Effective ways of molding man-made materials

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Abstract. The article is devoted to the development of multifunctional technological complexes for obtaining highly dispersed activated materials, including fast-hardening microfibrated composite mixtures. Special attention is paid to the development of conditions for their effective homogenization and the molding technology of various charges. Presented experimental design, aimed at improving the process of forming man-made mixtures. A low-tonnage technological complex for the utilization of technogenic materials with various physical-mechanical properties was developed. The urgency of the development of techniques and technology for the utilization of man-made materials by means of compaction when creating new high-tech industries is shown.

Keywords: technological complex, microfibration, composite mixtures, extrusion, granulation, additives.

1. Introduction
At the present stage of development of science and technology, one should hardly expect any "breakthroughs" in any industry of the industry using traditional technologies and physical methods of influence on the processed material. New discoveries can occur only with non-standard approaches to the object under study, often at the junction of various areas of knowledge. All of this, first of all, concerns such large-scale industries, which determine the economic and production potential of the country, such as the building materials industry, the mining industry and the metallurgical industry, the chemical, fuel, etc.

In this regard, a very promising direction of research is the study of the mechanism of interaction of particles at the submicroscopic level, which also determines new properties of composite materials [1–4].

2. Development of a multifunctional technological complex
Production of highly dispersed activated materials (including fast-hardening microfibrated composite mixtures), the development of conditions for their effective homogenization, the technology of molding various charges is a complex multi-faceted task that can be solved by creating multifunctional technological complexes (MTC) [5–11].
Taking into account the above factors, we developed and created MTC for obtaining highly activated materials with subsequent (if necessary) extrusion into granules of a given shape and size (figure 1,a,b).

Figure 1. Multifunctional technological complex for the extrusion of mechanically activated materials: a – with the disintegrating activator; b – with the mechanical activation of additives in the vortex-acoustic dispersant.

The technological complex (figure 1, a, b) consists of the following equipment:
1-receiving hopper of raw materials components; 2-elevator; 3-way gate; 4-hopper components; 5-cell feeders; 6-screw conveyor; 7-receiving hopper of grinding-mixing complex; 8-disintegrator activator; 9-supplement receiving bin; 10-press roller shredder; 11-belt conveyor; 12-screw feeder; 13-vortex acoustic disperser; 14-separator dust collector; 15-cell feeder; 16-screw conveyor; 17-bin mixer; 18-receiving hopper of mixing-extrusion complex; 19-additives hopper; 20-vertical screw; 21-binder dispenser; 22-fluidized bed mixer; 23-press roller extruder; 24-drying unit; 25-weight dispenser; 26-warehouse of finished products; 27-motor vehicles.

The technological complex (figure 1, a) includes the following redistribution:
I – receiving and dosing department; II – crushing and mixing unit; III – block for the homogenization and extrusion of the moistened charge; IV – drying department of granules with their classification; V – unit of weight dosing and packing of granules; VI – department of warehousing and shipment of finished products.

In addition, the technological complex contains aggregates for the production of highly activated additives (figure 1, b): press roller crusher 10, vortex-acoustic dispersant 13, separator 14.

The technological complex can function both in a straightforward scheme “a” and using highly activated additives - scheme “a – b”.

The most crucial unit of the MTC is the technological complex for the extrusion of materials (figures 2, 3). The complex works as follows:
Prepared charge for the molding, consisting of finely crushed materials, is fed into the receiving hopper 1 of mixture.
Highly activated additives are loaded into a receiving bin 2, equipped with a metering device. The original mixture with additives vertical screw feeder 3 is fed to the mixer 4 fluidized bed, equipped with a metering device 5 binder.
The moistened and homogenized mixture is uniformly fed into the press-roller extruder (PRE) 6 [12–16], consisting of a screw prehardening device 7 and the roller granulator 8.

Each of the units of the technological complex (screw feeder, mixer, press-roller extruder) has an individual drive and the following technical characteristics (table 1).

