Studying the Flax Fibers Grinding Modes

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Abstract. Successful development of road-construction machinery requires continuous improvement of existing and the introduction of new materials in the production of machine parts that would satisfy the requirements of reliability and process automation. Development prospects in this area are largely related to the use of polymer composite materials. The production of machine parts from polymer composite materials based on various types of binders containing dispersed and fibrous fillers is of a great interest to researchers. The tendency to replace metal parts with the ones made of polymer composite materials happens due to both economic and social factors. Polymeric composite materials consist of two or more components that differ in chemical composition, physical and mechanical characteristics. The main purpose of the filler is reinforcement, i.e. hardening of the material and imparting the required special properties, for example containing fibrous fillers. We took natural flax as fibrous filler in experimental studies. The paper attempts to study the intensity and quality of the grinding technological process depending on the time and frequency of rotation of the mechanism, the factors that influence it, the relationships and the laws of the technological grinding process in drum-type mixers, and increasing the efficiency of grinding material, reducing dynamic stresses.

Key words: flax, grinding, nanoscale, polymer composite material, fibers, machine parts.

1 Introduction

Nowadays, polymer composite materials (PCM) are widely used in mechanical engineering in the production and repair of transport, construction, communal machines parts, as well as in construction sphere. To create PCM with desired properties, we need various organic additives. Technological methods for the production of machine parts from PCM based on various types of binders containing dispersed and fibrous fillers are of interest to researchers. We chose natural flax a the material for experimental studies. Grinding is widely used in the construction industry for the preparation of materials of different fractions and sizes. The processes of crushing, grinding and screening are widely used in industrial activities and economy [1,2,3].

The aim of the study is to examine the intensity and quality of the technological process of grinding material - flax, depending on the time and frequency of rotation, the existing factors, relationships and patterns of the technological process of grinding in drum mixers; to study the increasing efficiency of grinding material and reducing dynamic tension. Grinding is the process of mechanical division of the processed product into parts in order to improve its technological use. Grinding is based on the action of forces seeking to overcome the adhesion forces between the particles, resulting in the formation of new surfaces. Mechanical grinding of the material leads to an increase in the surface of solids by crushing, splitting, abrasion, and impact. Grinding can be simple and selective. With simple grinding, the product is destroyed by passing through the grinding device once, and with selective grinding (usually multiple), particles of a certain substance are extracted, and the process is carried out sequentially. The main criteria for evaluating the effectiveness of the grinding process of any solids are: the degree of grinding, which is defined as the ratio of the total surface of the product particles after grinding to the total surface of the particles of the original product, the specific energy consumption of the process and the specific load on the working body of the grinding machine [4,5,6].

2 Materials and methods

Planning an experiment can dramatically increase the accuracy and reduce the amount of experimental research. It allows us to find the optimum function that characterizes the studied process. The process model is described by a regression equation, the coefficients of which are determined using special methods (for example, the least squares method). To search for the optimum, we can use various methods: gradient, gradientless, steep ascent and simplex. When planning the experiment, it is necessary to choose factors and determine: their influence on the output quantity, which of them can be set at the request of the experimenter, which ones are uncontrollable or random, the accuracy of the equipment with which the values of the variable factors are set and the output values are measured, whether the factors are independent or dependent values [7,8,9].

During experimental studies, the distribution of the particle time in the mixer was determined on the example of a four-link spatial mixer developed by a group of scientists B. V. Shitikov, P. G. Mudrov, A. G. Mudrov, M. G. Yarullin [10-13]. The experimental setup of the mixer is shown on Figure 1.

Fig. 1. The main elements of the experimental installation of the mixer are the mixer support, stand, electric motor, gearbox, four-link mechanism, mixing tank.

Since performance measurements at the outlet of the mixer by the standard measuring system are not provided, the measurement was carried out in a weighted way: by weighing on an electronic scale a portion of the material that left the mixer for a certain period of time. As model materials we used:

Material A. Flax technical, light brown - used as a building insulation and sealing material. (P = 200 g / m3, size 1x5mm);

Material B. Silite core (P = 3.21 g / cm3, size 20x20mm);

Material C. Cutters (tungsten);

Material D. Balls of bearings.

