Efficiency of granulation of production fibrous wastes due to their precompression

M.V. Sevostyanov*, *A.V.* Osokin and *A.M.* Protsenko

Department of Technological Complexes, Machines and Mechanisms, Belgorod State Technological University named after V.G. Shukhov (BSTU named after V. G. Shukhov), 46 Kostyukova Str., Belgorod, 308012, Russia

Abstract. The paper presents scientific and technical developments to solve the environmental problems of recycling fibrous waste from various industries. The efficiency of creating and using devices for precompression of fibrous materials before extruding them in a plane-shaped granulator was proven. Mixing, precompression and microgranulation are used to form technogenic fibrous wastes. These processes are implemented in specially designed patent-protected devices.

1 Introduction

The transition to new technologies, the growth of production volumes, as well as the growth of environmental problems attach particular importance to the careful and rational use of natural resources. Ever more attention is paid to the problem of storage, recycling and disposal of industrial waste. The most promising is their involvement in the technological process with the appropriate rational use of natural materials. At the same time, technogenic fibrous wastes (TFW) with a low bulk density are particularly difficult to process.

So, with the increase in the volume of road construction and the use of crushed stone-mastic bitumen-concrete mixtures (SMBCM), the study of the compression of fibrous materials is becoming ever more relevant. This is caused by the fact that to date the stabilizing additives for SMBCM are produced mainly from cellulose-based fibrous materials. Moreover, most often they are produced in extruded form, which simplifies the storage, transportation and introduction of additives in a mixture.

Until recently, the issues of extrusion of production fibrous waste were mainly addressed by agricultural industry when processing plant stems into compound feed. With the increase in the need for granular stabilizing additives (GSA) for the construction of road surfaces, the industry of building materials began to deal with the granulation of fibrous materials.

Belgorod State Technological University named after V.G. Shukhov developed and put into operation a production line for extruding fibrous waste from pulp and paper production [1]. This line is designed to produce import-substituting granular stabilizing additives of crushed stone-mastic bitumen concrete.

The main production process of GSA (extrusion of pellets) was carried out on a flat-matrix granulator GR-425 with 3 rotating rolls at their circumferential speed relative to the surface of the flat die υ_b = 0.785 m/s and a rotation speed n = 90 rpm. Press matrix diameter $d_м$ = 425 · 10^{-3} m; die diameter $d_ф$ = 5 · 10^{-3} m; width of rolls $B_{вал}$ = 120 · 10^{-3} m. Dimensions of obtained granules: $d \times l$ = (5 × 5 ÷10) · 10^{-3} m, density of granules $\rho_{гр}$ = 700 kg/m^3, bulk density of granules layer $\rho_{сл.гр.}$ = 600 kg/m^3. The extruder capacity was 150–200 kg/h. The temperature of the resulting pellets was T_1 = 80–90°C. Pellet cooling and classification (extraction of spillage after extrusion) were carried out in a drum-screw drying unit – cooler. The temperature of the cooled pellets was T_2 = 35–40°C [1].

The initial technogenic raw material was pulp and paper waste (PPW) from the production of multilayer corrugated board of MS-5B grade. PPW dimensions: $l \times b$ = (50÷70×100÷150) · 10^{-3} m, thickness δ = (5÷10)·10^{-3} m.

When tested as a SMBCM stabilizing additive, the resulting granules SA-BK and SA-K had the following composition:

SA-BK: crushed pulp and paper waste (fiber length ≤ 2 mm) cardboard/ paper 1:1 not less than – 80%, liquid organic binder not less than 15%, liquid plasticizing component – not more than 5%.

SA-K: crushed PPW (fiber length ≤ 2 mm) cardboard – not less than 80%, liquid organic binder – not less than 15%, liquid plasticizing component – not more than 5% [1].

