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Kinetics Of Mechanical Activation During The Manufacturing Process Of Nanostructured Binders

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Abstract. Presented article is of interest to specialists in the field of building materials. The provided information describes nanostructured binders (NB) that are promising in the production of building materials for various purposes. As a result of conducted researches the character of hardening kinetics of NB with different composition was identified, which is similar to the classic representative of binding system – Portland cement. The importance of keeping the technological and temporal parameters of NB receipt by comparing it with a quartz suspension was substantiated. Also a system for monitoring the grinding process allowing to control and manage the technology was provided.

Introduction.

Currently, in the Russian Federation much attention is paid for improving energy efficiency and in this regard this aspect of research is included in one of the priority areas of science, technology and engineering.

In building materials science energy-saving problems are also finding solutions. It is known that cement industry uses highly fuel- and energy-intensive technologies. Therefore, new clinker-free binders, which include nanostructured binders (NB) of polymerization-condensation hardening type are actual [1, 2]. Current binder is useful as a main binding component or as a modifying additive for building materials of broad functionality [3, 4, 5].

Production of NB is a complex technological process of wet grinding of silica-containing raw materials in a ball mill with uralite lining that undergoes with heat generation. Grinding of ultrafine materials is accompanied with the destruction of the crystal latitude and splitting of siloxane bond. On the surface of silicates O_2Si_2-O_3Si_3- ions are formed, which can later be active centers of the combination reaction [6].

Main part.

A necessary criterion of milling is the control of the following parameters: the system dispersion, pH of the medium and temperature. To perform intermediate control we are forced to interrupt the process of mechanical activation that affects the quality of the final product and complicates binder production process.

Currently available methods for optimizing grinding technologies adapted to nonstop grinding materials. In this connection it is important develop a monitoring system of NB manufacturing to reduce the energy and labor costs.

The proposed monitoring system analyzes the noise produced by the grinding machine, can reduce the technological process and identify its intensity in real time. During the in-place test the correlation dependence between the level of noise and the intensity of grinding was found, which determines the efficiency of grinding material at the outlet of the mill at steady noise state, and then grinding efficiency decreases (Fig. 1).

According to the research results we can say that in inefficient mode grinding efficiency mill's is extremely low, and it is reasonable to increase the allowable ranges of variation of particles dispersion.

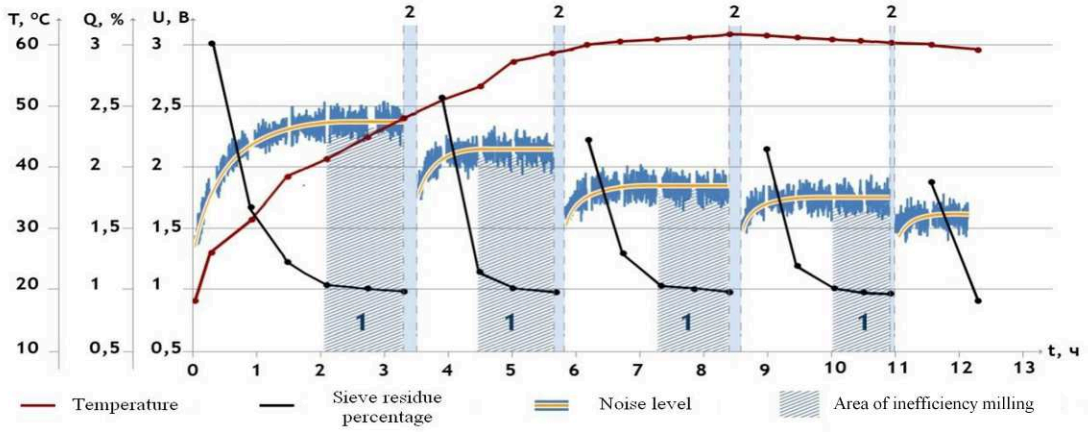

Fig. 1 – Correlation between the weight fraction of particles larger than 66 microns and noise: 1 – Ineffective grinding mode; 2 – During additional loading of materials[1]

Monitoring of the NB production process on the basis of acoustic noise can be represented as a scheme composed of hardware (microphone, amplifier, ADC (analog-to- digital converter)) and software components (algorithms, carrying out an analysis of acoustic signals' recorded fragments) (Fig. 2).