The PRE contains a screw prehardening device with a conical shaft (\(D_{av} = 85 \cdot 10^{-3} m\)), a taper of \(K = 0.01\) and an adjustable preloading unit, as well as a roll granulator with the following characteristics:

- The outer diameter of the drum (press matrix) \(D_{dr} = 450 \cdot 10^{-3} m\);
- Drum width – \(B_{dr} = 120 \cdot 10^{-3} m\);
- The drum wall thickness – \(b = 15 \cdot 10^{-3} m\);
- The number of holes in the drum – \(Z_{hole} = 1080\) pcs;
- The number of pressing rolls – \(Z_r = 2\) pcs;
- Roll diameter – \(D_r = 140 \cdot 10^{-3} m\);
- Roll width – \(B_r = 75 \cdot 10^{-3} m\);
- Roll rotational speed – \(n_r = 90\) rpm.

| № | Technical characteristics of technological complex units | Values of technical characteristics of units of the technological complex |
|---|----------------------------------------------------------|-------------------------------------------------------------------|
| 1 | Installed power of the electric drive, kW              | 1,5                                                                 |
| 2 | The frequency of rotation of the working body, rpm     | 400                                                                 |
| 3 | Screw pitch \(10^{-3}\) m                              | 60                                                                 |
| 4 | The angle of the blades of the mixer shaft, deg.       | 35 prehardenermana                                             |

The humidity of the formation of the charge is determined by its physical-mechanical characteristics (dispersion, plasticity, etc.) and mineralogical composition [17–20].

![Figure 2. Technological complex for extruding materials: 1-receiving hopper of the initial mixture; 2-receiving hopper of finely ground additives; 3-vertical screw feeder; 4-fluidized bed mixer; 5-metering device binder; 6-press roller extruder; 7-screw prehardening device; 8-roll granulator.](image)

The technological complex developed by us (figure 1) has a multifunctional purpose and can be used to perform various tasks:

- Produce highly dispersed materials in the manufacture of dry building mixtures;
Getting quick-hardening composite mixes using microfibers;

- Production of highly activated additives for various technological purposes;
- Getting highly activated cement-sand mortars with additives for the production of heat-insulating materials (foam blocks, shaped products, etc.)
- Production of extruded materials of various technological purposes (fillers for the reinforcement of foam blocks, Na-bentonite for waterproofing underground structures, calcium-containing organic fertilizers, granulated animal feed, etc.).

**Figure 3.** Press-roller extruder.

For compacting materials by the pressing method, a press-roll unit of stepwise compaction was developed, equipped with a device for prehardening of the charge (figure 4 a, b). This invention provides: at the 1st stage pre-compaction with elastic rollers to remove the gaseous phase from loose, low-flow materials and squeezing excess moisture from moisture saturated pressing rollers with giving the compressed bodies a given geometric shape and size. [21–25].

**Figure 4.** Press roller unit of stepwise consolidation and briquettes produced on it. the scheme of the press-roller unit, b) the resulting briquettes
We have developed effective methods of forming man-made materials and aggregates for their implementation, which can be used in the disposal of a wide range of powdered, viscoplastic and moisture saturated materials used in various industries.

Our complex design, technological, theoretical and experimental studies of the units developed at the level of inventions confirmed their efficiency and operational reliability.

The units can be used both in standalone mode and as part of energy-saving technological complexes for solving various high-tech technological problems.

Taking into account the results of experimental studies and the developed technological regulations for the process of utilization of man-made raw materials, we have designed and manufactured a technological complex for the production of various building materials and products based on them.

![Technological complex for the production of composite building materials](image)

**Figure 5.** Technological complex for the production of composite building materials: 1 - vehicles with powdered binder; 2 - elevator; 3 - hopper with powdered binder; 4 - vortex dispersant; 5 - a combined action separator; 6, 11, 14 - screw feeders; 7 - pneumatic transport; 8 - hopper with fiber filling; 9 - hopper with additives; 10 - hopper with material; 12 - centrifugal grinding and mixing unit; 13 - rotary circulation mixer; 15 - warehouse of man-made fibrous materials; 16 - percussion unit; 17 - hopper with a liquid binder; 18 - mixer-homogenizer; 19 - paddle mixer; 20 - ejection spray installation; 21 - vibropress; 22 - press roller unit; 23 - press roller extruder.

The developed technological complex has a multifunctional purpose and allows to solve issues related both to the utilization of man-made materials and the receipt of new types of building materials based on the developed composite mixtures.

Disposal methods include both the production of various types of molded products from man-made materials (figure 5, position 21, 22, 23) and the implementation of other technological operations: the production of thermal insulation coatings, etc. (figure 3, position 20 a, b, c).

3. Conclusion
In this way, our research and design and technological developments allowed us to create technological complexes that ensure the utilization of powdered and viscous-plastic man-made materials with different physical and mechanical properties, and the production of new types of building materials and products. The developed equipment and technologies for utilization of man-made materials can be used both at existing enterprises of the building materials industry and when creating new high-tech industries.

