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The Counterflow Mixer for Receiving the Disperse Reinforced Composites

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Abstract: In study considered using of innovative development in the field of the mixing equipment for receiving new qualitative dry construction mixes which will help with the solution of a number of problems of production of the disperse reinforced materials is considered. The design of pneumatic mixer with configuration of a technological production line of dry construction mixes on a basis of fibers is offered. Use of polypropylene fibers entered into concrete samples for the purpose of increase in durability of concrete is proved. The most important component of any process of mixture is the mechanism for formation of mix that is change of an order and sequence of actions of redistribution of initial components in the working volume of the camera and receiving an optimum surface of reacting substances. The formation of mix represents process of receiving a new material of two or several initial components. The purpose of this process is receiving essentially new materials; giving to materials of new physical and chemical properties; intensification or delay it is warm and mass-exchanged, chemical and biochemical processes.

Key words: Compressed-air mixer of continuous action, dry construction mixtures, disperse reinforced composites, performance, homogenization and quality of the mixture

INTRODUCTION

As properties of bulks are various, the big nomenclature of types of the mixing equipment is developed now. Depending on a design in the working camera of the mixer the following mechanisms of mixture can prevail: circulating, volume, diffusive. Basic element of the mixer is the camera of homogenization in which the working bodies moving components on being crossed trajectories (Orekhova *et al.*, 2011, 2012; Orekhova, 2011; Osiptsov, 1997) are located.

Today a large number of researchers point to prospects of development of the equipment with use of energy of the compressed air for material hashing. Implementation in the mixing unit of the intense states caused by such influences as: the twisting in streams of whirlwinds and movement in the horizontal plane-allows to approach to mixture process at qualitatively new level (Spiridonov *et al.*, 2009; Sukhova *et al.*, 2010; Seryh, 2005; Minasyan *et al.*, 2005).

THE MAIN PART

During the operation of the pneumatic mixer, impulses of the compressed air arrive under a different corner through pneumatic valves established in the case. Pneumatic impulses in a continuous mode direct a material up and to bunker walls before achievement of demanded homogeneity (Fig. 1).

The main processes of a technological chain of production of the dry construction mixes having essential

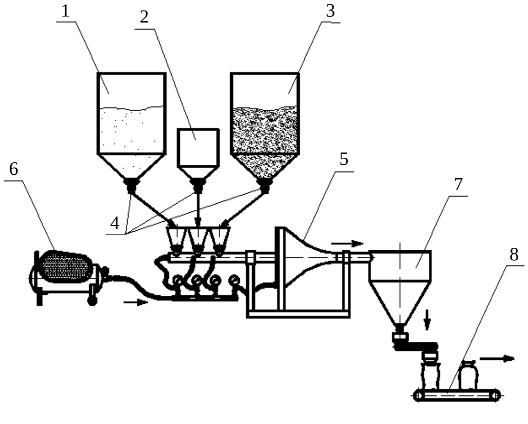

Fig. 1: The technological line for production of CCC: 1, 3) the bunker for input products, 2) the bunker of additives, 4) weight batchers, 5) the pneumatic mixer, 6) the compressor, 7) the packing car and 8) the conveyor

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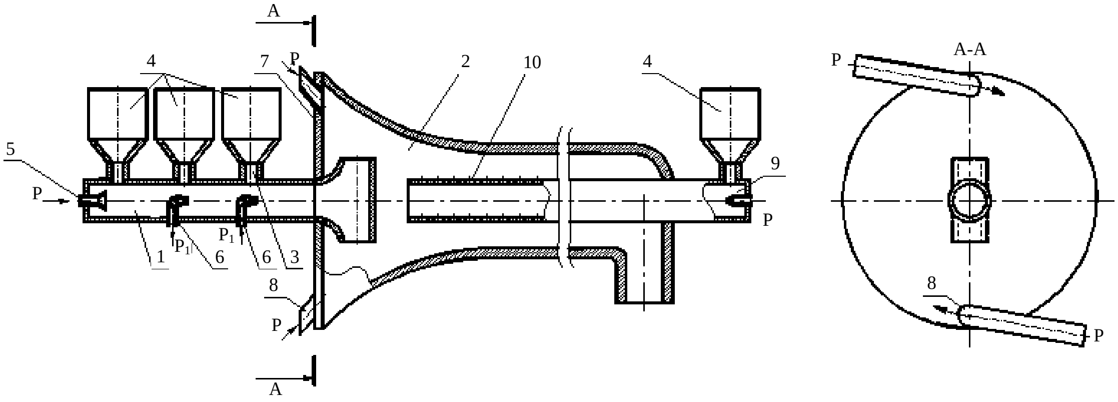

