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Research paper

The Research of Mortar Components Mixing Process

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Abstract

During the theoretical calculations of the power level consumed by the mortar mixer drive when mixing constructional mortar components, it is proposed to use the movement resistance specific coefficient. The developed method and a series of researches on an experimental test bench allowed to determine its numerical values when mixing cement-sand, lime-sand and complex mortars of various composition and lowability. The interpolated diagram of the consumed power of the band-screw operating device drive has been obtained, which has allowed to understand more deeply the technological process, as well as its characteristic stages and modes.

Keywords: *movement resistance specific coefficient, mortar, band-screw operating device, mortar mixer, mortar lowability.*

Introduction

In many branches of industry the processes of mixing and mixing of various components are used. In most technological processes, it is necessary to create a homogeneous system consisting of several phases. In some cases, it is necessary to ensure the maximum full and even in volume reacting components contact. The last one is achieved by mixing, that is, intensive movement within the total volume of individual particles and mixture parts. Considerable interest in technical practice is caused by the processes of mortars effective mixing. The most widely used equipment, in which mixture uniformity is required, is achieved by mechanical influence on the environment of special working body called the mixer. As a rule, mixers of mechanical action are used for building mortars preparation.

Power determination of the electric drive of the compulsory action mortar-mixing equipment is rather complicated. Mortar mixtures, which are coarse dispersion suspensions, are visco-plastic bodies and which properties and motion conditions are significantly different from viscous liquids. Of immaterial significance is the volatility of mortars physical and mechanical properties, depending on time and speed. This fact greatly complicates the situation of the mixture movement during mixing. In this case there are significant numbers of resistances. The most important among it can be called the resistance of internal and external friction forces, resistance of certain masses displacement, resistance arising from inertial forces, wave formation, etc. Many of these resistances, as noted above do not remain constant during the mixing cycle. In addition, we have a fairly wide range of mortars according to their components composition and characteristics. All this further complicates the problem of determining the constituents of resistance that arise in mixing process.

The first scientific papers devoted to the study of mixing processes and methods for calculating mixing equipment appeared in the 20es of the 20th century. The number of works related to the study of mixing processes in general was insignificant, and was even lesser than the works about the mixing of suspensions and visco-plastic environments. All the factors complicated the study of energy mixing processes, the development of general calculating methods of mixers, the effectiveness definition and the basic optimal parameters. In the 30es and 40es of the last century, the works devoted to issues of power consumption, which are consumed during mixing by shovel mixers, have been published. During 50-70 years of the previous century the optimal ratios of the shovel diameter and width and the mixer housing size, as well as the dependence of the power and the efficiency of mixing on the speed were established. The level of energy consumed for mixing is presented in the form of a functional dependence on the criteria of O. Reynolds and U. Froude. At the end of the last century, there are many works devoted to the calculation of power consumption using the speed coefficients of the working member, the apparent viscosity, criterion dependencies. The application of the calculation formulas for determining the power obtained from the criterion dependences developed for liquids does not provide satisfactory results for the mixing of visco-plastic bodies. As to the current state of scientific research, it is necessary to note the following.

Many works are devoted to the study of mortars properties [1-3]. The features of working environment transportation by various pipes are described in the papers [4-5].

In the paper [6] were made there theoretical investigations of mortar motion in the vertical mortar mixer. Its screw bands have a creature that changes its inclination angle depending on the height of the placement. We have received trajectories of motion, as well as expressions of displacements, velocities and accelerations of mortar particles for designing equipment parametric range. Energy consumption issues were not considered.

The authors of this research [7] studied the rheological properties of soluble and concrete mixtures using rheometer and viscometer. We have conducted comparison of the results with traditional

