

Features of process of preliminary grind of cellulose-containing materials

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Abstract. In the real work, features of technological process of preliminary grind of cellulose-containing materials raw materials are analysed and features of the existing technologies are considered. The expediency of use for grind of cellulose raw materials by a without knife way of influence by hydrodynamic cavitation in the electromechanical transformer with a discrete secondary part is presented.

1 Introduction

Great interest to cellulose fiber is explained by its ability under external influence to be dispersed in water, forming a nanodisperse system with particles up to 2000 nanometres long and no more than 60 nanometres thick. With growth of interest in the field, all new relevant and perspective researches of production and synthesis of composite materials on the basis of cellulose raw materials, with unique utilization properties appear. Influence on cellulose-containing materials raw materials of different physical and chemical power influences leads to formation of cellulose particles which in turn depending on a type of initial raw materials and a way processing can differ both in the sizes, and geometrical characteristics and are described in scientific literature as microfibrillary cellulose, microcrystalline cellulose and nan cellulose.

In these conditions rates of development of the industries dependent on cellulose production, including, such as chemical, electrotechnical, machine-building and others depend on level existing technologies of cellulose production. In our country there are all necessary conditions for pulp and paper industry development: huge forest and energy resources, the powerful system of the rivers and lakes with large reserves of water and also sufficient machine-building base for production of the paper-making equipment.

2 Main part

Today there is a set of works in which different techniques of selection of crystals of cellulose from different cellulose-containing materials are offered: enzymatic [1], acid hydrolysis by different mineral acids [2], hydrolysis with sulfuric acid [3]. But not less important and labor-intensive process is grind of cellulose-containing materials. Grind is

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one of the main methods of preparation of cellulose-containing materials in the course of which there is forming of properties of fibers. The grinding devices of different type are most often used to grind of cellulose in industrial conditions.

Shortening of fibers not basic purpose of process of grind. Splitting of fibers in the longitudinal direction on the thinnest fibrils fibrilla is in most cases more important [3]. At the same time significant increase in an outer surface of fibers leads to increase in a role of the phenomena occurring on this surface: adsorptions of the water accompanied with increase in fibers and increase in their flexibility; to creation of conditions for establishment between fibers of communications.

Mechanical impacts on fibers in the course of grind are shown in the cabin of fibers, their crush, combing with department of bunches of fibrilla and education on the surface of fibers of a peculiar pile from separate fibrilla (external fibrillation) [4].

Thus, the main goal of grind consists in preparation of a surface of cellulose fibers for formation of interfiber forces of communications, giving to fibers of ability to communicate among themselves. It is reached by partial destruction and removal of outside cellular walls, increase in flexibility and plasticity of fibers due to easing and the strengthened swelling of cellulose fiber on the surface of fibrilla [5].

Mills as the grinding device widely are used that is confirmed in the published results of scientific works of the last years [6,7]. Grind of weight happens between case walls the rotating disk to the knives having a smooth surface.

A number of authors [8,9] studied process of grind on disk mills at low concentration of weight (3-6%). Recently disk mills are used for receiving the microfibrillated and nanofibrillated cellulose [10-13]. However, energy consumption of such process very big because of need of repeated transmission of weight through disks of a mill [14]. Receiving nanofibrillyarny cellulose was carried out only after 30 passes through a mill, according to the data published in work [15].

Operation of cavitation devices is based on the principle of formation of gaps in a fluid flow due to discharge, emergence of steam-gas bubbles, their growth and the subsequent sharp collapse with formation of micro streams, a powerful shock wave and temperature increase.

According to authors [16], initial destructive speeds of micro streams already at distance of two initial diameters of a stream decrease twice. Therefore the bulk of cellulose fibers receives elastic deformation and destruction of fiber has the fatigue character which is expressed in increase in quantity of capillaries in fibers or internal fibrillation that leads to improvement of swelling, flexibility and elasticity of the last and finally to improvement of quality of a ready leaf. For example, after additional cavitation processing of weight from deciduous breeds of wood significant increase in strength indices, especially during an initial stage of processing was noted.

