

for mixing equipment.

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INCREASING OPERATION EFFICIENCY OF EQUIPMENT FOR CONSTRUCTION MIXTURE PREPARATION

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ABSTRACT. *The study considers features of construction mixture preparation and transport processes in mixing feeding equipment combining a forced action mixer and a screw conveying unit. The influence of physical mechanical and rheological properties of construction mixtures with varying consistency on mixing and subsequent transport conditions is analyzed. It is shown that efficiency of the technological process depends on coordination between working body design parameters, operating modes, and movement conditions of the mixture within the mixer working volume and conveying channel.*

Analytical relationships describing construction mixture particle movement under blade working body action, circulation flow formation within the mixing chamber, and subsequent axial movement of the prepared mixture by the screw conveying unit are presented. The obtained relationships consider the influence of working body kinematic parameters, blade geometry, screw helix parameters, and mixture viscosity on mixing and transport conditions within a unified technological process. The presented results can be used for justification of rational design and operating parameters for construction mixture preparation and transport equipment.

Keywords: *construction mixture, forced action mixer, screw conveying unit, mixing, transport, working body, technological process, construction equipment.*

Introduction. Construction mixture preparation and delivery processes are an important component of modern construction, since they determine material technological property formation conditions and efficiency of construction and finishing operations. Construction and finishing operation quality largely depend on mixture homogeneity, preservation of structural mechanical characteristics, and continuous material delivery to the application location. Accordingly, improvement of mixing equipment capable of ensuring intensive component mixing with minimal energy consumption and coordination between mixture preparation and transport parameters within a unified technological process becomes especially important.

Construction mixtures, depending on liquid phase content and physical mechanical properties, can exhibit different mobility, internal friction, and component cohesion, which directly influence mixing conditions and subsequent movement within technological channels. Under such conditions, equipment operation efficiency is determined not only by mixing body design parameters but also by coordination between conveying device operating modes and medium properties. A promising direction for technological system efficiency improvement involves application of universal mixing feeding units in

which construction mixture preparation and transport processes are integrated within a single design complex.

Analysis of recent research and publications. Sources [1, 2] consider general issues related to influence of rheological and structural mechanical properties of construction mixtures on preparation and subsequent transport processes. It is shown that mixture consistency variation significantly influences motion character within mixer working volume and conveying channels. Studies [3, 4] present approaches to efficiency evaluation for construction mortar and concrete mixture mixing considering working body design parameters and operating modes.

Research objective. Determination of rational design and operating parameters for construction mixture preparation equipment considering intensive component mixing conditions, coordination of mixing and screw transport processes, and efficient equipment operation with mixtures of varying consistency.

Main part. Equipment combining a forced action mixer and a screw conveying unit is considered for investigation of construction mixture preparation and transport processes. Component mixing is performed by blade working bodies within mixer working volume, after which the prepared mixture enters the screw assembly for subsequent transport to the unloading location.

During forced action mixer operation, blade working bodies form complex spatial movement of the construction mixture within the mixing chamber. Material movement is accompanied by circulation flow formation, mutual component displacement, and shear deformation occurrence within mixture working volume. Character of such motion is determined by working body kinematic parameters, blade geometry, and physical mechanical properties of the mixed medium.

Construction mixture particle movement within forced action mixer working volume occurs under action of blade working bodies forming material circulation flows within the mixing chamber. Linear velocity of mixture particle movement is determined by the following relation

$$v_p = \omega \cdot R, \quad (1)$$

where v_p – linear velocity of mixture particle movement, m/s;

ω – working body angular velocity, rad/s;

R – blade rotation radius, m.

Increased working body angular velocity is accompanied by higher mixture component motion intensity and acceleration of mutual displacement process within mixer working volume. At the same time, blade rotation radius determines particle motion trajectory and influences circulation flow formation character within the mixing chamber. Rational combination of these parameters ensures intensive mixture mixing without stagnant zone formation within working volume.

Circulation movement intensity of the mixture within forced action mixer working volume depends on working body angular velocity, blade rotation radius, blade quantity, geometric shape, and mixing chamber fill level. The following relation can be used for generalized evaluation of this process

$$I_c = \omega \cdot R \cdot z_l \cdot k_f \cdot k_z, \quad (2)$$

where I_c – conditional circulation movement intensity indicator for the mixture within mixer working volume;

z_l – working body blade quantity;

k_f – coefficient considering blade shape and inclination angle;

k_z – mixing chamber fill factor.

Increased blade quantity and variation of geometric parameters promote higher mixture circulation movement intensity and improved conditions for mutual component displacement. At the same time, mixing chamber fill level substantially influences medium motion character and efficiency of homogeneous mixture structure formation. For dry mixtures, repeated particle cascading within working volume is decisive, whereas for plastic media formation of shear deformations and forced material movement under action of working bodies become especially important.

For dry construction mixtures, the mixing process is mainly accompanied by repeated component cascading within mixer working volume under action of blade working bodies. Under such conditions,

homogeneous mixture structure formation intensity is determined by particle circulation movement frequency and uniformity of displacement between separate mixing chamber zones. For semi dry mixtures, destruction of local structural contacts between material particles and ensuring uniform moisture distribution within medium volume become especially important. In the case of plastic construction mixtures, the mixing process is characterized by occurrence of significant shear deformations and increased internal resistance to material motion, requiring forced medium displacement throughout the entire mixer working volume.

