Physics’ identification of formation process of wood polymer heat insulation material

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Abstract. The article presents and describes in detail the physical picture of the process of forming the created wood-polymer insulation material in vacuum. It is proved that the developed material is a multicomponent system in which wood particles form a strong adhesive bond with a polyurethane foam matrix, characterized by complex physical and chemical reactions that occur in the process of interaction of all components of the system. Since the process of forming polyurethane foam occurs in the presence of wood filler, its influence on the process of gas phase formation during polymer foaming was studied. The main technological parameters affecting the formation of strong intermolecular bonds and the interaction of the components of wood-polymer insulating material with each other are revealed. In particular, it was found that the process of polymerization of polyurethane foam in the presence of wood filler under vacuum allows one not to deform or destroy the gas-structural elements during their formation. Also, basing upon the results of experimental studies, the dependence of the influence of wood filler moisture on the process of structure formation of the created material was established.

1. Introduction

There are certain difficulties in the utilization of wood waste in Russia. Basically, wood waste is not even tried to be used in production, usually it's simply destroyed. This is due to the loss of the scientific base for the development of wood waste processing technologies, since the practice of using this raw material was not popular, and there was no need for such developments [1-4].

In connection with the increase in the volume of construction work on the construction of buildings and structures, the demand for new building materials, in particular heat-insulating materials, with improved operational properties and low cost price [5-8] is rapidly growing. Therefore, the most promising direction in the field of wood waste processing is the development of new and improvement of existing technologies for the production of thermal insulation materials based on wood waste. Creating a modern thermal insulation material based on wood waste will solve two main problems: first, to reduce the environmental impact by means of the processing of wood waste, and second, to
obtain a new thermal insulation material with high performance properties at a comparably low market value [9-13].

As a result of research and development work, wood-polymer insulating material was created, consisting of wood filler and polymer binder, namely polyurethane foam.

2. Study of problem
The studying of the physical model and structure of the created insulating material, created on the basis of wood filler and polymer binder, is necessary to fully understand the process of forming bonds and the interaction of the components of the wood-polymer system.

Polyurethane foam materials are inherently complex physical systems that are difficult to quantify. The spatial structure, shape and size of the gas-structural elements of the matrix [14-20] are the most important in these systems. With the introduction of wood filler, the macrostructure of polyurethane foam changes, as its properties respectively, since wood particles affect the processes occurring at all stages of the formation of polyurethane foam.

The created wood-polymer insulating material is a multicomponent system, characterized by physical chemical bonds between the components that make up the material. In the created system a wood particle is a polymeric binder, there are adhesive bonds formed by the interaction of materials of various natures [21-25]. The created wood-polymer system differs in physical mechanical and thermal physical indicators from the indicators of each component presented in this system, when considered separately.

In view of the fact that the process of forming polyurethane foam occurs in the presence of wood filler, it is necessary to study its influence on the process of nucleation of the gas phase during the foaming of the polymer. A diagram of the process of nucleation of gas-structural elements in the presence of wood filler is shown in figure 1.

![Diagram](image)

**Figure 1.** The process of nucleation of gas-structural elements in the presence of wood filler: 1 - liquid phase; 2 - wood particle; 3 - gas bubble; 4 - a bursting bubble of gas; a) the formation of bubbles with a gas in the presence of a filler; b) deformation of gas structural elements; c) polymer shrinkage.

As can be seen from fig. 1a, at the initial stage of gas bubble formation, a wood particle does not affect the process of formation of the gas phase. However, its immersion in a liquid medium is observed due to a larger specific gravity as compared with a polymer. This leads to the fact that with the further formation of new gas bubbles, their diffusion and an increase in size, the wood particle deforms and destroys the gas-structural elements due to its pressure on them (Figure 1b). As a result, when filled with wood particles, the density of the wood-polymer composition increases by reducing the formation of small pores in the presence of a filler, shrinkage of the polymer occurs during its formation (Figure 1c), and, as a result, the operational, in particular, thermal physical properties of the material deteriorate [26-31]. The use of wood particles as the main component during the filling of polyurethane foam makes it possible to preserve the strength properties that perform one of the main functions of the insulating material. Although the wood filler introduced into polyurethane foam
changes the parameters of the foaming process and, as a result, the macrostructure and properties of polyurethane foam. It is impossible to unambiguously assess the effect of wood filler as negative. It is assumed that the formation of wood-filled polyurethane foam under the vacuum condition will be accompanied by an improvement in the foaming process and an increase in the number of pores with a decrease in the density of the material. The process of initiation of gas-structural elements in the presence of wood filler under the vacuum condition is presented in the form of a diagram in figure 2.