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methods of measuring solutions and high-yield concrete.
An overview of various mixing and equipment methods is presented in [8]. The attention is paid to the mixers of continuous and periodic action. To determine the mixing method, it is necessary to take into account certain production factors. An important quality indicator is the homogeneity of material after its mixing. Methods of mixing, methods of determining the mixing efficiency are considered. Unfortunately, this material is devoted to concrete, not to the mortars.
The effect of the mortar rheological properties, the mixing quality factor, as well as the effective production time of the equipment are investigated in [9]. The power equation consumed by the mixer has been recorded. The optimal operating time of the mixer is set at 120 sec.
A new mixer design is proposed in [10]. This mixer can be used for insignificant volumes of construction works. It is noted that the equipment efficiency is affected by the sequence of components of the mixture introduction to the mixer. Among the advantages of this equipment the authors note of the following: less small durability three-blend of mixing (at 2 minutes for a mortar), higher homogeneity of the final product; high energy efficiency; low cost. The mixer can also be used for the concrete preparation.
Experimental investigation of the mortars properties is represented in paper [11]. The obtained model, which provided a satisfactory description of the carried out researches results of the samples for compression, which were made both from concrete, and from mortars.
In paper [12] there was carried out the numerical simulation of dry and volatile granulated media inside the mixer using the discrete method. The results of the research confirmed the significant differences between the peculiarities of the processes flow in the investigated environments. The intensity of mixing significantly affects water presence of, which significantly increases the member speed.
On the basis of literary analysis, we can note the existence of a considerable number of scientific works. Moreover, most of them are devoted to the study of confined environments rheological properties, the development of new effective equipment structures, mathematical modelling of work processes, the sequence of loading mortar components. The issue of energy consumption is poorly understood, and therefore requires a detailed study.
The purpose of the research is to further improve the calculating methods of the power consumed by the mixer with the band-screw member during preparation mortars with various composition and mobility.
To achieve the goal, the following tasks were set:
- to determine the methodology of conducting experimental studies on determining the coefficient value of specific motion resistance;
- to offer the design of an experimental bench;
- to determine the numerical values rational range of coefficient of the specific resistance of motion for cement-sand, lime-sand and complex mortars, which makes it possible to correctly pick up the electric motor at the power at the design stage of this equipment type.

2 Main Body

The power is influenced by a significant number of resistances, which are interconnected. With all due reliability, all these variables are not practically possible. Therefore, it is considered appropriate to estimate the entire set of composite phenomena occurring during mortars mixing, one coefficient of resistance of the screw mixer to the solution, *k*, kPa, which is sufficiently determined for these operation modes, the size of the member and the composition soluble mixture. Taking into account this provision, the following procedure is proposed for determining the engine power of the solution-mixing equipment, which generally reflects the work picture of the mixer band-screw type.
During rotation, the drive of the band-screw mixer undergoes resistance to the mixing medium. We can point out this working body an elementary surface in the sizes $db \times dr$ (Fig. 1).

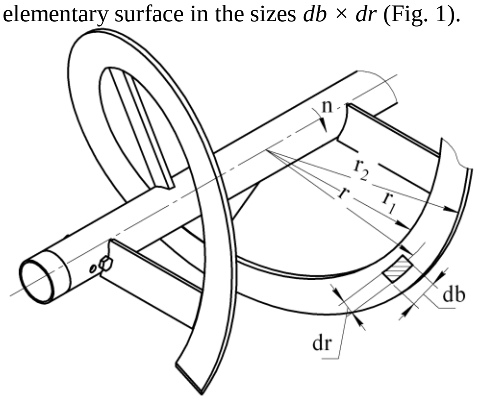


Fig.1. Design scheme to determine the resistance strength, *dF*, acting on the elementary area of a screw mixer

The area of the elementary site dS in this case will be

$$dS = db \cdot dr \ . \quad (1)$$

The resistance strength, dF, kN, acting on the elementary area

$$dF = k \cdot dS \ . \quad (2)$$

where k – the specific movement resistance, kPa.
Elementary torque of resistance forces, *dM*, H · m

$$dM = dF \cdot r = k \cdot dS \ . \quad (3)$$

Full torque, *M*, H·m, from all elementary resistance forces, taking into account the brackets