Multifunctional technological complexes, which include the main stages of various production of building materials industry (dosing, grinding, mixing, molding, drying, etc.) are a good material and
technical base of practice for students and graduate students, conducting research and development, the integration of creative thought university scientists from various departments (technologists, mechanics, specialists in electric drives and automated control systems, ecologists, economists, etc.), as well as real-life production Competitive products business facility.

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References
[1] Rybiev I A 2002 Stroitel’noe materialovedenie [Construction Materials] (Moscow:Vy’sshaya shkola) [In Russian]
[2] Poluxina L M and Barambojm N K 1993 Mexanoximicheskaya aktivaciya polimerov pri dispergirovaniem. Texnologicheskie problemy’ izmel’chenii i mexanoaktivacii [Mechanochemical activation of polymers during dispersion. Technological problems of grinding and mechanical activation] Materialy’ nauchno-tekhnicheskogo seminara stran sodruzhestva. Mogilev pp 171-78 [In Russian]
[3] Sevostyanov V S, Shestakov V L, Dubinin N N and Sevostyanov M V 2010 Processy’ v proizvodstve stroitel’ny’x materialov [Processes in the production of building materials] (Belgorod: BGTU im. V.G.Shukhova) [In Russian]
[4] Glagolev S N, Sevostyanov V S, Ilyina T N and Uralskii V I 2011 Production modules for combined reprocessing of technogenic materials Chemical and Petroleum Engineering 46(9) 556-9
[5] Sivachenko L A, Sevostyanov V S and Il’ina T N 2018 Problem Tasks in the Field of Resource and Energy Saving Technologies J. Phys.: Conf. Ser. 1066 012021
[6] Laskorin B I, Barsky L A and Persits B Z 1984 Bezotxodnaya tekhnologiya pererabotki mineral’nyx sy’r`ya. Sistemny`j analiz [Waste-free technology of mineral processing. System analysis] (Moscow: Nedra) [In Russian]
[7] Lvov V V 2013 Novye’ tehnologii v tonkom i sverxtonkom izmel’chenii mineral’nyx sy’r`ya. Zapiski Gornogo instituta [New technologies in fine and ultra-fine grinding of mineral raw materials. Notes of the Mining Institute.] vol 202 pp 115-7 [In Russian]
[8] Gridchin A M, Sevostyanov V S, Lesovik V S, GlaGolev S N, Sevostyanov M V and Funikov I M 2007 Texnologicheskie kompleksy’ dlya proizvodstva porizovanny`x zapolnitelej iz texnogenny`x materialov [Technological complexes for the production of porous aggregates from technogenic materials] Izvestiya vy`sshix uchebny`x zavedenij. stroitel`stvo 7 pp 22-8 [In Russian]
[9] Glagolev S N, Sevostyanov V S, Gridchin A M, Uralsky V I, Sevostyanov M V and Yadykina V V 2013 Resuro-e’nergosberegayushhie moduli dlya kompleksnoy´ utilizacii texnogenny`x materialov [Resource-energy-saving modules for the integrated recycling of man-made materials] Vestnik BGTU im. V.G.Shukhova 6 pp 102-6 [In Russian]
[10] Sevostyanov M V, Il’ina T N, Kuznetsova I A, Osokin A V and Martakov I G 2016 Resursosberegayushhij texnologicheski kompleks dlya proizvodstva granulirovanny`x stabiliziruyushshixx dobavok shhebenochno-masticnogo asfal`tobetona [Resource-saving technological complex for the production of granular stabilizing additives of crushed stone-mastic asphalt concrete] Vestnik Tambovskogo gosudarstvennogo texnicheskogo universiteta vol 22 pp 272 – 9 [In Russian]
[11] Sevostyanov V S, Shatalov A V, Sevostyanov M V, Krutov V S and Shatalov V A 2018 Technics and Technology of Processing Basalt Waste J. Phys.: Conf. Ser. 1066 012027
[12] Gridchin A M, Sevostyanov V S, Lesovik V S and Sevostyanov M V 2002 Press-rollonyy ekstruder [Press-roll extruder] Patent RF No 2207247 [In Russian]
[13] Sevostyanov M V, Dubinin N N 2003 Konstruktivno-tekhnologicheskoe sovershenstvovanie press-valkovy`x e`kstruderov [Design and technological improvement of press-roll extruders] Sovremennye tehnologii v prony`shlennosti stroitel`ny`x materialov i industrii: Sh. stud. dokl. Mezhdunarodnogo kongressa (Belgorod: BGTU im. V.G.Shukhova) 3 pp 31-5 [In Russian]