The presence of rarefaction helps gas bubbles during their formation to keep the wood particle in an equilibrium state in the system (Figure 2a) due to the fact that the pressure in the bubble increases by the amount of vacuum created above the liquid polyurethane foam. Thus, the conditions, under which the wood particle is not able to deform and destroy the gas-structural elements during their formation, are created. The process of formation of the cellular structure takes place in conditions favorable to it, as can be seen from Figure 2b.

After the rise of foam ends and the formation of new gas bubbles ceases, the final stage of set up of polyurethane foam begins - the curing. At this stage, the final phase of cross-linking of the polymer cells occurs due to gas diffusion and curing of the material.

Since the process of formation of polyurethane foam is an exothermic reaction, the formation of a strong adhesive bond between the components will be prevented by the evaporation of moisture presented in the outer layer of wood particles, due to the increase in temperature as a result of the reaction. In order to study the effect of wood filler moisture on the process of structure formation of wood-polymer material, experimental studies were conducted on the basis of the laboratory of the Department of Processing Wood Materials FSBEI HE "KNITU".

The tensile strength of the samples was determined depending on the absolute moisture content of wood filler (Figure 3) at different concentrations of the components. It is revealed that the increase in the content of wood filler from 40 to 80% and humidity from 10 to 110% reduces the tensile strength.
of the obtained samples by an average of 40-50%. This confirms the assumption about the destruction of the boundary layer during the evaporation of free moisture in the outer layers of wood particles as a result of the exothermic reaction of the components of polyurethane foam.

It has been experimentally proved that in the process of evaporation of moisture presented in the outer layer of wood particles, gas formation is suppressed during the interaction of the components of the polyol and the polyisocyanate. This fact leads to the formation of fragile walls of polyurethane foam cells, which are destroyed during foaming. Therefore, the boundary layer between the polyurethane foam and the wet wood particle is destroyed even before the wood-filled polyurethane foam is cured.

3. Description of the object under development
Created plate insulation material consists of wood filler, treated with flame retardant impregnating composition, and a polymeric binder. Figure 4 shows the appearance of an experimental sample of wood-filled polyurethane foam insulation material.

Technological chips according to GOST 15815-83 were used as a filler in the created thermal insulation material [32-33]. As a binder we used a two-component polymer system used for the production of closed-cellular rigid polyurethane foam in accordance with TU 5762-001-35532087-95, consisting of components "A" and "B":

1. Component "A" includes the main component - polyol and additives included in its composition: blowing agent (freon, water), emulsifiers, activator, plasticizer, flame retardant and other additives [34]. Polyols are organic compounds of the class of alcohols, are sources of hydroxyl (-OH) groups, which, reacting with the polyisocyanate, form a polyurethane structure. In this work we used a polyol component (component A) - the "Khimtrast KAS-40/141(131)" trademark, a ready-to-use polyol component that contains stabilizers, catalysts, flame retardants, a mixture of allowed freon 365/227 and 245, and water.

2. Component B includes the main component - the polyisocyanate. Isocyanates are organic compounds that form a group of neutral derivatives of primary amines with the general formula R — N = C = O. Isocyanates spontaneously react with compounds containing active hydrogen atoms. Chemical compounds that include hydroxyl groups spontaneously form esters with a substituted carbon dioxide group or urethanes. In this work we used the isocyanate component (component B) - the “Millionat MR-200” trademark, manufactured by Nippon Polyurethane Industry (Japan), which is a polymethylene polyphenyl isocyanate, which contains 4,4-diphenylmethane disocyanate, its isomers and higher oligomers homologues. 4,4-diphenylmethane disocyanate.

In connection with the addition of wood particles to polyurethane foam, which are inherently combustible material, in order to improve the flame retardant properties of the final product, they were treated with flame retardant impregnating compound (fire retardant). The flame retardant slows down the burning and ignition of the material due to substances-retardants of combustion (chlorides, ammonium phosphates and borax). In our case, for the impregnation of wood particles, a flame
retardant of the Attic brand, which is a solution of non-toxic inorganic salts, was selected. Impregnating composition "Attik" corresponds to the I group of fireproof efficiency, according to the established fire safety requirements in accordance with GOST 16363-98.4.

4. Conclusion
Thus, the presented physical picture of the process of forming the created wood-polymer insulation material proves that the developed material is a multicomponent system in which the wood particles form a strong adhesive bond with polyurethane foam, characterized by complex physicochemical reactions that occur in the process of interaction of all system components. The main technological parameters affecting the process of formation of bonds and interaction of components of wood-polymer insulating material are identified.

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