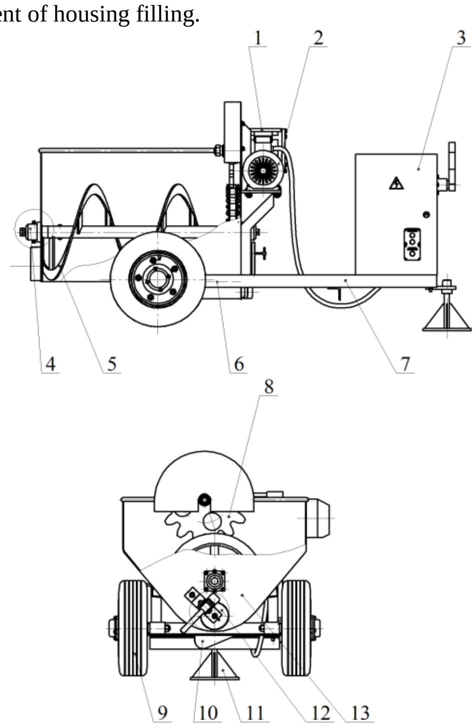
$$M = k \cdot \left(\int_{r_1}^{r_2} dS + \int_{r_{sh}}^{r_1} dS_b \right) = \frac{k}{2} \cdot \left[b_{eb} \cdot \left(r_2^2 - r_1^2 \right) + b_b \cdot \left(r_1^2 - r_{sh}^2 \right) \right]. \quad (4)$$

where r_1, r_2 – the internal and external mixer band radii respectively, m;
r_{sh} – shaft radius, m;
b_{eb} - expanded band length, m;
b_b – bracket width, m.
The power, *P*, W, consumed on mixing the mortar by a belt-screw mixer with an inclination angle of the helical line, *α*, degrees, and brackets, will be:

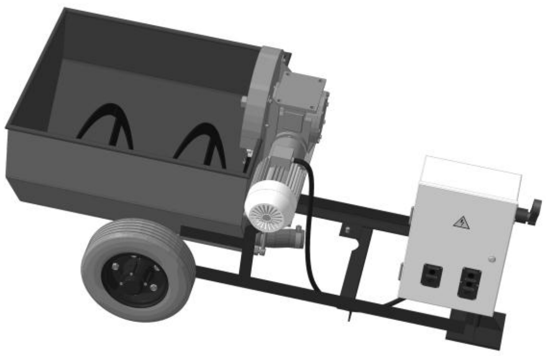
$$P = M \cdot \omega = \frac{M \cdot \pi \cdot n}{30} = \frac{\pi \cdot k \cdot n \cdot \varphi}{60} \times \\ \times \left[b_{eb} \cdot \left(r_2^2 - r_1^2 \right) + b_b \cdot \left(r_1^2 - r_{sh}^2 \right) \cdot z \right] \cdot \cos\alpha \ . \quad (5)$$

where ω – the shaft rotation angle, rad/s;
n – shaft rotational speed, rpm;
φ – filling coefficient of the housing with mortar;
α – inclination angle of the mixer screw line, deg;
z – number of brackets.
In formula (5), which is proposed for determining the useful power of a cyclic melt mixing equipment with a belt-screw mixer, all the values are estimated by the working body geometry of and the rotation speed.
The only research coefficient, k, is determined depending on the mortar composition of the, the speed and geometry of the member movement, as well as the filling coefficient, φ, of the housing.
Consequently, the physical meaning of the coefficient is that it determines the effective stress in Pa, which must be created for the irreversible deformation (mixing) of the building-soluble mixture. It can also be called the specific work of deforming the mixture unit volume.

Measurements of power consumption at the experimental mortar bench [13, 14], shown in Fig. 2 according to the method [15] and calculated values of the specific resistance of motion coefficient, k , kPa, give its specific values for various solutions in terms of composition, motion, frequency of the member rotation and coefficient of housing filling.



а)



б)

Fig.2. Mortar mixer [14]: a – is a constructive scheme:1 – worm gearbox; 2 – electric motor; 3 – electric cabinet; 4 – tapered roller bearing; 5 – band-screw mixer; 6 – the filter grid; 7 – frame; 8 – tread gear; 9 – pneumatic wheel; 10 – camera-feeder; 11 – stand; 12 – valve design latch; 13 – housing; b – the overall view

The value of the motion specific resistance coefficient, k , kPa, at measurements of power consumption was determined by the formula:

$$k = \frac{60 \cdot (P_m - P_{ip})}{\left[b_{eb} \cdot \left(r_2^2 - r_1^2 \right) + b_b \cdot \left(r_1^2 - r_{sh}^2 \right) \cdot z \right] \cdot \cos\alpha \cdot \pi \cdot n \cdot \varphi}, \quad (6)$$

where P_m – the of the measured power value, kW;

P_{ip} – idle power, kW;

b_{eb} – expanded bande length, m;

r_2 , r_1 – external and internal mixer radius, m;

b_b – bracket width, m;

r_{sh} – shaft radius, m;

z – brackets number;

α – angle of the mixer screw line inclination, deg .;

n – rotational speed, rpm;

φ – coefficient of the housing filling with mortar.