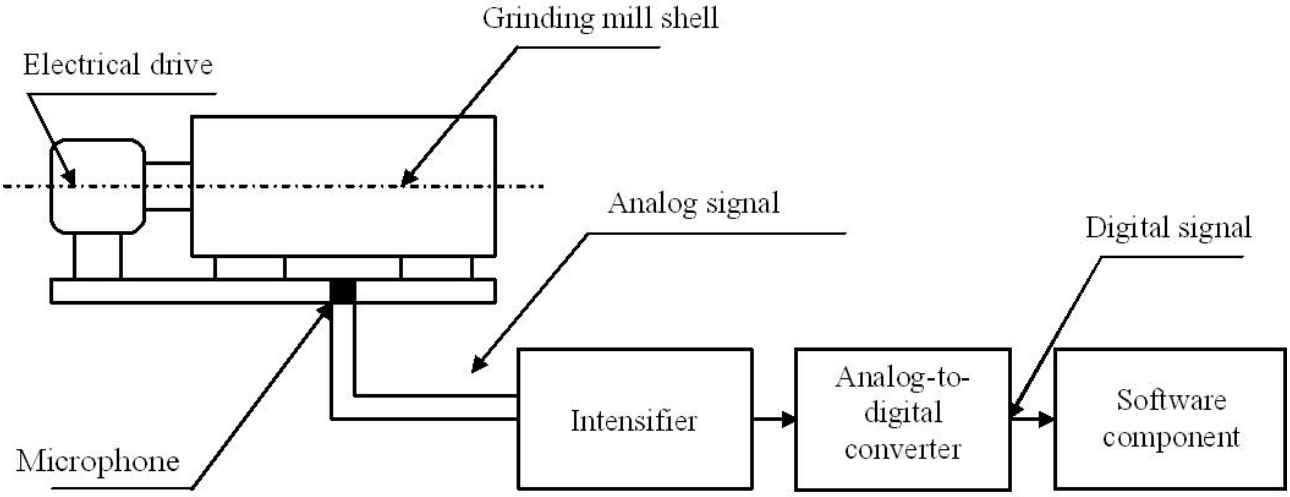

Fig. 2 – Block diagram of the monitoring of NB production process

Aim of this system is the primary conversion of the acoustic signal of mill into electric, its intensification, conversion to a digital form and sending via the data network. The program consists of two main parts – server and client. The server part is responsible for the exchange of information with the controllers, the client – for project planning and visualization [7].

The program performs the following functions:

- displays the current values and a diagram of noise time change;
- saving the measurement results in the database;
- export data to other applications;
- generation of reports.

[1] T, ºC – temperature of the material during grinding; U, V – the noise level of the mill; Q,% – the number of particles larger than 66 microns

System of monitoring and decision support in NB production process based on the analysis of noise emitted by the mill, allows to regulate the kinetics of binder obtainment on the basis of a different raw materials and manage the production technology of NB.

The proposed control system performs an important condition – strict observance of technological and time modes. In order to justify this hypothesis and confirm the prospect of its application, a comparative analysis of the cellular material on the basis of NB and silica suspension was made. Quartz suspension represents the initial product of NB obtained by wet grinding of quartz-containing materials in a ball mill not the entire cycle, but only for 4 hours and without subsequent stabilization.

Quartz suspension has slightly exhibited binding properties, which is caused by nonobservance of technological nuances in production of NB. In turn, low polydispersity level and low concentration of nanoparticles in the system provoke insufficient activity of binding system, layering, weak aggregate stability and increase of setting time of binders and composites based on it.

Application of NB as the main binding component in the manufacture of cellular composites promotes formation of a homogeneous pore structure, reduced porosity of interporous septum due to the presence of nano-dispersed particles.