We carried out a preliminary series of experiments to explore the efficiency of the mixer’s grinding, which is one of its most important properties that determine the indicators of technological efficiency [14-17]. It is obvious that it depends on the rotation speed, rotation time, their size and shape, on the filling volume of the mixing tank, as well as on the physicomechanical properties of the material. The experiments were carried out in the following oreder. Using a frequency controller, the maximum parameter of which did not exceed 50 Hz, we established the speed of the mixer hopper. The hopper was pre-filled with a measuring cup with materials A and B. After filling the hopper according to certain loading parameters, we turned on the unit and mixed at the set time. After the time of the mixing experiment, the mixer stopped and the mixing tank was removed. Without removing the container from the sleeve, we performed sampling. The sampler works as follows. It is made in the form of a wedge to facilitate sampling in the mixture, and consists of two aluminum pipes of different diameters. The sampler has three cells for sampling from different levels of the mixture. A closed sampler was pushed to the bottom of the mixer tank. Then, rotating the knob on the cover for 360 degrees, the cells were filled with a loose mixture. Then the sampler was pulled out from the mixer tank and the contents of each cell were poured out in turn. After pouring the mixture onto a sieve, the sample was experimentally sieved.

A total of 24 experiments were conducted with various parameters of grinding factors. For each experiment, the mixing vessel was loaded with unmixed materials for the accuracy of the experiments. After receiving all the parameters, the data were processed in the Statistica.exe program and graphs were compiled.

Material characteristic:

Common flax belongs to the class of dicotyledonous plants and is one of the oldest plant crops. Long stalks, familiar to the eye, with small blue flowers, were first grown in ancient India and China. Today it is one of the most common crops in our country (grown mainly in central Russia). Flax seeds are used in medicine and cosmetology, fiber - in weaving and light industry. Fibers of technical flax have found application in the construction industry - they are used to weave a rope, and heaters and materials for hemp wooden houses. The combed flax has long enjoyed the well-deserved fame of one of the best sealants in plumbing. This type of compactor is a long plant fiber obtained in the process of combing shabby flax stems. Depending on the length of the fibers and their purity, all the used material is divided into grades. The technical characteristics of sanitary flax depend on its variety and must comply with GOST 10330-76. GOST 10330-76 governs the process of production, processing, and also sorting of flax used as a seal. Due to the resistance of the fibers, the plumbing flax cannot be destroyed by twisting the plumbing fixtures. Thin, long linen fibers are collected in the depths of the threaded channels and when connecting parts completely fill all the gaps and the slightest non-density. During further operation, the fibers closest to the wet area swell, thereby blocking the path for moisture to move out. Compounds sealed with plumbing flax can withstand temperatures up to 150 degrees Celsius.

Technical flax is a natural material that is completely harmless and even useful for our body. But the properties of flax fiber, however, are extraordinary. Flax contains wax, water, pectin and lignin. These substances give it the following characteristics: flax is hygroscopic (does not absorb water, but, on the contrary, quickly gives it away), has high tensile and bending strength, elastic, durable, not afraid of corrosion and bugs, not dangerous to our health, has beautiful ashen shade (Fig. 2).

Fig. 2. Technical flax

3 Results

The main task of the preliminary experiment is the selection of factors (factorial signs) and state variables (functional signs), which are then included in the plan of the main experiment. Based on a priori information, it divides the variables into input (factors), output (state parameters), and interference [18-20].

Table 1. Results of the preliminary experiment

Flax fibers - tungsten	Mixer operating time		
Filling volume	30 min	60 min	90 min
40%	20	15	15
60%	10	10	5
80%	5	2	1,5

Flax fibers - silite	Mixer operating time		
Filling volume	30 min	60 min	90 min
40%	45	40	35
60%	35	25	30
80%	30	20	15

Flax fibers - metal	Mixer operating time		
Filling volume	30 min	60 min	90 min
40%	40	25	15
60%	25	20	10
80%	15	5	2

The results of preliminary experiments show that the optimal filling volumes will be 60-80%, mixing time 60-90 minutes, the ratio of materials from 30-70%, and the current frequency at 40-50Hz.

Then we carried out the model experiments to study the process of grinding technical flax on an experimental setup. Bulk materials for experiments should be well separated when analyzing their content in the sample. The simplest method of material separation is separation using sieves, therefore, technical flax (average particle diameter 0.1 mm), bearing balls (diameter 20 mm) and a silicon core (diameter 20..25 mm) were used as components of the mixture. To control the quality of processes for obtaining the required sizes, instant sampling is required, i.e. samples characterizing the state of the material in time. Samples are taken over the entire volume of the mixer from the mixing chamber. The heterogeneity coefficient is determined by the component with the lowest total weight. A large number of samples provides fairly accurate results.