During mixer operation, separate construction mixture motion zones are formed within working volume, characterized by different material displacement intensities. The most active mixing occurs in the region of direct blade working body action, where maximum particle motion velocities and medium shear deformations arise. At the same time, zones with reduced circulation movement intensity can form in peripheral mixing chamber regions, negatively influencing uniformity of mixture component distribution. Increased working body rotation speed and rational selection of blade geometry parameters promote expansion of active mixing zones and improvement of conditions for mutual displacement of material components.

After completion of the mixing process, the prepared mixture enters the screw conveying unit, where movement occurs along the conveying channel axis through rotational motion of the screw surface. Axial mixture movement velocity is determined by the following relation

$$v = \omega \cdot R \cdot \cos \alpha, \quad (3)$$

where v – mixture movement velocity along the screw axis, m/s;
 α – screw helix angle.

Variation of the screw helix angle influences axial mixture movement velocity and conditions of interaction with conveying channel walls. Increased screw rotation speed raises material movement intensity, however excessive increase of kinematic parameters can be accompanied by higher internal friction and nonuniform mixture movement within the conveying channel.

During subsequent construction mixture transport by a screw conveying unit, material motion character is determined not only by screw rotation speed but also by geometric parameters. Important influence on mixture movement conditions is exerted by screw diameter, screw surface pitch, and screw helix angle. Increased screw pitch raises axial material motion velocity, however conditions of mixture retention within interflight space can deteriorate together with higher nonuniformity of movement through the conveying channel.

For plastic and semi dry mixtures, interaction between the material, conveying channel walls, and screw surface becomes especially important. Increased medium internal friction is accompanied by higher resistance to mixture movement and increased shear stresses within the flow. Under such conditions, coordination between mixing and transport parameters becomes important, since insufficient component mixing can lead to mixture structure nonuniformity, local compaction formation within the conveying channel, and deterioration of material movement conditions during delivery to the unloading location.

The following relation is used for evaluation of construction mixture movement conditions within the conveying channel

$$\tau = \tau_0 + \mu \frac{dv}{dr}, \quad (4)$$

where τ – shear stress within the mixture flow, Pa;
 τ_0 – yield shear stress, Pa;
 μ – dynamic mixture viscosity, Pa·s.

The presented analytical relationships enable evaluation of construction mixture movement features within forced action mixer working volume and during subsequent transport by a screw conveying unit. The obtained relationships consider influence of working body design and kinematic parameters on mixing and mixture movement conditions within a unified technological process.

Conclusions. Results of the performed study established that construction mixture preparation equipment efficiency largely depends on coordination between material mixing and transport process parameters. It was determined that forced action mixer application ensures intensive component movement

within working volume and creates conditions for homogeneous mixture structure formation during operation with materials of varying consistency.

It was established that subsequent transport of the prepared mixture by a screw conveying unit enables continuity of the technological process and coordinated material movement to the unloading location. The presented analytical relationships can be used for justification of rational design and operating parameters for construction mixture preparation and transport equipment.

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ЕНЕРГОЕФЕКТИВНА СИНХРОНІЗАЦІЯ МОБІЛЬНИХ АВТОНОМНИХ ДЖЕРЕЛ ЖИВЛЕННЯ З БУДІВЕЛЬНОЮ ТЕХНІКОЮ, ЩО ПРАЦЮЄ НА ВІДНОВЛЮВАНИХ ДЖЕРЕЛАХ ЕНЕРГІЇ

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АНОТАЦІЯ. Розглянуто проблему енергоефективної синхронізації мобільних автономних джерел живлення з будівельною технікою, що працює на відновлюваних джерелах енергії. Показано, що похибки фазового узгодження між інвертором і навантаженням призводять до зростання циркулюючих струмів, додаткових комутаційних втрат та зниження коефіцієнта потужності. Запропоновано кооперативну архітектуру керування з адаптивним регулюванням віртуальної інерції, яка узгоджує роботу джерела та споживача до настання перехідних режимів. На основі математичних співвідношень і порівняльного аналізу робочого циклу встановлено зменшення втрат інвертора, скорочення витрати палива та підвищення загального ККД системи. Отримані результати підтверджують доцільність інтеграції процесів синхронізації та енергоменеджменту для мобільних гібридних енергосистем..

Ключові слова: енергоефективність; синхронізація; мобільні джерела живлення; інвертор; віртуальна інерція; мікромережа; відновлювані джерела енергії; будівельна техніка; втрати потужності.

Вступ. Глобальна будівельна галузь перебуває на переломному етапі: вона відчуває зростаючий тиск щодо декарбонізації та відмови від викопного палива [1, 2]. Значну частку викидів на майданчиках створюють дизельні генератори, які живлять баштові крани, інструменти та інше обладнання. Інтеграція відновлюваних джерел енергії (ВДЕ) є перспективним рішенням, проте мобільність будівельних майданчиків та нестабільність сонячної та вітрової енергії створюють серйозні технічні труднощі. Ключова проблема — ефективна синхронізація мобільних джерел живлення (BESS, паливних генераторів) з обладнанням на ВДЕ. Без точної синхронізації погіршується якість електроенергії, виникають збої техніки та втрати енергії

Аналіз літературних джерел. Область синхронізації різномірних джерел енергії добре досліджена для стаціонарних мікромереж. Ключовим досягненням є концепція віртуального синхронного генератора (VSG), яка дозволяє інверторним джерелам (зокрема GFM-інверторам) емулювати інерцію традиційних синхронних генераторів. Це критично важливо для стабільного