


ANALYTICAL CALCULATIONS OF ENERGY CONSUMPTION WHEN MIXING SOLUTION WITH THE HELP OF FUNCTIONAL CHARACTERISTICS

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The influence of rheological characteristics of the mortar mix and the mixer's quality factor on its energy intensity have been studied. We have also determined the recommended operating time for the mixer.

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Determination of capacity of electric actuator in a mortar mill of coercive action is rather complicated. Building mortars that are coarse suspensions fall into visco-plastic bodies, which properties and flow conditions differ significantly from viscous liquids. The changeability of physical and mechanical properties of building mortars depending on time and speed assumes great importance. This fact greatly complicates the process of mortar mix flow during the mixing. Therewith there appears a significant amount of resistances, the most prominent among which are frictional strength (internal and external), resistances, caused by the operation of mass motion, and resistances arising from inertial efforts, from wave generation and etc. Many of these resistances do not remain constant during the mixing cycle. Besides, we have a wide range of building solutions depending on mortar formula and on component performances. All of this complicates the matter of determining the resistance components arising in the process of mixing.

Currently there is mostly used the equipment, in which the mixing process takes place due to mechanical impact on the environment.

The first scientific works, dedicated to the study of mixing process and calculation methods of mixing equipment, appeared at the beginning of the last century. There were not many of these works and the number of works that considered mixing suspensions and visco-plastic medium was even less. All this complicated the studying of energetic characteristics in mixing processes, the development of common methods for calculating mixers and the determination of effectiveness and fundamental optimal parameters.

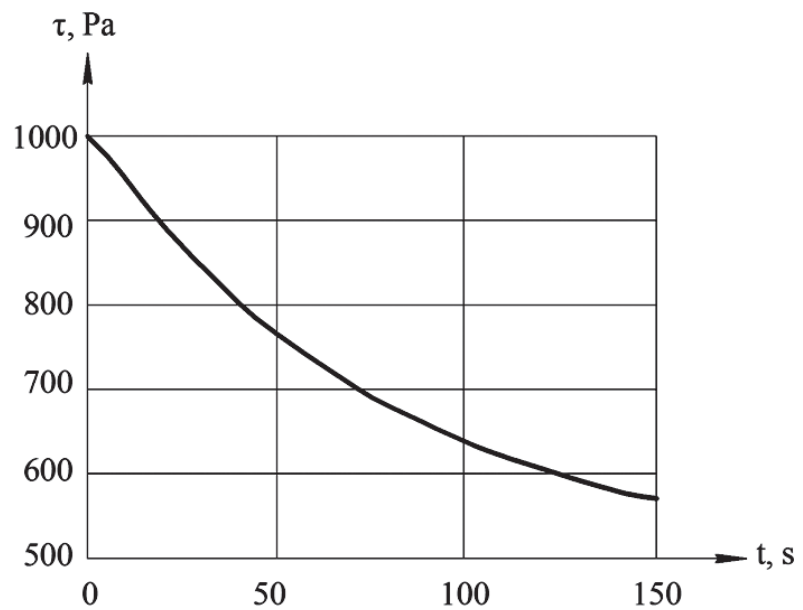


Fig. 1. The dependence of the critical shift voltage on time t

When studying mixing processes the authors of the above-mentioned works considered liquid motion and blending of liquids processes, efficiency determination of blending, heat transfer and catalyzation of chemical behavior. Only a few papers dealt a little with the studying of suspension flow and mixing of suspensions and other visco-plastic bodies [1, 2, 3, 4].

In the 1930-40s there were published the works, dedicated to the issues of power expenditure during mixing [5, 6].

In the research paper [7] there was applied the Newton's law of internal fluid friction to determine the resistances arising during mixing.

In the research paper [8] there was offered the method of calculating screw mixers.

Based on the analysis of the problem, it can be said that the issue of visco-plastic fluid motion has not been studied enough

yet, it is especially subject to coarse suspensions, which include building mortars. There are also no generally accepted calculation methods for mortar mixers. Generally the calculation of equipment, working with such mixtures, is performed by empirical dependences and formulas developed for the cases of viscous fluid motion.