When processing the results of the main experiment in the Statistica.exe software environment by the simplex method, we obtained the regression equations:

$$V_C = \frac{100}{\bar{C}}\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(c_i-\bar{c})^2}$$

Table 2. The results of measurements of grinding

№ п/п	Name of parameter				
	t, min	V, m^3	A,%	n, Hz	Size, nm
1	30	80	30/70	40	5
2	60	80	30/70	40	10
3	90	80	40/60	40	20
4	30	80	50/50	50	300
5	60	80	30/70	50	25
6	90	60	50/50	50	10
7	30	60	60/40	30	5
8	60	70	70/30	30	20
9	90	80	30/70	30	20
10	30	80	20/80	50	3
11	60	80	40/60	30	50
12	90	80	40/60	20	30
13	30	60	40/60	10	50
14	60	70	40/60	50	10
15	90	60	40/60	50	20
16	30	60	50/50	20	5
17	60	70	30/70	30	10
I8	90	70	30/70	30	20
19	30	80	30/70	30	35
20	60	70	30/70	30	25
21	90	70	70/30	30	10
22	30	70	50/50	30	15
23	60	70	30/70	40	15
24	90	70	30/70	20	15

Tests were made in six different cases. In the first, the ratio of materials is 70/30, in the second 30/70, in the third 40/60, in the fourth 60/40, in the fifth 50/50 and in the sixth 20/80. Basically, the study has 24 experiments, where in each experiment, a sample was taken 3 times. All research data are presented in the table 2. The distribution of experiments was carried out according to the plan for 4 Boxing factors. The results are processed in Statistica.exe.

Figure 4 shows samples of ground flax material using a Carl Zeiss AxioSkop 40 electron microscope.

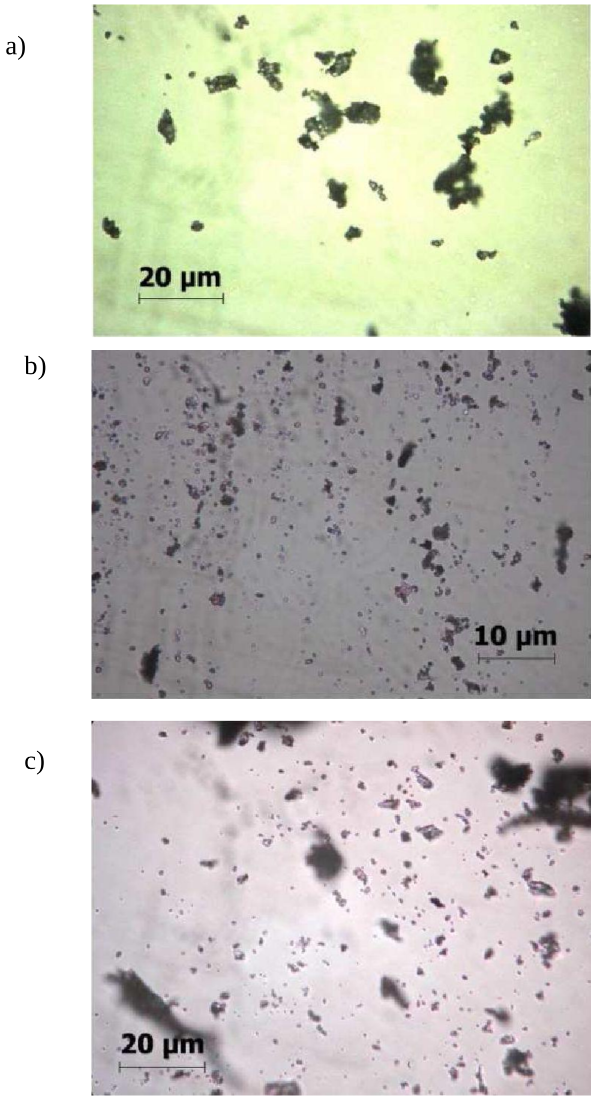

Fig. 3. Grinded flax under the microscope a) Flax – metal balls, b) flax - tungsten, c) flax - silite core.