Determination of particle size distribution of these two systems was performed on a laser particle analyzer «MicroSizer» model 201C. The study revealed the percentage of particles divided on 40 fractions from 0.2 to 600 microns. In quartz suspension basic particle size distribution is in the range of 1-50 microns, and in NB – from 0.75 to 33 microns. Presence of particles greater than 90 microns is not observed in NB, while in the quartz suspension the maximum fraction is in the range up to 220 microns. Fairly wide variation of available fractions percentage in NB helps to create an effect of micro-filler.

Microstructure analysis allows to prove the benefits of applying NB in comparison with quartz suspension and determines the prospects of the use in the production of cellular materials where NB is considered as the main binding system. In this regard, further stydy is possible by comparison with the classical binding system – portland cement.

It is known that the concrete under normal conditions over time gradually gaining brand strength, so for the first 3 days the strength gain is 30 %, for 7–14 days – 60–80 %, up to 28 days – 100%, for 90 days – 120 % . But this is not the limit, and subsequently when accessing moisture concrete will slowly continue to gain strength.

Similarly it is expected to examine the kinetics of hardening of nanostructured binder over time. For research NB on the basis of quartz sand and granite was used. Basic physical and mechanical characteristics of the binders are shown in Table 1.

Table 1. Physical and mechanical characteristics of NB with different composition

Material	Humidity, %	The average density, kg/m^3	Residue on the sieve № 063, %
NB on quartz sand	23,63	1927,5	0,18
NB on granit	22,53	1925,4	0,16

To study the strength properties of binders test beams with size of 4×4×16 cm were formed, which then had bending and compression-tests on 3rd, 7th and 28th day after the forming (Fig. 3).

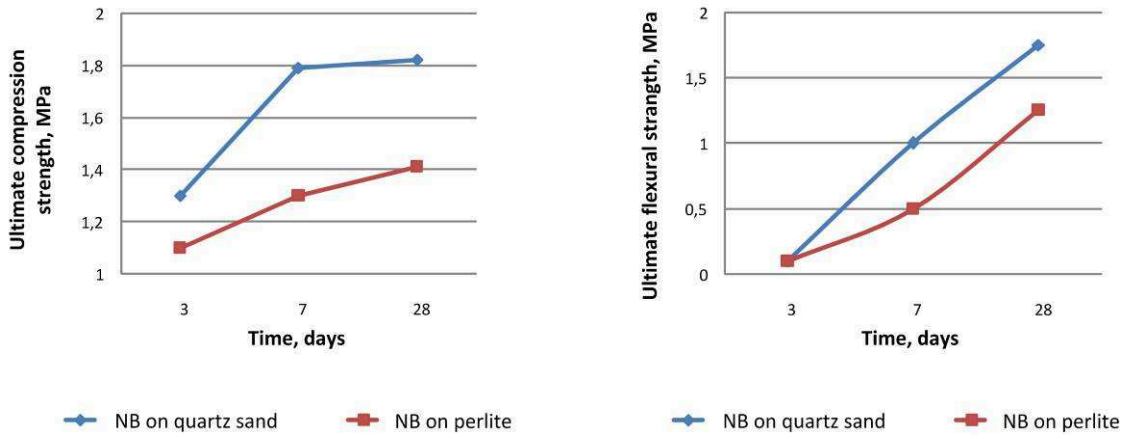

Fig. 3 – Strength characteristics of nanostructured binders: a) Compression; b) Bending

The graphs show that the kinetics of nanostructured binders hardening is similar to portland cement binders. The main strength characteristics of quartz NB are formed during 3–7 days, but hardening of binders continues further until day 28. At the same time the strength properties of NB of aluminosilicate composition are steady increasing within 28 days. The analysis of results suggests that after 28 days the samples of binder continue to gain strength, but with an extremely low velocity.

Cnclusion.

Studies of NB with various compositions made it possible to determine the kinetics of hardening, to identify the features of the technology of production of binder and justify the need for their keeping. NB is a promising alternative to cementitious system and is applicable for materials of wide functionality.

Summary.

Application of NB manufacturing technology in the production of various building materials will allow to create a competitive product that meets all modern requirements of construction with improved technical performance and thermal characteristics; reduce the cost of production due to energy-saving technology and application of the available resource base.

Acknowledgments.

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