However, the process of granulating fibrous materials for the GSA production (for example, finely ground paper waste and waste paper) has its own characteristic features. The degree of compression of fibrous materials $\lambda_{упл}$ during molding (compression) can reach $\lambda_{упл}$ ~ 15 (increase in the density of the mixture – from ρ_0 = 50 kg/m^3 to $\rho_{гр}$ = 750 kg/m^3). In the agricultural industry, in the production of mixed feed, $\lambda_{упл}$ can reach 5–8 [2, 3]. The degree of compression of bulk powdered materials during extrusion is usually 1.5÷4 [4].

* Corresponding author: msev31@mail.ru

It is very difficult to achieve such a compression degree of typical molding units. For example, with a single compression of combined feed mixtures in closed press channels $\lambda_{упл}$ = 2.0...2.5 [2]. Besides, this process will require high energy costs.

2 Problem Statement

An important aspect in solving the problem of forming fibrous materials is the staging of the precompression process. The scientific and technological developments aimed at rational combination of the processes of processing materials in one unit make it possible to achieve the compactness of the equipment and technological granulation line, which significantly reduces the metal consumption and energy capacity of production.

The purpose of the present paper is to study the process of preliminary compression of technogenic fibrous wastes for subsequent formation of the feedstock in a granulator with a flat matrix.

3 Materials and Methods

The analysis of the main directions of structural and technological improvement of flat-matrix press-roller units [5] showed that in granulators that process powdered and fibrous materials with a low bulk density (ρ_0 > 250 kg/m^2) an additional granulation stage is most often included in order to increase process efficiency. The expression of the average speed of material propulsion (rate of extrusion of granules) through the holes of the die: $v'_{пр} = H \cdot (\rho_0/\rho_{гр}) \cdot z_{п.в} \cdot n_в$, where H – height of the layer of material before pressing into the die, (m); ρ_0 – initial density of the material (feedstock), (kg/m^3); $\rho_{гр}$ – density of the material after granulation, (kg/m^3); $z_{п.в}$ – number of press rolls, (pcs); $n_в$ – speed of the carrier (drive shaft), (c^{-1}), shows that $v'_{пр}$ is directly proportional to the initial density of the material ρ_0, namely, the higher the initial density, the higher the speed and, accordingly, the higher the productivity of the machine.

Precompression is traditionally understood as the treatment of the starting material (feedstock, paste) by pressure before the main molding process (granulation, briquetting, pressing, rolling, etc.). In the case of processing technogenic fibrous waste, precompression should mean the preparation of the starting material for molding, in which the batch either increases its initial density ρ_0 or improves its rheological properties necessary for a particular molding process, sometimes these actions are combined. In this way, the efficiency of the TFW forming process can be improved.

Technogenic fibrous waste will be understood as materials based on fibers of natural origin (mainly cellulose fibers) with a different range of their geometric sizes (lengths).

Based on numerous experiments on TFW granulation, it was found that in the case of processing finely divided paper waste with an initial density ρ_0 = 50 ± 20 kg/m^3, the following options for their preliminary compression are allowed before extrusion in granulators with a flat matrix (Fig. 1).

Precompression by mixing is implemented in devices of various designs. The mixture is compressed due to the formation of local coagulation centers when the following reagents are introduced into the mixer working chamber, which improve plastic properties of the mixture: steam, oil, liquefied paraffin, bitumen or bitumen mastic. The quality of compression of the mixture depends on the method and quality of introduction of the binder component.

The conducted experimental studies on the mixing of finely ground paper waste in turbulent mixers of horizontal and vertical type made it possible to determine that the best way to introduce a plasticizer into the mixture is to spray it in the working chamber of the mixer. This method implies that the local sealing centers are formed in the form of droplets with fibers adhered to them. During subsequent granulation, the plasticizer is squeezed out, evenly "wetting" the batch in the squeezing zone, gives it viscous-plastic properties, ensures adhesion of the portion layers during squeezing.

The drip injection turned out to be ineffective, since most of the injected plasticizer adhered to the working organs of the machine.

As an example, a horizontal mixer developed at the Department of Technological Complexes, Machines and Mechanisms (DTCMM) of BSTU named after V.G. Shukhov can be used for this process [7].