Fig. 2: Pneumatic mixer; 1) the giving; 2) closed torahs; 3) input branch pipe; 4) bunker; 5-7) nozzles additional; 7) end face; 8, 9) nozzles and 10) cylinder hollow

impact on their operational characteristics is: preparation of input products, material downing their dispensing and mixing, distribution of chemical additives in the bulk product. Uniformity of a material is a basis of demanded quality of modern construction mixes.

Basis for dry construction mixes are kinds of cement, various fillers and mineral additives which define properties and a scope of mixes. The choice of the mixing equipment is the major step on a way of receiving a high-quality product. In communication with what innovative development in the field of the mixing equipment are the pneumatic mixers working at compressed air (Fig. 2).

The offered design is directed on improvement of quality of the disperse reinforced mix on a basis of fibres that is reached due to the technical effect consisting in improvement of quality of a downing and mixture of components of mix, received by use of counter flow giving of components of mix and providing a difference of pressure in various zones of the pneumatic mixer.

The counter flowing pneumatic mixer for production of the disperse reinforced mixes, the containing case executed in the form of a horizontal confusor with inclined nozzles and connected to it in the central part, the giving pipe bearing loading bunkers with branch pipes of input and air nozzles. Thus, the closed end face of a giving pipe is executed in the form of a diametrical flange with two opposite exits on forming and placed in a horizontal confusor and inclined nozzles are entered into a horizontal confusor tangently with a being crossed arrangement of the axes and axes of exits of a giving pipe. Besides from unloading in a horizontal confusor the branch pipe in the form of the hollow cylinder with openings on forming is established, the bearing additional loading bunker and an additional air nozzle and size of pressure of the compressed air p_1 and in air nozzles and inclined air nozzles-p are in a giving pipe and an additional air nozzle in the ratio $p_1 = 2p$.

In the mixer of continuous action components of mix move separate batchers, the quantity of feeders corresponds to quantity of mixed components. Mixture process in continuously operating mixer depends on adjustable parameters of system (input parameters) to which the speed of the expiration of the compressed air belongs; speed of an entrance to the camera of mixture of particles of components of the mix [v] υ. For the description of process of mixture in the camera of the mixer we will make a number of assumptions:

- We will consider that quality of separate components arriving from feeders is a constant that in turn is the reason of lack of influence of revolting parameters
- Initial value of concentration of a key component of mix will be defined by the total law of dispensing
- Movement of mixed components in a giving pipe happens without interaction

For effective mixing it is necessary to remove mathematical dependences for definition of movement of particles of a material in a loading pipe.

We will consider movement of firm particles of the material, transported by feeders in an air stream of a loading pipe. At viscous movement force of the interphase interaction which value will be defined by the following expression (Klyuev, 2011; Klyuev and Lesovik, 2012) will act on a horizontal site of a loading pipe on a particle of a material:

$$F = C_0 \cdot \rho \cdot \frac{S}{2}(U\text{-}\vartheta)^2 \tag{1}$$

Where:

C_0 = Coefficient of resistance of a particle
ρ = Density of air (kg/m^3)
S = Midel's section of a particle (m^2)
U = Energy carrier speed on any site of a loading pipe (m/sec)
ϑ = Speed of movement of a particle of a material in a loading pipe (m/sec)

Therefore, on the basis of a ratio Eq. 1 of movement of a particle of a material weight "m_i" can be written down as:

$$\text{-}m_i \frac{d\vartheta}{dt} = C_0 \cdot \rho \cdot \frac{S}{2}(U\text{-}\vartheta)^2 \tag{2}$$

