IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

New technology and energy-saving equipment for production of composite materials

To cite this article: A A Romanovich *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **327** 052013

IOP Conf. Series: Materials Science and Engineering **327** (2018) 052013 doi:10.1088/1757-899X/327/5/052013

New technology and energy-saving equipment for production of composite materials

A A Romanovich, S N Glagolev, A N Babaevsky

Belgorod State Technological University named after V.G. Shoukhov, 46, Kostyukov St., Belgorod, 308012, Russia

E-mail: alexejrom@yandex.ru

Abstract. The article considers industrial technology and energy-saving equipment for cement and composite binder production with a reduction in energy intensity of the process up to 50% due to the synergetic effect during mechanic activation of the raw mix with the replacement of part of the clinker component with the mineral hydro-active additive. The technological process is based on the sequential introduction of components in dispersed phases into the feed mixture in the grinding path and at the stage of product separation with certain dispersed characteristics. The increase in the energy efficiency of the line is achieved by the joint operation of the press roller aggregate, which is the development of BSTU named after V.G. Shoukhov, and rotor-vortex mills of a very fine grinding of a new design. The experienced design of the aggregate with the device for deagglomeration of the pressed tape allows combining the processes of grinding and disaggregation of the pressed material, thereby reducing the operating costs and increasing the efficiency of using the grinding unit. Comparative tests of cement samples obtained in energy-saving aggregates (PRA + RVM) are given which allowed establishing that their beam strength for compression and bending is higher by 15-20% than the traditional method obtained in a ball mill. An analytical expression is also given that allows one to determine the power consumed for the deagglomeration of crushed and pressed material between the main rolls, taking into account the geometric dimensions of the rolls and the physico-mechanical characteristics of the material.

1. Introduction

In Russia, 50-60 million tons of cement are produced with an annual consumption of 70-75 million tons. To cover the deficit of cement is possible due to the creation of regional grinding units, which are based on the processing of local raw materials and allow one to get not only cements, but various composite astringents, which will reduce costs, including transportation.

In addition, the energy intensity of cement production in the traditional way in Russia does not fall below 0.2 GJ/t, which is almost twice as higher as in developed countries, the best world indices are in the range of 0.09-0.11 GJ/t.

The data show that the cement produced in the traditional way has a high energy intensity and, due to the constant increase in the cost of energy resources, while the consumption volumes are growing at the same time, the urgency of reducing the energy intensity of the binder getting process is becoming increasingly important.

The implementation in recent years of the national project "Affordable and Comfortable Housing for Russian Citizens", as well as the overhaul of secondary housing, has led to increased construction activities and to the increased need for dry construction mixtures, the volume of output currently at about 3.5 million tons per year.

All this requires a new approach to the organization and implementation of cement production and cheaper different composite binder and building mixes. Many scientists have proposed various technologies and equipment to increase efficiency in the production of cement [1-5].

However, cement is still transported to regions where there are no cement manufacturers, which requires higher costs since not only the clinker component in cement is transported, but also additives that reach up to 40% or more.

One of the solutions to reduce costs and increase the production of cement and composite knitting and building mixtures is the development of regional energy-saving grinding units using local raw materials.

2. The main part

Scientists of BSTU named after V.G. Shoukhov developed industrial technology and energy-saving equipment to produce cement and composite binder with a decrease in energy intensity of the process to 50% due to the synergistic effect in mechanoactivation of the raw mixture with the replacement of part of the clinker component with a mineral hydro-active additive [6-11]. The technological process (Figure 1) is based on the sequential introduction of components in dispersed phases into the raw mixture in the grinding path and at the stage of product separation with certain dispersed characteristics.

The increase in the energy efficiency of the line is achieved by the joint operation of the press roller aggregate (PRA), which is the development of scientists of BSTU named after V.G. Shoukhov, and a rotor-vortex mill (RVM) of ultra-fine grinding of a new design. In this case, a synergistic effect is obtained. The technology of producing cement and composite binder means the crushing of raw materials to the dispersion with specific surface characteristics of 4000 ... 4500 cm^2/g. However, the rotor-vortex mill is designed for a certain size of the input piece of material, which should not exceed 5 mm.