Additional grinding is prevented due to the complete destruction of fibers, which leads to a decrease in specific volume (with simultaneous increase in specific surface area). This happens, as shown in [8], due to an increase in the milling time. The reduced length of the obtained fibers reduces the internal friction of the feedstock (f_0) and contributes to better pressing of the material through the press matrix.

It is possible to increase the milling time, for example, by two-stage milling. For this purpose rotor-centrifugal grinder, hammer crusher or other grinding device of similar operating principle is installed behind main grinding device.

Precompression by rolling is aimed at obtaining some conglomerates from the initial feedstock – intermediate granules, for example, spherical or oval. Such a product would improve the uniformity of the material feed into the granulation chamber.

An example of a machine implementing this process is a granulator of fibrous materials [9] developed with the participation of authors at the DTCMM of BSTU named after V.G. Shukhov.

The combined method is most often implemented, since it is rather difficult to create only one type of effect on the material to solve the precompression problems. A device in which mixing and rolling of material is realized is a pneumatic mechanical device for microgranulation of dispersed materials developed at the Department of heat and gas supply and ventilation and the Department of Technological Complexes, Machines and Mechanisms of BSTU named after V.G. Shukhov [10] (Fig. 2).

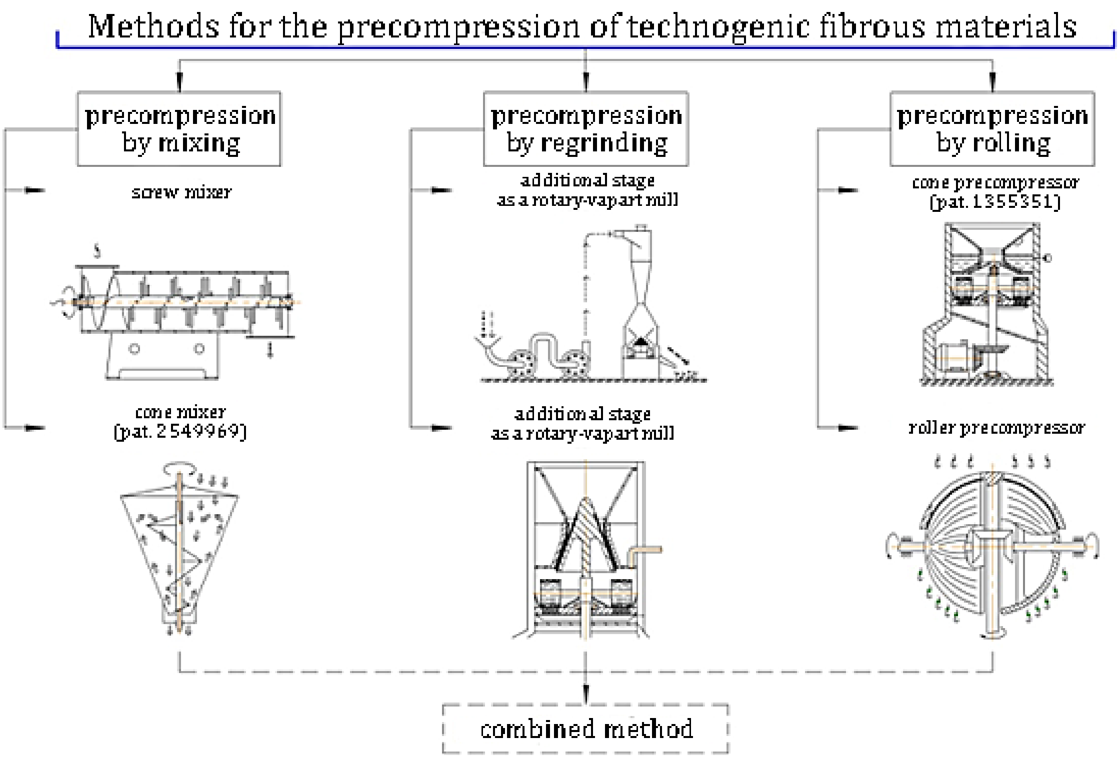

Fig. 1. Methods for precompression of finely divided paper waste prior to extrusion

Its simple design and the combination of several successive stages of material compression in one unit, as well as the creation of material recycling, increase the operating efficiency and improve pelletizer productivity. It is possible to use different technogenic materials with low bulk density and different structure. Intensive and more uniform mixing of components at the unit inlet is provided.