If to consider that the mass of a particle of a material is defined by a ratio:

$$m_i = V \cdot \gamma_i \tag{3}$$

Where:

γ_i = Density of a particle of a material in relation to "i" a component
V = The volume of a particle of a material, m^3 which can be led to the following look

$$V = \frac{\pi d^2}{4} \cdot \frac{4}{3} \cdot \frac{d}{2} = S \cdot \frac{2}{3} d \tag{4}$$

where, d diameter of a particle (m). Taking into account expression Eq. 3 assumes an air:

$$m_i = \frac{2}{3} S \cdot d \cdot \gamma_i \tag{5}$$

Substitution (Eq. 5) in Eq. 2 leads to the following result:

$$\frac{d\vartheta}{dt} = \frac{3}{4} C_0 \cdot \left(\frac{\rho}{\gamma_i}\right) \cdot \frac{1}{d} (U\text{-}\vartheta)^2 \tag{6}$$

Complexity when finding the solution of the nonlinear differential Eq. 6 consists in determination of dependence of coefficient of resistance of a particle of a material from a high-speed mode of movement of a particle, namely (Osiptsov, 1997; Klyuev *et al.*, 2014; Klyuev, 2011; Klyuev and Lesovik, 2012):

$$C_0 = f(\text{Re}) \tag{7}$$

where (Re) Reynolds's number which is equal:

$$(\text{Re}) = \frac{|U - \vartheta| \cdot d}{\nu} \tag{8}$$

At number, U> ϑ number $\text{Re} = |U - \vartheta| \cdot d / \nu$. ν-coefficient of kinematic viscosity, m^2/page. According to references of the most exact dependence of coefficient of front resistance of particles of a material on number Re in the range of $1<\text{Re}<10^3$ is defined by Klyachko's equation:

$$C_0 = \frac{24}{\text{Re}} + \frac{4}{\sqrt[3]{\text{Re}}} \tag{9}$$

Taking into account Klyachko's expression Eq. 8 assumes the following air:

$$C_0 = \frac{24\nu}{(U - \vartheta) \cdot d} + \frac{4\nu^{\frac{1}{3}}}{(U - \vartheta)^{\frac{1}{3}} \cdot d^{\frac{1}{3}}} \tag{10}$$

Initial value of speed of the energy carrier (air) can be defined from the ratio determining speed of the expiration of gas from an opening in a thin wall:

$$U_0 = \varphi_0 \sqrt{\frac{2 \cdot (P_1\text{-}P_2)}{\rho_0}} \tag{11}$$

Where:

φ_0 = Speed coefficient equal 0.668
P_1 = pressure in a snivel (Pa)
P_2 = External pressure (Pa)
ρ_0 = Air density in a snivel (kg/m^3) which can be found on the basis of the law connecting pressure and temperature at isothermal process

$$\rho_0 = \frac{P_1}{RT} \tag{12}$$

where, R a universal gas constant, 8.31 kJ/(kg·°K). We enter size τ_0 according to a ratio:

$$\tau_0 = \frac{1}{A} = \frac{d^2}{18\nu}\left(\frac{\gamma_i}{\rho}\right) \tag{13}$$

It is easy to be convinced that the entered size τ_0 has dimension of time which we will call relaxation time. We will enter size ϑ_0 according to a ratio:

$$\vartheta_0 = \frac{\nu}{d} \tag{14}$$

Size (Eq. 14) has dimension of speed. Therefore, pertinently to call this size the speed of braking of a particle of a material due to kinetic viscosity of the environment and the particle size. Taking into account ratios Eq. 11 and 13 expression (Eq. 14) can be presented in the following look:

$$\vartheta = U_0\left\{1\text{-}e^{-\frac{t}{\tau_0}}\left[1+\frac{1}{6}\left(\frac{U_0}{\vartheta_0}\right)^{\frac{2}{3}}\left(1\text{-}e^{-\frac{2}{3}\frac{t}{\tau_0}}\right)\right]^{-\frac{3}{2}}\right\} \qquad (15)$$