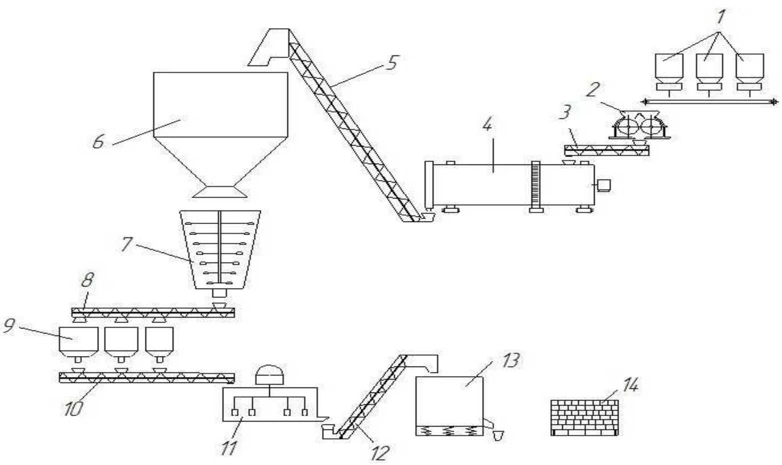
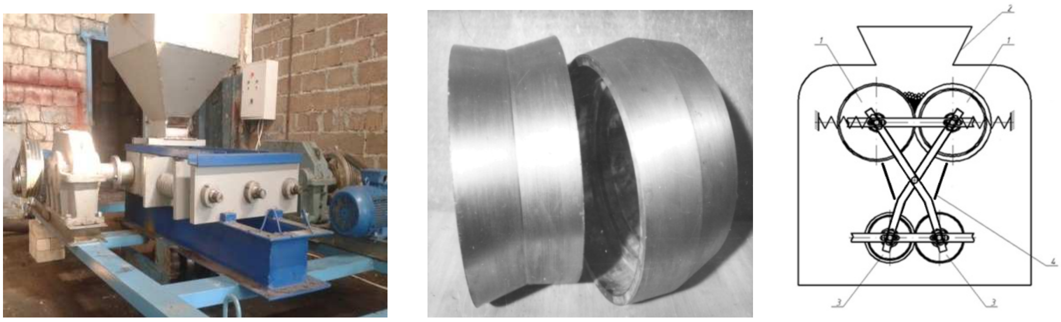


Figure 1. A technological scheme of composite materials production: 1,2,3 **-** bunker of raw materials; 2 - PVA; 3,5,8,10,12, - screw feeder; 4-drying drum; 6 - storage bunker; 7 - rotor-vortex mill; 9-bumker of additives; 11-mixer; 13-packing machine; 14- finished goods warehouse.

Application at the stage of rough grinding, which is implemented in a press-roller grinder (Figure 2a), allows one not only to grind the raw materials to the above-mentioned size, but also to reduce specific energy consumption by 25-30% through the use of a conical profile of the rolls (Figure 2b). This profile of rolls allows one to create volume-shear deformation of crushed material, which leads to its destruction with less effort grinding compared with the traditional cylindrical shape.



a) b) c)

Figure 2. A press roller grinder with a device for disaggregation materials: a) general view, b) view of installation in the line, c) scheme

However, the material after the processing pressure is in the form of compressed plates, which makes it difficult to re-grind it without disaggregation in a rotor-vortex mill. Analysis of the shape and the structure of the material pressed into the PRA made it possible to establish that it has an anisotropic texture with maximum strength in the direction of application of the grinding force (Figure 3) and requires special conditions for its de-agglomeration and grinding. The experimental studies carried out to study the influence of grinding forces on the deagglomeration of compacted plates (Figure 4) made it possible to establish that with increasing compacting pressure not only the degree of crushing of the material, but also the strength of the compacted plates increases.

And for their destruction, it is necessary, depending on the direction, to apply various efforts. For example, when the clinker is crushed with a pressure equal to 320 MPa, the forces necessary to deagglomerate the pressed plates when applying a force in the direction of pressing the material are equal to $P_{\text{dis.prod}}$ = 23.5 MPa, and in the perpendicular direction less than 4 MPa, which is substantially lower. This indicates that to destroy effectively the crushed and pressed materials in the plates in the PRA, it is advisable to make efforts in the direction perpendicular to the force action in the PRA.

Figure 3. Form of clinker, pre-deformed in PRA

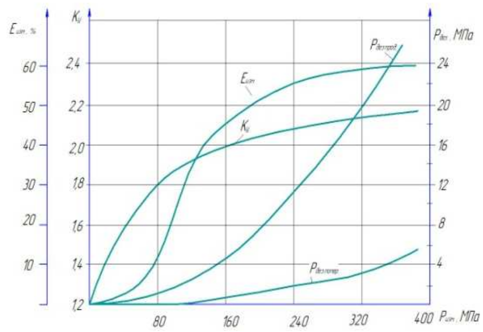


Figure 4. Influence of clinker grinding pressure on the number of deagglomeration forces of its compacted plates

Therefore, the authors developed the experimental design of PRA with the device for deagglomeration of the pressed tape, which allows combining the processes of grinding and disaggregation of the pressed material, thereby reducing the operating costs and increasing the efficiency of the grinding unit use (Figure 2a, c).