According to a number of researchers [18], the destroying impact of cavitation processing is a consequence of blows of high-speed micro streams and impulses of pressure of the bubbles arising at short circuit. Repeated impact of shock waves on material leads to emergence in it fatigue stresses, and then and deformations. In view of the fact that the range of micro streams is small, they render effective effort to fiber only at a collapse of bubbles in close proximity to a surface.

The main operating part of devices of this type are the kavitator of different configurations set permanently in a flow of suspension or fixed to the rotating shaft in the form of plates of a trapetsiyedalny form, turned big the basis towards rotation. For gain of effect kontrkavitator can be installed in the camera.

Power expenses of this way of processing of fiber still considerable. Despite good strength characteristics of castings from weight not only coniferous, but also deciduous breeds of wood, it was not widely used in the industry.

For reduction in cost of receiving nanocellulose process of impact of hydrodynamic cavitation in the electromechanical transformer with a discrete secondary part is offered. The main operating part of devices of this type is the big set of the small ferromagnetic elements representing the working secondary discrete part moving under the influence of an outside electromagnetic field.

Power expenses of this way very insignificant and caused only by power costs of movement of elements on the set trajectory depending on an algorithm of switching of phases of the inductor.

In the electromechanical transformer with a discrete secondary part each ferromagnetic body in the liquid environment in volume of an electromagnetic field is affected by a complex of forces forcing to make their heavy traffic with frequent change of speed and the direction. Among forces having the main impact it is possible to select gravity force, centrifugal force, Coriolis force, electromagnetic effort, hydrodynamic forces, from movement processed the liquid environment. This complex of forces causes intensive movement of ferromagnetic elements with a large number of degrees of freedom and creates conditions for emergence of a large number of power influences. A complex of forces providing processing of liquid raw materials: a magnetostriction, friction of particles, local temperature increase, the acoustic waves arising under the influence of a magnetostriction, electrolysis, cavitation processes.

For definition of a source of effective processing of raw materials for a short period, it is necessary to carry out the analysis of each power influence separately.

The movement of ferromagnetic elements first is characterized by big accelerations that leads to emergence of the most important phenomenon in process to processing, mechanical crushing and hashing of raw materials collision and friction of elements. According to some researches, considering the size of unit ferromagnetic element and traverse speed in volume of the working chamber, the substance, which is between two elements, is exposed at the time of their collision to pressure in 300 MPas.

Among a set of the created power influences in terms of a possibility of implementation of technological process of grind there are cellulose, cavitation is most interesting to the analysis. In liquid, understand process of education in a fluid flow of cavities (bubbles, cavities) filled with gas because of local pressure reduction as cavitation.

It should be noted that distinguish the acoustic cavitation arising when passing through liquid of acoustic vibrations, and the hydrodynamic cavitation arising due to local pressure reduction in a fluid flow at flow of a solid body.

In the electromechanical transformer with a discrete secondary part two types of cavitation are created at the same time: acoustic and hydrodynamic for which definition of advantages it is necessary to treat each look apart.

The electromagnetic field has significant effect on the ferromagnetic elements placed in the working chamber of the device, forcing them to be remagnetized at the movement and change of polarity, initiating the magnetostriction phenomenon. Under the influence of a magnetostriction, the sizes of ferromagnetic elements change with high frequency that inevitably leads to emergence of acoustic waves of broad range from tens of hertz to several tens megahertz. However only acoustic waves of ultrasonic range over 20 kHz contribute significantly to activation of processes of cavitation. Existence of effect of a magnetostriction allows to use acoustic cavitation without use of the cavitating generators in the form of piezoelements or other vibrating systems. The ferromagnetic elements located during work on all volume of the processed raw materials allow to solve a problem in the form of attenuation of ultrasonic waves in the large volume of the raw materials of high viscosity, thus, strengthening a supersonic way grind off. Acoustic vibrations of ultrasonic range split bunches of fibers at their insignificant shortening. The mechanism of impact on fiber has fatigue character here.