The following are the results of experimental studies with a grinding time of 60 minutes:

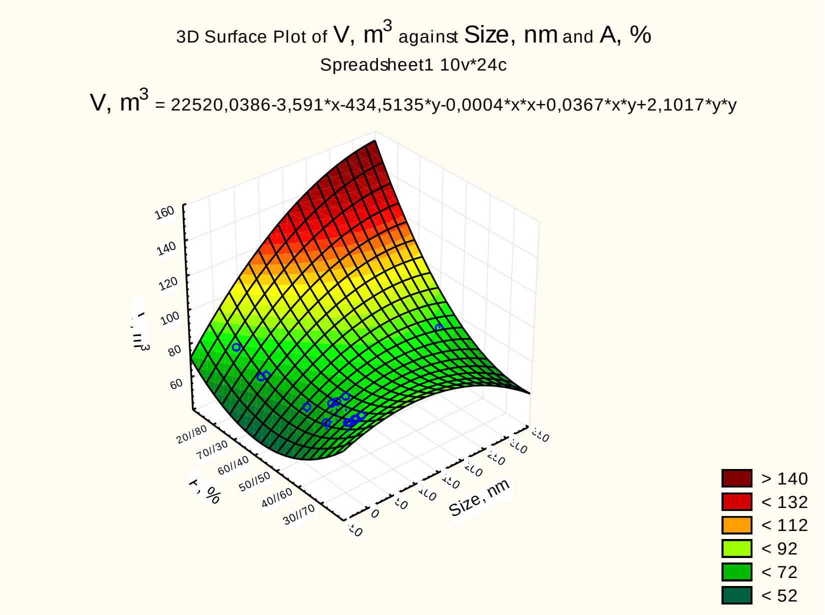

Fig. 4. The effect of filling volume and the ratio of the volume of materials on particle sizes

This graph (Fig. 4) shows the dependence of particle sizes on time and the ratio of the volumes of materials at a grinding time of 60 minutes. The regression equation has the following form:

V= 22520,0386 – 3,591*x – 434,5135*y - 0,0004*x*x + 0,0367*x*y + 2,1017*y*y.

Analyzing the graph, we can see that the optimum ratio of grinding volumes is 20/80%, the grinding quality improves with a further decrease in the filling of the mixer drum.

The following graph (Fig. 5) shows a two-dimensional dependence of the ratio of the material on the volume of filling. The regression equation has the following form:

V=178,3828 - 1,0396*x.

The graph shows that with a decrease in the filling volume, the volume of the crushed material decreases. With a decrease in the filling volume by 10%, the volume of the crushed material decreases by 10%, respectively, the grinding quality increases. The optimal ratio of volumes on schedule is 20/80%.

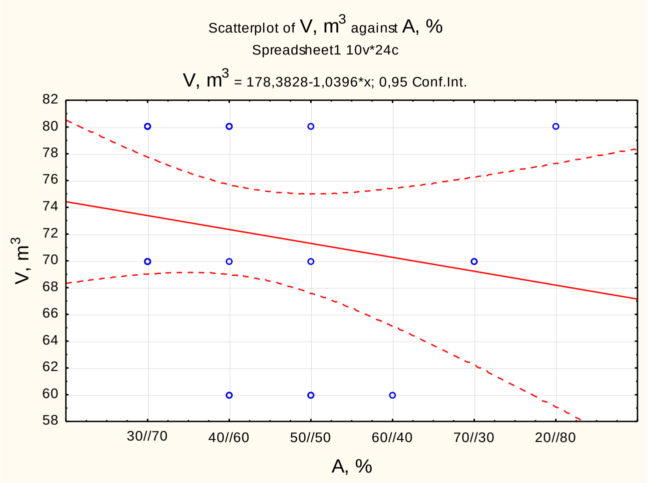

Fig. 5. Influence of the filling volume and the ratio of the volumes of materials on the grinding process

The following are the results of experimental studies when grinding materials at a current frequency of 50 Hz.

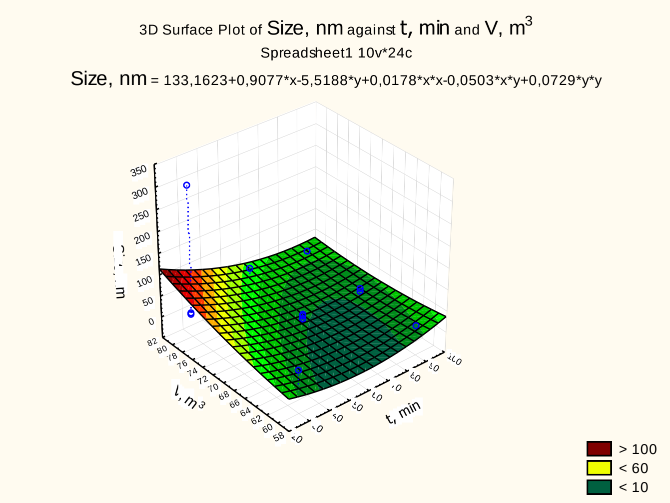

Fig. 6. The effect of filling volume and grinding time of materials on particle sizes

This graph (Fig. 6) shows the dependence of particle size on time and volume at a current frequency of 50 Hz.