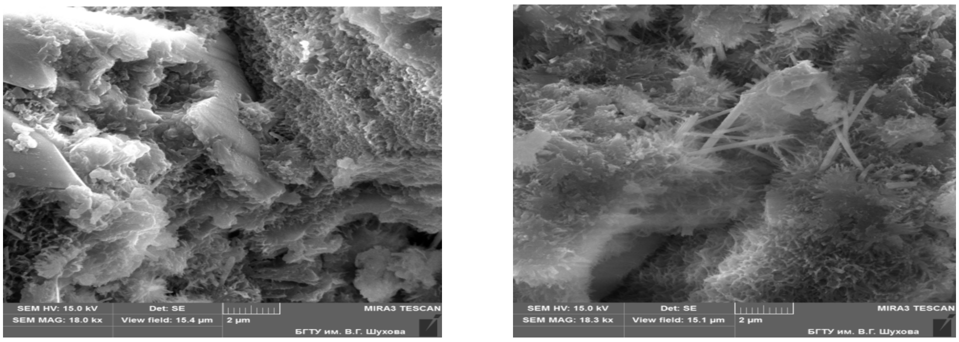
The press roller aggregate with the device for deagglomeration includes bunker 2 mounted on frame conical rollers 1 and a disinhibiting device which consists of additional rollers 3 having a conicity opposite to the main rollers.

The aggregate for grinding materials works as follows. The raw material is supplied in bunker 2, for example, a clinker that is gripped by conical rollers, between which it is broken and pressed.

Leaving the roll space in the form of compressed plate material is destroyed between two additional rolls of conical rolls.

Additional rolls have an inverse cone with the main conical rolls and thereby perform an oppositely directed force action on the material crushed and compressed in the main rolls, which allows one not only to disaggregate it but also to uncover the microcracks of the particles.

Comparative tests of cement samples obtained in energy-saving aggregates (PRA + RVM) made it possible to establish that their beam strength for compression and bending is higher by 15-20% than in the traditional way. This is due to the fact that the activated sample (Figure 5a) has a denser homogeneous structure with good adhesion of the cement stone to the aggregate compared to the reference one (Figure 5b).



a) *b)*

Figure 5. The structure of the cement stone samples: a - from cement obtained in energy-saving aggregates (PRA + RVM); b - in a ball mill

However, the process of deagglomeration of materials is additionally expended on the power used to move and destroy the pressed plates, and the lack of a method for calculating its magnitude inhibits the introduction of this PRA design into production.

To find the power expended on the destruction of the pressed plates, the material between the press rolls, refer to the design scheme presented in Figure 6.

According to the design scheme (Figure 6), the area of the force action from the moment of capture of the material to its exit from the rolls (shaded figure) and the volume are respectively equal to:

$$S_0(\alpha_0) = h_0 R \sin \alpha_0 - R^2 \alpha_0 + \frac{R^2}{2} \sin 2\,\alpha_0 \quad (1)$$

$$V = S_0(\alpha_0) \cdot b \quad (2)$$

As a result of the gripping by the rotating rolls of the material plate under the action of elastic force, energy is equal to:

$$Q_b = k \int_d^{h_0} y\, dy = \frac{k}{2}(h_0^2 - d^2), \quad (3)$$

where k is the coefficient of rigidity of the spring assembly; h_0 is the initial thickness of the material plate; d is the linear size of the particles of the crushed material.

As a result of the introduction of energy (3) in volume (2), work is carried out to destroy the material plate, the value of which is equal to:

$$A = \frac{\sigma_P^2 V}{2E} = \frac{\sigma_P^2 S_0(\alpha_0) \cdot b}{2E}, \quad (4)$$

where σ_P- ultimate strength of the material plate under uniaxial compression; E – Young's modulus of the destroyed material; b – width of rolls.

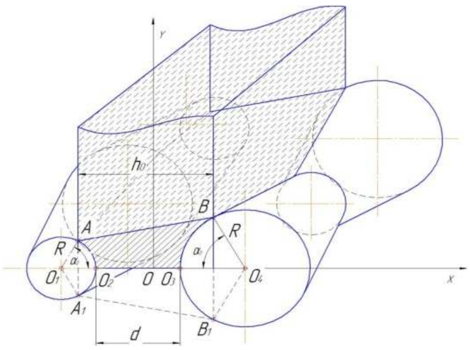


Figure 6. A calculation scheme for determining the area of the destroyed material

On the basis of (3) and (4) let us obtain the following relation:

$$\frac{k}{2}(h_0^2 - d^2) = \frac{\sigma_P^2 S_0(\alpha_0)\cdot b}{2E}. \tag{5}$$

Starting from (5), the size of the linear size of the crushed material is:

$$d = h_0 \cdot \sqrt{1 - \frac{\sigma_P^2 S_0(\alpha_0)\cdot b}{kE}}\,. \tag{6}$$

Because of the radical positivity of the expression in (6), one can obtain the following inequality:

$$k \geq k_0 \tag{7}$$

where there is the following notation introduced:

$$k_0 = \frac{\sigma_P^2 S_0(\alpha_0)\cdot b}{E} \tag{8}$$

Resulting relation (8) determines the stiffness values of the block of springs at which de-agglomeration of the pressed material occurs.