The most important power influence is the hydrodynamic cavitation caused by flow of ferromagnetic elements with the liquid environment. Heavy traffic of ferromagnetic elements under the influence of the rotating electromagnetic field is followed by constant change of the directions. Between the fluid flows moving along ferromagnetic elements in opposite directions there are zones of reduced pressure in which cavities (cavitation bubbles) filled with steam of the processed raw materials, which then collapse at hit in a zone of big pressure form.

The overall picture of formation of a cavitation bubble is presented in the following form. In a depression phase in liquid the gap in the form of a cavity, which is filled, with saturated steam of liquid is formed. In a compression phase under the influence of the elevated pressure and forces of surface tension the cavity collapses. The considerable effect of cavitation processes is connected with high concentration of the energy emitted in the course of collapse in the processed environment. At the time of collapse, pressure and temperature of gas reach considerable values, and according to some information reach 100 MPas and 1000 °C respectively. The small volume of substance explains this phenomenon at the time of achievement by a bubble of the minimum radius preceding collapse. Relying on results of scientific research, it is possible to claim that the radius of a cavitation bubble at the time of collapse can reach, as a rule, 10^{-7} - 10^{-8} m, against radius in an equilibrium status of 10^{-10} - 10^{-6} m. The change of volume of a cavitation bubble reaching the 1000th values leads to achievement of high values of stored energy. It is known that cavitation "germ" receives the maximum radius of R_{max} in a depression phase (acoustic wave, the movement of a ferromagnetic element along a fluid flow). The R_{max} value considerably exceeds the minimum radius of R_{min} preceding collapse process. As a result, the equation of the energy reserved in a cavitation bubble can be written in the following look:

$$W = \frac{4}{3} \pi R_{max}^2 \cdot P_0 \quad (1)$$

where, – pressure of surrounding liquid, Pa; – energy, J.

The destroying impact of cavitation processing is a consequence of blows of high-speed microstreams and impulses of pressure of the bubbles arising at short circuit. Repeated impact of shock waves on material leads to emergence in it fatigue stresses, and then and deformations. In view of the fact that the range of microstreams is small, they render effective effort to fiber only at a zakhlopyvaniye of bubbles in close proximity to a surface.

The bulk of cellulose fibers receives elastic deformation and destruction of fiber has the fatigue character which is expressed in increase in quantity of capillaries in fibers or internal fibrillation that leads to improvement of swelling, flexibility and elasticity of the last and finally to improvement of quality.

The research of samples after cavitation processing revealed good fibrillation of a surface of fibers. Their ends were subject to the greatest processing. Also It should be noted lack of deep destructions of fibers, increase in flexibility and plasticity that is important for receiving high physicommechanical rates.

It should be noted that drying of the received cellulose can become one of shortcomings of this system. Drying of the received microfibrillated cellulose demands big energy costs and worsens its properties. Breakdown of suspension under big pressure through an opening of very small diameter comparable with fiber sizes, will entail local dehydration of cellulose, poor performance and big specific power consumption on grind.

3 Conclusion

The electromechanical transformer with a discrete secondary part can be used for cellulose grind process implementation by hydrodynamic cavitation. Thanks to intensive processing of suspension of cellulose the big set of ferromagnetic particles managed by an outside electromagnetic field suspension evenly on all volume is influenced by hydrodynamic cavitation. Crushing using hydrodynamic cavitation in this device well is suitable for grind of short-fibred cellulose, grind of weight from waste paper, for activation of fillers and their introduction to paper stock. Processing of cellulose with use of the electromechanical transformer with a discrete secondary part is an effective, inexpensive, convenient way.

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