The launch of the mortar mixer was carried out with empty housing. In this case, it is necessary to overcome first of all the inertia of the rotating masses of the working member of the mortar mixer and its drive chains.

When calculating the engine power, it is necessary to keep in mind three typical operating modes of the mortar mixer, namely: starting, unbalanced (unsteady) and balanced (constant) mixing modes.

The unstable mixing mode is the time period when the total volume of the mortar from the static state is driven to a certain reduced speed. At this time period, power consumption is much higher than on a steady state. This is because in the initial period, the individual components are uneven, and the whole solution has not started to move. The structural relations between the particles are not completely destroyed, in connection with which member it is necessary to overcome additional supports. The specific motion resistance in this time zone will be different than during the steady mode.

On Fig. 3 there is given the record of the electric motor power consumption characterizing the mixing mode. As we can see from this diagram, the power after the starting jump decreases to the idle speed, then at loading the body increases to the maximum value and gradually decreases to the nominal in steady state. Power during unsteady mixing mode is 1.5 times higher than nominal, and the corresponding time interval is quite significant. This indicates that when calculating the power it is necessary to take the coefficient value with the corresponding correction.

The operating time of the belt-screw mixer in a non-steady mixing mode mainly depends on the mortar composition, its mobility, the coefficient of housing filling and the member rotation frequency.

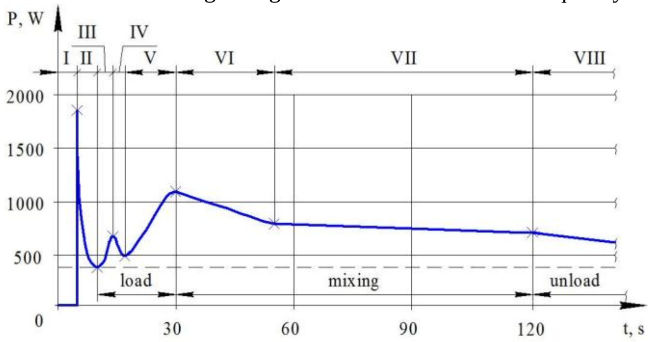


Fig.3. Interpolated diagram of the power consumption of the band-screw mixer drive during the preparation of the cement-sand mortar (composition 1:5, lowability 6 cm, φ = 1, n = 40 rpm.

Analyzing the diagram depicted in Fig. 3, we can distinguish eight characteristic areas corresponding to the mortar mixing cycle of the r, namely: I – the start of the mixer ($P_{\max}^{I} = 1824$ W, $t_I = 5$ sec); II – idling ($P_{xx}^{II} = 380$ W, $t_{II} = 5$ sec); III – loading binder ($P_{\max}^{III} = 646$ W, $t_{III} = 4$ sec); IV – addition of water ($P_{\min}^{IV} = 494$ W, $t_{IV} = 3$ sec); V – addition of placeholder ($P_{\max}^{V} = 1064$ W, $t_V = 13$ sec); VI – unbalanced mixing mode ($P_c^{VI} = 986$ W, $t_{VI} = 25$ sec); VII – balanced (stable) mixing mode ($P_c^{VII} = 750$ W $t_{VII} = 65$ sec); VIII – unloading of mortar ($P_{\min}^{VIII} = P_{xx}^{II} = 380$ W).

Below there is represented the Table 1 of the specific resistance coefficient values, *k*, kPa, for stable mixing mode.

Table 1: The value of the specific movement resistance coefficient, *k*, for mixing mortars in a mortar mixer with a belt-screw member.