We will consider a period much less time of a relaxation, i.e., the interval for which is carried out a ratio:

$$t \ll \tau_0 \qquad (16)$$

For a considered interval of time meeting the condition (Eq. 16) to within sizes of the first order of a malost can conclude that:

$$e^{-\frac{t}{\tau_0}} \cong 1\text{-}\frac{t}{\tau_0} \qquad (17)$$

and:

$$e^{-\frac{2}{3}\frac{t}{\tau_0}} \cong 1\text{-}\frac{2}{3}\frac{t}{\tau_0} \qquad (18)$$

Substitution Eq. 17 and 18 in expression (Eq. 15) to within the size of the first order of a malost also leads to a ratio:

$$\begin{aligned}\vartheta &\cong U_0\left\{1\text{-}\left(1\text{-}\frac{t}{\tau_0}\right)\left[1+\frac{1}{6}\right]\left(\frac{U_0}{\vartheta_0}\right)^{\frac{2}{3}}\cdot\frac{2}{3}\frac{t}{\tau_0}\right\}^{-\frac{3}{2}} \cong \\ &U_0\left\{1\text{-}\left(1\text{-}\frac{t}{\tau_0}\right)\left(1\text{-}\frac{1}{6}\left(\frac{U_0}{\vartheta_0}\right)^{\frac{2}{3}}\frac{t}{\tau_0}\right)\right\} \cong \\ &U_0\left\{1\text{-}1+\frac{t}{\tau_0}+\frac{1}{6}\left(\frac{U_0}{\vartheta_0}\right)^{\frac{2}{3}}\frac{t}{\tau_0}\right\} \simeq U_0\left(1+\frac{1}{6}\left(\frac{U_0}{\vartheta_0}\right)^{\frac{2}{3}}\right)\frac{t}{\tau_0}\end{aligned} \qquad (19)$$

Thus, for periods (Eq. 16) change of speed of movement of particles of a material in a loading pipe on the basis of the received ratio (Eq. 19) happens under the linear law.

For definition of the time spent of particles of a material in a loading pipe we will calculate the size of acceleration of particles of a material. We will calculate derivative of expression Eq. 19 on time and we will receive the following result:

$$a = \frac{d\vartheta}{dt} = \frac{U_0}{\tau_0}\left(1+\frac{1}{6}\left(\frac{U_0}{\vartheta_0}\right)^{\frac{2}{3}}\right) \qquad (20)$$

According to a ratio (Eq. 20) particles of a material in a loading pipe for an interval of time (Eq. 16) move with continuous acceleration. Therefore, the ratio connecting the passable way and time of movement of a particle has an appearance:

$$l = \frac{a\Delta t^2}{2} \qquad (21)$$

Where:

l = Length of a site of a loading pipe (m)

Δt = Interval of time during which the particle of a material moves on a loading pipe to the camera of mixture (Klyuev, 2011)

On the basis of Eq. 21 we find that the time spent of a particle of a material in a loading pipe will be defined by a ratio:

$$\Delta t = \sqrt{\frac{2l}{a}} = \sqrt{\frac{2l\cdot\tau_0}{U_0\left(1+\frac{1}{6}\left(\frac{U_0}{\vartheta_0}\right)^{\frac{2}{3}}\right)}} \qquad (22)$$

Therefore, on an entrance to the mixture camera the material particle with a diameter and kinematic viscosity of the environment will matter following speed:

$$\vartheta = (t = \Delta t) = \sqrt{\frac{2lU_0\left(1+\frac{1}{6}\left(\frac{U_0}{\vartheta_0}\right)^{\frac{2}{3}}\right)}{\tau_0}} \qquad (23)$$

OUTPUT

Work practice showed that reinforcing of a cement matrix by the polypropylene fiber possessing high chemical stability to the alkaline environment gives a positive effect. Polypropylene fibers join in concrete samples for the purpose of increase in durability of concrete at compression from 10-60% and a bend from 10-200% (Klyuev *et al*., 2014; Klyuev, 2011; Klyuev and Lesovik, 2012).

CONCLUSION

Thus, the received value of speed of an entrance of a particle of a material in the mixture camera according to (Eq. 23) depends as on design data l-length of a loading pipe and on technological parameters: coefficient of kinematic viscosity, diameter of a particle, density of a material, energy carrier density and as initial speed of the energy carrier.

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