The dependence of the critical shift voltage on time is expressed by the equation

$$\tau(t) = \tau_n + (\tau_0 - \tau_n)e^{-Kt}, \quad (1)$$

where τ – is the critical shift voltage, which goes from its initial value τ_0 (dry mix) to the nominal value, corresponding to ready mix;

K – is the coefficient that characterizes the mixer's quality: the location and geometry of the blades and belts;

t – is time.

Let's see how the value τ (the critical shift voltage) varies according to time t .

Analyzing Fig. 1 we can see that the solution is being mixed to the acceptable level ($\tau = 600 \text{ Pa}$) over the time of 120 seconds.

Power consumed by the mixer is described with the mathematical relation

$$P = \int_S \int \tau \cdot (\vec{n} \cdot \vec{v}) ds =$$

$$= \tau \cdot \omega \cdot tg \sigma_1 \left[\frac{(R_1 + R_2)}{2} \right] \cdot \pi \cdot (R_2^2 - R_1^2) +$$

$$+ \tau \cdot \omega \cdot m \cdot \frac{tg \sigma_2}{\cos \sigma_2} d \cdot a \cdot b \quad (2)$$

where \vec{n} – is the normal to the elementary area, the unit vector;

\vec{v} – is the speed of elementary area's movement in solution;

S – is the area of belts and blades;

ω – is the rotational speed;

σ_1 – is the belt angle;

σ_2 – is the blade angle;

R_1, R_2 – are the least and the biggest radiuses of the belt;

m – is the number of blades;

d – is the shoulder of the blade attachment;

a – is the blade width;

b – is the blade length.

In order to search out the total work it's necessary to find t_{stop}

$$\tau_n + (\tau_0 - \tau_n) e^{-Kt_{stop}} = 0,1 \tau_n;$$

$$(\tau_0 - \tau_n) e^{-Kt_{stop}} = 0,1 \tau_n;$$

$$e^{-Kt_{stop}} = \frac{0,1 \tau_n}{\tau_0 - \tau_n};$$

$$-Kt_{stop} = \ln \frac{0,1 \tau_n}{\tau_0 - \tau_n};$$

$$t_{stop} = \frac{1}{K} \ln \frac{\tau_0 - \tau_n}{0,1 \tau_n}. \quad (3)$$

The relation for the total energy is the following (4).

The energy per unit of volume that is expended while stirring the solution, is calculated from the ratio

$$E_{mix.spec.} = \frac{E}{\rho \cdot V \cdot K_{b.f.}}, \quad (5)$$

where ρ – is the density of the mixture;

V – is the mixer's volume;

$K_{b.f.}$ – is the blending hopper's

$$E_{mix.} = \int_0^{t_{stop}} (\tau_n + (\tau_0 - \tau_n) e^{-Kt}) dt \cdot \omega \left(tg \sigma_1 \left(\frac{R_1 + R_2}{2} \right) \pi (R_2^2 - R_1^2) + mtg \sigma_2 dab \right) =$$

$$= \omega \left(tg \sigma_1 \left(\frac{R_1 + R_2}{2} \right) \pi (R_2^2 - R_1^2) + mtg \sigma_2 dab \right) \left[\tau_n \cdot t_{stop} + \frac{\tau_0 - \tau_n}{K} (1 - e^{-Kt_{stop}}) \right] \quad (4)$$

coefficient of charge.

Let's calculate the power consumption = 412 mm; $R_1^2 = 350 \text{ mm}$; $m = 4$; $\sigma_2 = 45^\circ$; $d = 0,3 \text{ m}$; $a = 0,2 \text{ m}$; $b = 0,3 \text{ m}$;