Rotation frequency, *n*, rpm	Housing filling coefficient, *φ*	Specific resistance coefficient, *k*, kPa, (numerator) and lowability of the mortar, cm (denominator)				
		cement-sandy 1:5	cement-sandy 1:3	limestone-sandy 1:5	limestone-sandy 1:3	complex 1:1,5:5
40	1,0	19/6	18/6	14/6	10/6	15/6
		16/8	15/8	12/8	9/8	14/8
		13/10	10/10	8/10	6/10	9/10
		7/12	6/12	4/12	2/12	5/12
20		17/6	13/8	6/10	1/12	10/8
30		18/6	14/8	7/10	1/12	12/8
40		19/6	15/8	8/10	2/12	13/8
50		21/6	17/8	9/10	4/12	15/8
40	0,5	10/8	16/6	2/12	2/10	13/6
	0,75	13/8	17/6	3/12	4/10	14/6
	1,0	16/8	18/6	4/12	6/10	15/6

On Fig. 4-6 there are graphs representing the change in this coefficient from the lowability of the mortar, the rotation speed and the coefficient of the housing filling, respectively. Analyzing it, we conclude that the coefficient value of specific movement resistance for cement-sand mortars is greater in approximately 1,3-2 times than that of limestone and sand. With the increase in the mortar lowability, the value of this coefficient decreases, and with increasing the member rotation frequency and the coefficient of filling it increases.

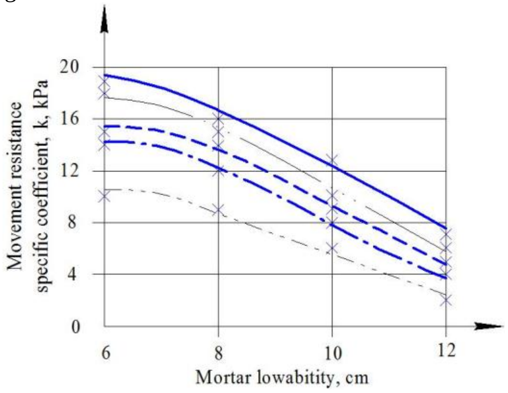


Fig. 4. Dependence of the specific resistance coefficient, *k*, kPa, on the lowability of the mortars at *φ* = 1, *n* = 40 rpm:

——— – cement-sand 1:5;
— — — – cement-sand 1:3;
—- - —- – limestone and sand 1:5;
—— – – —— – limestone and sand 1:3;
—— · · · —— – complex 1:1,5:5

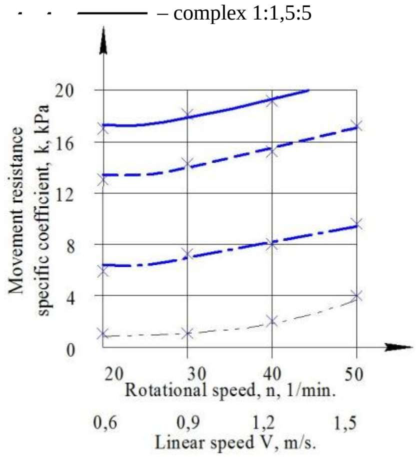


Fig. 5. The dependence of the specific resistance coefficient, *k*, kPa, on the rotating frequency and the mixer speed at *φ* = 1:

——— – cement-sand 1:5, 6 sm;
— — — – cement-sand 1:3, 8 sm;
—- - —- – limestone and sand 1:5, 10 sm;
—— – – —— – limestone and sand 1:3, 12 sm

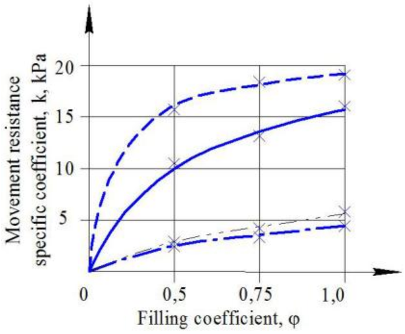


Fig. 6. Dependence of the specific resistance coefficient, *k*, kPa, on the coefficient of the housing filling at *n* = 40 rpm .:

——— – cement-sand 1:5, 8 sm;
— — — – cement-sand 1:3, 6 sm;
—- - —- – limestone and sand 1:5, 12 sm;
—— – – —— – limestone and sand 1:3, 10 sm

3. Conclusion

Mortar mixing equipment is suitable for the preparation of mortars of various compositions and lowabilities, therefore it is obvious that the estimated coefficient values of specific resistance of motion must be taken at the maximum value, that is, when mixing the cement-sand construction mortar mixture (1: 5, 6 cm) with unstable mode. According to the results of experiments for this case, the maximum useful power was 684 W, at which k_{max} = 35 kPa.