The regression equation has the form:

Size, nm =133,1623 + 0,9077*x – 5.5188*y + 0,0178*x*x - 0,0503*x*y + 0,0729*y*y.

Analyzing the graph, we can see that the optimal filling volume is 80%, the grinding quality improves with a further increase in time of 60 ... 90 min.

The following graph (Fig. 7) shows a two-dimensional dependence of particle size on grinding time. The regression equation has the form:

Size, nm = 64,4583 – 0,5687*x

The change in particle size decreases with increasing grinding time, with increasing time from 30 to 60 minutes, the grinding of particles decreases by 50%, from 60 to 90 minutes by another 25%, the optimal crushing time is 60-90 minutes.

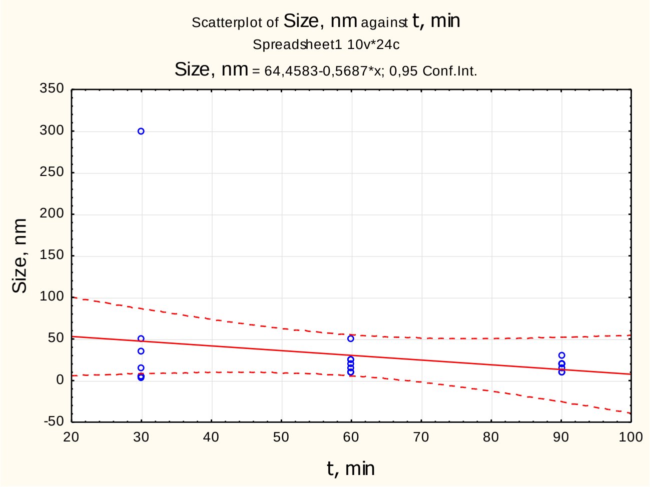

Fig. 7. The effect of grinding time and particle size on the grinding process

The following are the results of experimental studies of grinding materials with a filling volume of 80%.

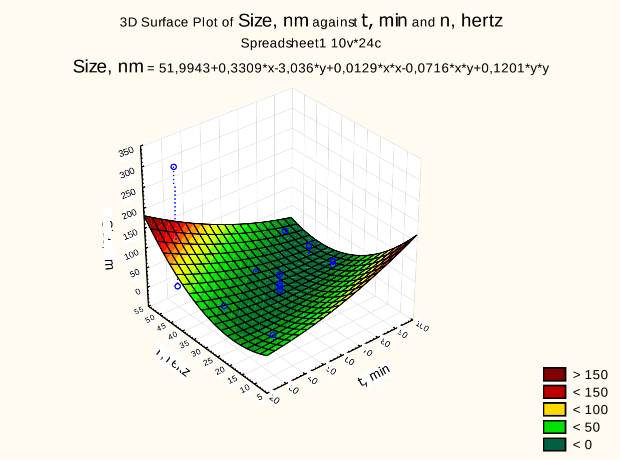

Fig. 8. Effect of rotational speed and material grinding time on particle sizes

This graph (Fig. 8) shows the dependence of particle sizes on time and frequency, with a ratio of materials of 20/80%.

The regression equation has the form:

Size, nm = 51,9943 + 0,3309*x - 3,036*y + 0,0129*x*x - 0,0716*x*y + 0,1201*y*y.

Analyzing the graph, we can see that the optimal rotation speed is at a current frequency of 45 ... 50 Hz, the grinding quality improves with a further increase in time of 60 ... 90 minutes.

4 Conclusion

Thus, when considering the process of flax fibers grinding, we determined the most important characteristics of the grinding devices. We examined the structure and kinematics of four-link mechanisms with rotational pairs, which have a wide range of properties used in various fields of technology and which are a module for the formation of multi-link spatial mechanisms of this group.

Analyzing the results of studies of the grinding process of materials in a single-drum planetary type mixer, we considered the influence of crushing time, filling volume, and rotation speed of the grinding device. It turned out that increasing the speed, increasing the time of rotation of the working bodies, as well as changing the volume of the hopper and the ratio of materials and the concentration of the key component as a whole, leads to an increase in the grinding coefficient of the flax material to the required nanoscale series.

The nanoscale samples of crushed flax obtained as a result of experimental studies were put into installations for the creation of polymer composite materials in the form of fibrous fillers for further comparative studies of the properties of new materials.

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