_г \) - number of cycles of machine operation per hour (\( t_г \) is the duration of one cycle, which consists of the sum of the time for loading components \( t_1 \), mixing them \( t_2 \) and unloading the finished mixture \( t_3 \) (\( t_г = t_1 + t_2 + t_3 \)), c);
- \( k_m \) is the machine utilization factor (0.85).

In this case, the feeding of the components of the concrete mixture into the mixer will be as follows:

\[
M = \int (Q_{x1} - Q_{x2}) \, dt
\]  

(4)

where are:
- \( M \) - total mass of components;
- \( t \) - the time interval for loading all components;
- \( Q_{x1} \) - the flow of the components of the mixture upon leaving the storage bin;
- \( Q_{x2} \) - the flow of the components of the mixture as it leaves the feeder.

The ratio of the total mass of \( M \) components to the entire working volume of mixer \( V \) is as follows:
\[
\frac{M}{T} = \Delta t - \frac{Q \cdot (x_1 - x_{\text{out}})}{P} dt,
\]
where are:
- \( M \) - is the total mass of the components;
- \( T \) - is the time interval for loading all components;
- \( x_1 \), \( x_{\text{out}} \), \( x \) - respectively, the content of the components at the inlet, outlet and inside the mixer;
- \( Q \) - the capacity of the mixer under steady operating conditions.

Among the main performance indicators of a small-sized technological set of equipment for the preparation of a building mixture, it is worth mentioning the power costs.

The power costs for the operation of a technological equipment set intended for the preparation of fiber-concrete mixtures consist of the sum of the power costs of the individual types of equipment that are included in the kit (Figure 1, c): the machine-tool of the fiber, the base machine (concrete mixer), feeders and dispensers. Thus, the dependence for determining the power of the technological set of equipment has the form [7]

\[
N_{\text{TKO}} = N_{\text{a,a}} + N_p + N_f + N_a,
\]
where are:
- \( N_{\text{TKO}} \) - Total costs of power for the operation of the technological set of equipment, kW;
- \( N_{\text{a,a}} \) - power costs of the base machine, kW;
- \( N_p \) - power consumption of a fiber cutter, kW;
- \( N_f \) - power consumption of dispensers, kW;
- \( N_a \) - power costs of the operation of the technological set of equipment, kW.

Taking into account the design features of the base machine of the three-shaft concrete mixer (Figure 1), when working on dry building mixtures, \( N_{\text{TKO}} \) should be defined as for a three-shaft mixer \( N_{\text{TKO}} \), taking into account the operation of the machine on dry building mixtures

\[
N_{\text{a,a}} = \frac{N_1 + N_2 + N_3}{1000 \cdot \eta},
\]
where are:
- \( N_1 \) - the power used to mix the components of the mixture with the upper shaft;
- \( N_2 \) - the power used to mix the components of the concrete mix and transport it to the discharge port by the middle shaft;
- \( N_3 \) - the power used to mix the components of the mixture by the lower shaft;
- \( \eta \) - the efficiency of the mixer drive.

\[
N_I = N_{I1} + N_{I2},
\]
where are:
- \( N_{I1} \) - the power expended on the mixing process in the first zone,
- \( N_{I2} \) - power costs for the mixing process in the second zone

\[
N_{I1} = \omega \cdot F_s \cdot C_i \cdot f \cdot (R^2 - r^2) \cdot Z^2 \cdot \kappa^s \cdot \rho_2,
\]
where \( \omega \) - angular velocity of the shaft, \( \text{s}^{-1} \);
- \( F_s \) - Blade area, \( \text{m}^2 \);
- \( C_i \) - coefficient of resistance to movement of particles of dry concrete mixture along the blades in the first zone, \( C_i = 9 \);
- \( f \) - coefficient of friction of the dry mixture over the surface of the blades, \( f = 0.4 \);
- \( R \) - outer radius of rotation of the blade, \( \text{m} \);
- \( r \) - internal radius of rotation of the blade, \( \text{m} \);
- \( Z^2 \) - number of blades on the upper shaft in the first zone;
- \( \kappa_u \) - load factor of the concrete mixer relative to the upper shaft;
- \( \rho_2 \) - average density of dry mix, \( \text{kg} / \text{m}^3 \).

\[
N_{I2} = N_{I21} + N_{I22},
\]
where are:
- \( N_{I21} \) - the power expended on the process of mixing the components of the dry construction mixture in the first zone on the process of mixing the components of the mixture and transporting it to the second zone;
- \( N_{I22} \) - power expended in the second zone of the mixer.

\[
N_{I21} = m_c \cdot g \cdot W \cdot \omega \cdot R_u,
\]
where are:
- \( m_c \) - mass of the components of the mixture in the auger zone, \( \text{kg} \);
- \( W \) - Drag coefficient (when the body moves in hostile environments \( W = 4 \));
- \( \omega \) - Angular speed of rotation of the shaft, \( \text{s} \);
- \( R_u \) - Radius of screw, \( \text{m} \);
- \( g \) - acceleration of gravity.

\[
N_{I22} = \omega \cdot F_s \cdot C_i \cdot f \cdot (R^2 - r^2) \cdot Z^2 \cdot \kappa^s \cdot \rho_2,
\]
where is:
- \( Z^2 \) - number of blades on the middle shaft in the second zone.

The Definition of Basic Parameters of the Set of Small-sized Equipment for Preparation of Dry Mortar for Various Applications
The power required to mix the components of the mixture with the lower shaft

\[ N_l = N_{l1} + N_{l2} \]  
where:
- \[ N_{l1} \] – power expended on the process of mixing in the first zone;
- \[ N_{l2} \] – the power expended on the mixing process in the second zone of the mixer;
- \[ N_l \] и \[ N_{l2} \] – are determined by analogy with the upper shaft.

For a gravity-forced-action mixer [5] \( N_{z1} \), spent on the process of preparing a dry construction mix, consists of the power required to rotate the mixer body and the power required to rotate the blade shaft

\[ N_{z1} = N_k + N_{b}, \text{kBM} \]

where:
- \( N_k \) - power required to rotate the body of the mixer,
- \( N_{b} \) - the power required to turn the blade of the mixer body, \text{kBM}.

The power required to mix the components of the mixture, when installing a two-rotor turbulent mixer

\[ N_{z, u} = \alpha_{r, u} \cdot F_s \cdot q_{m, u} \cdot f \cdot (R - r) \cdot \text{Cos} \beta \cdot Z_z \cdot \kappa_s \cdot \psi, \]  
where:
- \( \alpha_{r, u} \) – angular speed of rotation of the mixer's blade shaft, \( \text{s}^{-1} \);
- \( F_s \) – the area of the blade, \( \text{m}^2 \);
- \( q_{m, u} \) – pressure on the blade on the mixture side, \( \text{Pa} \);
- \( f = 0.4 \); \( R \) – outer radius of blade rotation, \( \text{m} \);
- \( r \) – internal radius of blade rotation, \( \text{m} \);
- \( Z_z \) – number of blades on the upper shaft in the first zone;
- \( \kappa_s \) – load factor of the concrete mixer;
- \( \psi \) – average density of dry mix, \( \text{kg} / \text{m}^3 \);
- \( \beta \) – blade angle

Thus, the proposed technological kits of small-sized equipment can be successfully used to work directly on the construction site.

3. CONCLUSION

1. Technological sets of small-sized equipment of a new configuration and a new design solution are proposed to perform small volumes of work in the conditions of a construction site.

2. Dependencies are given allowing to determine the performance indicators of new technological equipment sets for the preparation of dry building mixtures in the construction site.

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