Hydrodynamics of cotton stalks filtration drying

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Waste from agriculture and industry can serve as a renewable source of raw materials for the production of building materials suitable for use in building structures, as fillers for composite wood-plastic panels and for the production of biofuel pellets. Increasing their usage will not only provide the industry with additional raw materials and expand the range of building materials and products, but also contribute to the preservation and rational use of natural materials, which is an important environmental task.

Keywords –cotton stalks (guza-pie), filtration drying, hydrodynamics, composite materials.

Introduction

Every year the world generates a large amount of plant waste after processing cereals and cotton, in particular from 500 thousand tons of cotton stalks about 70% is used inefficiently. At the same time, cotton stalks (guza-pie) can be used for the production of fuel briquettes, as a filler for energy-saving heat-insulating building materials, in particular arbolite composite products, etc.

Given that the cotton stalks after the annual harvest of cotton are stored in open areas, their humidity can reach more than 40%. Therefore, to use cotton stalks as an organic cellulose-containing raw material for the production of various products, they must be dried and grinded. Grinded cotton stalks are characterized by a large variety of physical and mechanical properties, including initial moisture content, amount of free and bound moisture, internal structural structure of particles, pore size and capillaries containing moisture, polydispersity and porosity of the stationary layer, which determine energy costs for drying. The processes of heat exchange between wet material and heat agent are limited by the low thermal conductivity of organic material, and mass transfer is limited by the intensity of moisture transfer from cells into the intercellular space and through micro and macropores into the heat agent. Thus, study of the laws of filtration drying of dispersed materials with plant origin will outline the optimal conditions and create a technology for preparing plant raw materials for use in wood-plastic panels and building materials, products and structures.

Abroad, wood is widely used as a substitute for filling composite wood-plastic materials and boards, flax stalks, pruning vines, hemp, kenaf and various types of straw. Currently, planches of plant residues are produced in Poland, France and several other countries. Planches from bagasse, sugar cane waste, are obtained in Cuba, the Philippines, Argentina, India, Brazil, Mexico, South Africa and other countries.

In this aspect, the development and production of composite wood-plastic board materials based on fillers from cotton stalks (guza-pie) and their implementation into production are of particular importance. The need for wood-plastic materials and boards at the expense of internal resources is provided that will allow to save valuable wood raw materials which have important ecological value.

Existing theoretical and experimental studies of filtration drying patterns: hydrodynamics, external and internal heat transfer, are insufficient to build clear theoretical dependences of process parameters on the physicochemical properties of guza-pie, so the aim is to develop energy-saving technology for production alternative composite materials from plant raw materials and its industrial implementation.

The aim of the work is a theoretical analysis and experimental study of the hydrodynamics of filtration of a heat agent through a stationary layer of guza-pie and presentation of the results of experimental studies in dimensionless form.

Experimental part

The first stage of the study of the filtration drying process is an experimental study of the hydrodynamics of heat agent filtration through the porous structure of the stationary layer of the guza-pie due to the pressure drop. The values of heat and mass transfer coefficients, as well as the thickness of hydrodynamic, heat and diffusion boundary layers, which in turn affect on the intensity of heat and mass transfer during filtration drying, depend on the filtration rate of the gas flow through the stationary layer of dispersed material.

The hydrodynamics of the stationary layer of the guza-pie was experimentally investigated according to the standard method. Changes in pressure losses were investigated in the layer of the guza-pie with a height of $60\text{-}160\cdot10^{-3}$ m. The results of experimental studies of pressure losses as a function of the fictitious rate of filtration of the heat agent through the stationary layer of the guza-pie are shown in Fig. 1.