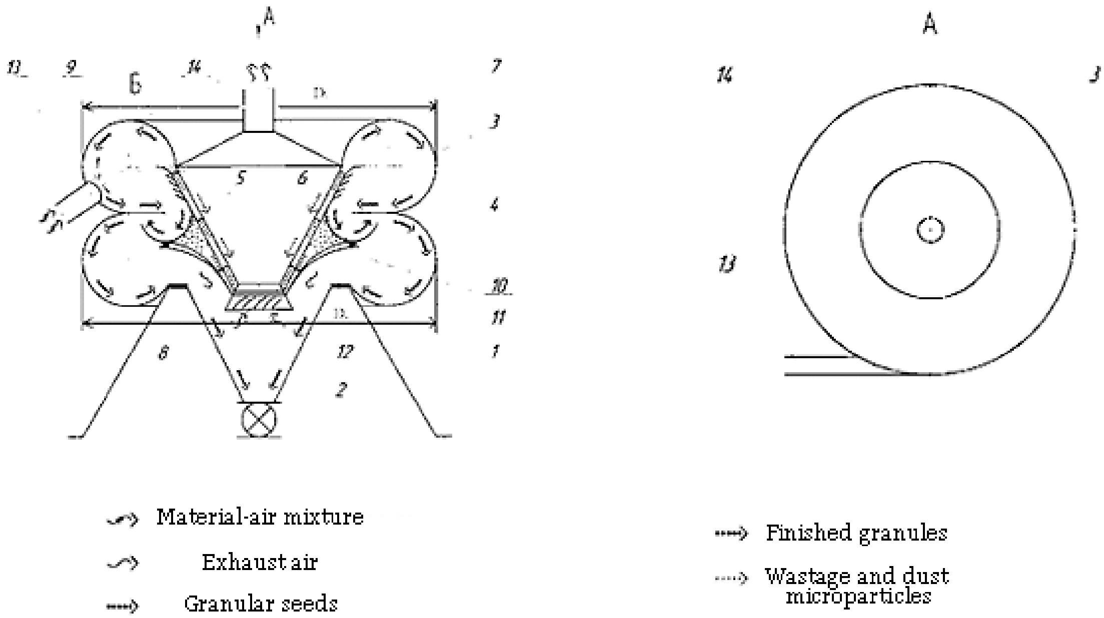

Fig. 2. Pneumatic mechanical device for microgranulation of dispersed materials: 1 – vertical housing, 2 – unloading hopper, 3, 4 – upper and lower torus-shaped chambers, 5 – truncated cone with double walls, 6 – annular cavity, 7 – louver-shaped slit-shaped holes, 8 – inlet hole, 9 – spiral-shaped plates, 10 – plates, 11 – spring-loaded plates, 12 – truncated cone-steam receiver, 13 – inlet branch pipe, 14 – exhaust pipe.

4 Results and Discussion

The studies aimed at establishing effective principles of compression of various technogenic fibrous and powdered wastes with low bulk density in a granulator with a flat matrix revealed the need for preliminary compression of the feedstock. To find a rational method of precompression, their most effective options were classified. These methods confirmed the rationality of precompression using the example of finely divided paper waste. Specific technical means for effective precompression of technogenic feedstock with low bulk density depending on molding conditions were identified. The operating principle of the devices for material precompression is indicated.

5 Conclusion

Thus, the theoretical and experimental studies of the compression processes of technogenic fibrous and powdered materials with low bulk density made it possible to identify general regularities of their compression, which formed the basis for the development of recommendations for the design of special equipment.

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