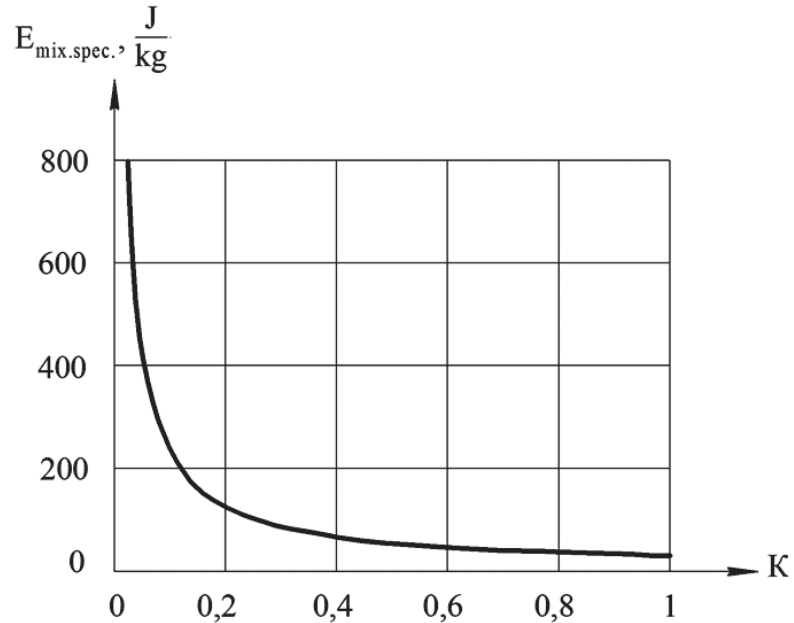


Fig. 2. Dependence of the energy of mixing per unit of volume $E_{mix.spec.}$ on the coefficient K

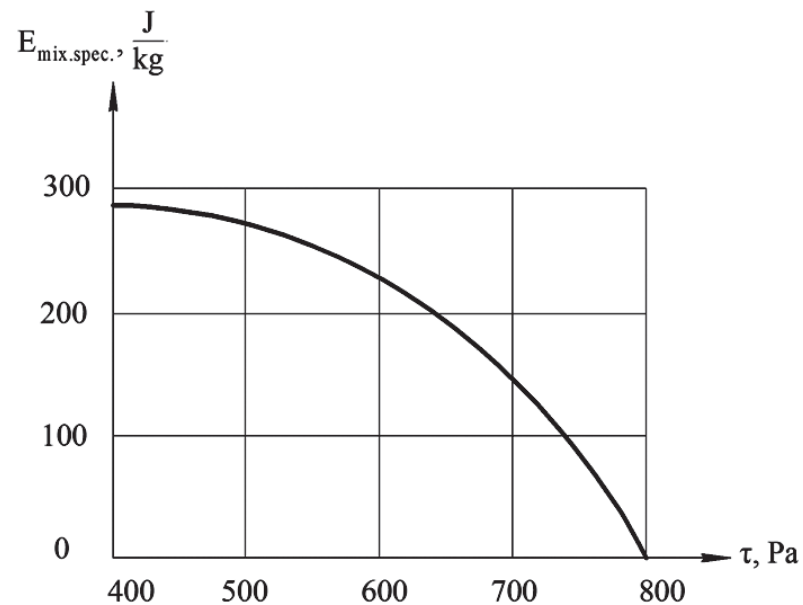


Fig. 3. The dependence of the specific energy of mixing $E_{mix.spec.}$ on the yield point of the ready mix τ_n

following parameters:

$\tau_n = 600 \text{ Pa}$; $\tau_0 = 1000 \text{ Pa}$; $\omega = 2,2 \text{ rad /s}$; $\sigma_1 = 30^\circ$; $l = 1,5 \text{ m}$; $R_2^2 = 2000 \text{ kg/m}^3$; $V = 3,2 \text{ m}^3$; $K_{b.f.} = 0,8$.

From the graph in Fig. 2 we can see that the sustainable range of coef-

ficient's values K ranges within 0.4 – 0.8. Values less than 0.2 lead to a sharp increase in the specific energy consumed for mixing.

Thus, knowing the initial data and the number of K of the mixer, that is conditional upon its geometrical dimensions and knowing also the solution weight, which is prepared by the formula (5) one can determine and compare the energy intensity (J/kg) of various designs of faucets during the preparation of solutions with differential mobility yet drawing-board stage and in the design selection phase.

If we need to determine the dependence of specific energy of mixing on rheological characteristics of the mixture, namely on the τ_n – is the critical shift voltage of the ready mix, then the graph will take the following form.

The proposed method of calculating power consumption allows to the into consideration the basic geometric and

kinematic characteristics of blade and screw mixers, to evaluate the specific energy that is consumed for mixing not only depending on the value of the yield point of the ready mix τ_n , but also on the coefficient K , which characterizes the quality of the mixer.

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