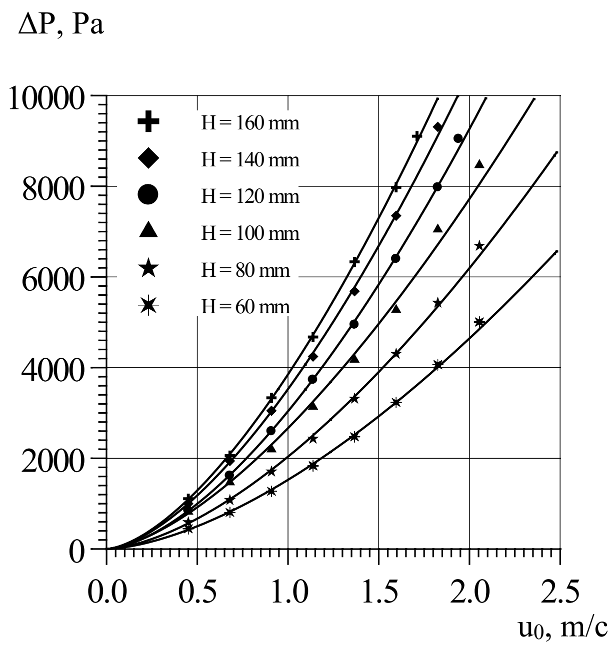

Fig.1 Dependence of pressure losses ΔP in the stationary layer of the guza-pie on the fictitious rate u_0 for different heights of the layer H

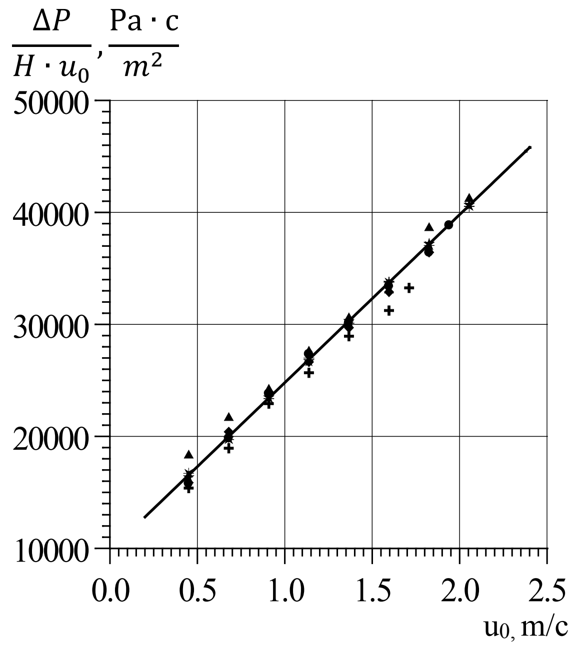

Fig. 2. Graphic dependence $\frac{\Delta P}{H\cdot u_0} = f(u_0)$ to determine the unknown coefficients A^* i B^* in the layer

As can be seen from fig. 1, with increasing height of the guza-pie layer the hydraulic resistance increases, and its value is relatively small, which is positive for the organization of the process of drying the guza-pie by the filtration method. It also should be noted that the dependence of pressure losses on the fictitious rate is parabolic, so the process is influenced by both inertial and viscous components.

To predict the pressure losses in the stationary layer of material in the technical literature is used a modified two-term Ergan equation, which is linearized relatively to the fictitious filtration rate of the gas flow in the form:

$$\frac{\Delta P}{Hu_0} = A^* + B^* \cdot u_0 \quad (1)$$

To determine the unknown coefficients A * and B *, the obtained experimental results of pressure losses in the guza-pie layer were presented in the form of the functional dependence ΔP /(H u_0), shown in fig. 2.

From the graphical dependence (fig. 2), the coefficient A * was determined by the segment intersecting the line on the ordinate axis, and the coefficient B * was determined by the tangent of the angle of inclination of the line to the abscissa axis. Therefore, having determined the unknown coefficients, equation (1) can be presented as follows for the dry layer of the guza-pie:

$$\frac{\Delta P}{Hu_0} = 9800 + 15000 \cdot u_0;$$

Conclusion

Thorough study of the physicochemical properties of grinded guza-pie and determination of optimal conditions for its preparation when used as fillers for composite wood-plastic materials and planches is an urgent task. The use of plant waste or the use of cheap plant raw materials will undoubtedly have a significant economic effect, supported by an effective method of filtration drying, which involves the usage in the technological scheme. The hydrodynamics of gas flow filtration through the stationary layer of the guza-pie was investigated and the unknown coefficients of the modified Ergan equation were determined.