[14] Sevostyanov V S, Goryagin P Yu, Obolonsky V V and Ermilov R A 2018 Resource-Saving Technological Complex for Polymer Waste Processing J. Phys.: Conf. Ser. 1066 012025

[15] Sevostyanov M V, Il`ina T N, Uvarov V A and Shinkarev L I 2015 Sposoby` kompaktirovaniya texnogenny`x materialov i texnicheskie sredstva dlya ix realizacii [Ways of compacting man-made materials and technical means for their implementation] Vestnik BGTU im. V.G.Shuxova 2 pp 107-11 [In Russian]

[16] Gridchin A M, Sevostianov V S, Lesovik V S and Sevostyanov M V 2003 Mnogotselevoy granulyator [Multipurpose granulator] Svidetel'stvo RF na poleznuyu model` No 30244 [In Russian]

[17] Sevostyanov M V, Sevostyanov V S and Martakov I G 2018 Analysis of Design Features of Circulating Action Mixers J. Phys.: Conf. Ser. 1066 012002

[18] Gridchin A M, Sevostyanov V S, Lesovik V S, Gorlov A S, Perelygin D N, Romanovich A A and Kolesnikov A V 2006 E`nergo-resursosberegayushhie kompleksy` tonkого i sverxtonkogo izmel`cheniya materialov [Energy-saving complexes of fine and ultrafine grinding of materials] Izvestiya vy`sshix uchebny`x zavedeniy. Stroitel`stvo 11-12 pp 60-8 [In Russian]

[19] Kravchenko V P 2010 Aktivaciya domenny`x shlakov [Activation of blast furnace slag] Vestnik Priazovskogo derzhavnogo texnicheskogo univer-siteta. Texnicheskie nauki 2 pp 17-20 [In Russian]

[20] Il`ina T N 2009 Processy` aglomeracii v tehnologiyax pererabotki dispersny`x materialov [Agglomeration processes in the processing technologies of dispersed materials] (Belgorod: BSTU V G Shukhova) [In Russian]

[21] Sevostyanov V S, Goryagin P Y, Sevostyanov M V and Ermilov R A 2018 Constructive and Technological Features of Units for Milling Polymer Material J. Phys.: Conf. Ser. 1066 012006

[22] Sevostyanov V S, Sverguzova S V, Sevostyanov M V, Spirin M N, Shinkarev L I and Fetisov D D 2011 Press-valkovy`j agregat dlya formovaniya texnogenny`x materialov s maloy nas'y`nnoj massoj [Press-roll unit for the formation of man-made materials with a low bulk weight] Sb. dokl. IV Mezhdunar. nauch.-prakt. konf. «E`kologiya – obrazovanie, nauka, prony`shlennost` i zdrov`e» (Belgorod: BGTU im. V.G.Shukhova) pp 125-30 [In Russian]

[23] Il`yna T N, Sevostyanov V S, Uralskii V I, Sevostyanov M V and Shkarpetkin E A 2010 Research, design, calculations, and operating experience. Processes and equipment for chemical and oil-gas production: Mechanism of stagewise polydispersed material granulation Chemical and Petroleum Engineering 46(3) 193-200

[24] Sevostyanov V S, Sverguzova S V, Sevostyanov M V, Spirin M N, Shinkarev L I and Fetisov D D 2012 Teknika i tehnologiyax briketirovaniya poroshkoobrazny`x i vyazkoplasticchny`x texnogenny`x materialov [Technique and technology of briquetting powdery and viscous-plastic man-made materials] (Vestnik BGTU im. V.G.Shuxova) 3 pp 87-90 [In Russian]

[25] Sevostyanov M V, Sevostyanov V S, Shinkarev L I and Malkov A V 2012 Izuchenie processa dvizheniya skorost`ny`x potokov shihvy`x iz pityavyshhix ustrojstv val`cevogo pressa [Studying the process of movement of high-speed flows of the charge from the feeding devices of a roller press] Mezhvuz. sb. nauch. statej ITOM BGTU im. V.G. Shuxova «E`nergosberegayushhie tehnologicheskie kompleksy` i obrudovanie dlya proizvodstva stroitel`ny`x materialov» (Belgorod: BGTU im. V.G.Shukhova) pp 322-8 [In Russian]