The amount of power is expended in breaking the plate of material N_p when turning the wolves of the press roller grinder at angle α_0 :

$$N_P = A \cdot t, \tag{9}$$

Time can be defined as:

$$t = \frac{\alpha_0}{\omega}, \tag{10}$$

where *w*- rotational speed of rollers.

Taking into account expressions (10), (9), (4), let us obtain the equation for determining the power, spent on the destruction of crushed and pressed into the plate material between the main rolls of the PRA:

$$N_P = \frac{\sigma_P^2 S_0(\alpha_0)\cdot b\cdot \alpha_0}{2\cdot E\cdot \omega} \tag{11}$$

Thus, obtained analytical expression (11) makes it possible to determine the power expended on the deagglomeration of crushed and pressed material between the main rolls, taking into account the geometric dimensions of the rolls and the physico-mechanical characteristics of the material.

3. Conclusion

The proposed industrial technology and energy-saving equipment for the production of cement and composite binder can reduce the energy intensity of the process to 50%, due to the joint work of the press roller aggregate and rotor-vortex mill of ultrafine grinding. As a result, a synergistic effect is achieved in the mechano-activation of the raw mixture with the replacement of the part of the clinker component with a mineral hydro-active additive.

The new design of PRA with additional rolls allows combining the processes of material grinding by pressure and deagglomeration of pressed plates in the direction of their least strength, which leads to a reduction in energy costs. An analytical expression is obtained that allows one to determine the power required for the deagglomeration of the crushed and pressed material between the main rolls. Conducted comparative tests of cement samples obtained in energy-saving aggregates (PRA + RVM) made it possible to establish that their beam strength for compression and bending is higher by 15-20% than the traditional method in a ball mill. The use of this technology and equipment allows one to increase the production of cements and mineral binders with the use of local raw materials and to reduce costs, including transportation.

4. Acknowledgement

The article was prepared within the development program of the Flagship Regional University on the basis of Belgorod State Technological University named after V.G. Shoukhov, using equipment of High Technology Center at BSTU named after V.G. Shoukhov

References

[1] Romanovich A A 2011 Investigation of the process of the pre-compacting of anisotropic materials in a press roller grinder *Bulletin of BSTU named after V.G. Shukhov* **1** 56–60
[2] Manukhina O A, Sycheva S E 2017 Composite materials - as the basis of the effectiveness of the construction of buildings *Economics and entrepreneurship* **4-2** 928-933
[3] Pol'skoy P P, Mailyan D R 2012 Composite materials - as the basis of efficiency in the construction and reconstruction of buildings and structures *Engineering journal of don*. **23** 162-165
[4] Romanovich M A, Yevtushenko E I, Romanovich L G and Ospischev P I 2012 State support for innovative entrepreneurship of young scientists on the basis of Russian universities and Belgorod region *Bulletin of BSTU named after V.G. Shukhov* **2** 117-120
[5] Bogdanov V S 2008 Optimization of the grinding process in the production of cement *Intern. congress of cement manufacturers 9-12 October 2008 Belgorod State Technological University named after V.G. Shoukhov* 20-39
[6] Romanovich A A, Glagolev S N, Romanovich M A and Babaevskiy A N 2016 The method of computing the efforts of preconsolidation of materials in roll device *International Journal of Pharmacy & Technology* **8** 25015 – 23
[7] Dias S 2004 Influence of druinq on concrete Sorptivitq *Cement and Concrete Research* **09** 102 – 126
[8] Jones M R 2003 Estimation of the filter content required to minimize voids ratio in conerete *Cement and Concrete Research* **02**
[9] Shonert K, Knobloch O 1986 Crushing cement on a roller grinder in bearing material *Zement-kalk gips* **37** 1-9
[10] Romanovich A A, Glagolev S N and Romanovich M A 2016 Technology for the producchion of nanomaterial with the use of traditional grinding equipment *International Journal of Pharmacy & Technology* 2016 **8** 25007 – 14
[11] Romanovich A A, Glagolev E S and Babaevskiy A N 2014 Technology binders using industrial waste *Bulletin of BSTU named after V.G. Shukhov* **5** 102-105