References

[1] Hendrickx R., Roels S., Van Balen K. (2010), Measuring the water capacity and transfer properties of fresh mortar, Cement and Concrete Research, 40 (12), 1650–1655. DOI: 10.1016/j.cemconres.2010.08.002.

[2] Xiao H.Y., Yue W.H. (2011), Experimental Research on Rheological Properties of Cemented Mortar in Tail Void Grouting of Shield Tunnel. Advanced Materials Research, 261 – 263, 1201 – 1205. DOI: 10.4028/www.scientific.net/AMR.261-263.1201.

[3] Pedrajas C., Rahhal V., Talero R. (2014). Determination of characteristic rheological parameters in Portland cement pastes. Construction and Building Materials, 51, 484 – 491. DOI: 10.1016/j.conbuildmat.2013.10.004.

[4] Jacobsen S., Haugan L., Hammer T. A., Kalogiannidis E. (2009), Flow conditions of fresh mortar and concrete in different pipes. Cement and Concrete Research, 39 (11), 997 – 1006. DOI: 10.1016/j.cemconres.2009.07.005.

[5] Roussel N. (2005) Steady and transient f1ow behaviour of fresh cement pastes, Cement and Concrete Research, 35, 1656 –1664. DOI: 10.1016/j.cemconres.2004.08.001.

[6] Korobko B., Vasilyev O., Rogozin I. (2015). Analiz kinematiki sumishi v korpusi zmishuvacha z vertikalnim shnekom zi zminnoyu tvirnoyu. Eastern-European Journal of Enterprise Technologies, 3, 7 (75), 48–52.

[7] Noor M.A., Uomoto T. (2004). Rheology of High Flowing Mortar and Concrete. Materials and Structures, 37, 513-521. DOI: 10.1007/BF02481575.

[8] Ferraris C.F. (2001). Concrete Mixing Methods and Concrete Mixers. Journal of Research of the National Institute of Standards and Technology, 106/2, 391 – 399.

[9] Korobko B. (2015). Analytical calculations of energy consumption when mixing solution with the help of functional characteristics. International Academy of Science and Higher Education, 22 – 24. DOI: 10.18007/gisap:pmc.v0i7.1185.

[10] Gurao A., Keskar A., Jadhav M., Jadhav P., Mithari R. (2017). Horizontal Axis Electric Operated Concrete Mixer. International Journal of Innovative Research in Science, Engineering and Technology, 6/2, 3813-3820.

[11] Chen X., Wu S., Zhou J. (2013). Experimental and modelling study of dynamic mechanical properties of cement paste, mortar and concrete. Construction and Building Materials, 47, 419 – 430. DOI:10.1016/j.conbuildmat. 2013.05.063

[12] Radl S., Kalvoda E., Glasser B.J., Khinast J.G. (2010). Mixing characteristics of wet granular matter in a bladed mixer. Powder Technology, 200(3), 171-189. DOI: 10.1016/j.powtec.2010.02.022
[13] Kravchenko S., Popov S., Gnitko S. (2016). The working pressure research of piston pump RN-3.8. Eastern-European Journal of Enterprise Technologies, 5, 1 (83), 15–20. DOI:10.15587/1729-4061.2016.80626
[14] Popov S., Vasilyev Ye., Tobolchenko Ye. (2017). Udoskonalennya konstruktsiyi mobilnoyi rozchinozmishuvalnoyi ustanovki URZ-3,8. Naukoviy visnik budivnitstva (Zbirnik naukovih prats), 9, 202–206.
[15] Popov S., Yasko S., Kislichenko D. (2008). Eksperimentalnoe opredelenie moschnosti privoda shnekovogo rastvorosmesitelya. Mehanizatsiya stroitelstva, 9, 8–12.
[16] Korobko B. (2016), Investigation of energy consumption in the course of plastering machine’s work, Eastern-European Journal of Enterprise Technologies, 4/8 (82), 4 – 11. DOI: 10.15587/1729-4061.2016.73336.