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Equipment for the Production of Wood-Polymeric Thermal Insulation Materials

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Abstract. This article presents developed pilot-plant equipment for slabby patterns of wood-filled polyurethane foam insulation material and its specifications are presented. Based on the results of experimental studies of pilot models the allowable range of equipment's technological parameters was defined.

1. Introduction
Thermal insulation materials are the structural elements that reduce the rate and amount of heat transmitted through the layer of material, i.e. acting as main thermal resistance in the structure [1].

The need for thermal insulation materials is due, firstly, to the requirements of energy saving increase and a decrease of the energy consumption for space heating in winter and cooling in summer respectively [2]. Secondly, the outer insulation of the building provides ecqualized heat distribution throughout the whole volume of the facilities, thus there is no need for a progressive heating [3]. Third, the insulation improves indoor climate in winter time, preventing the formation of condensation and mold growth on the inner walls of the facilities [4]. Fourth, the insulation increases the service life of the building and its supporting elements, which significantly affects the cost of the building when sale or rent [5].

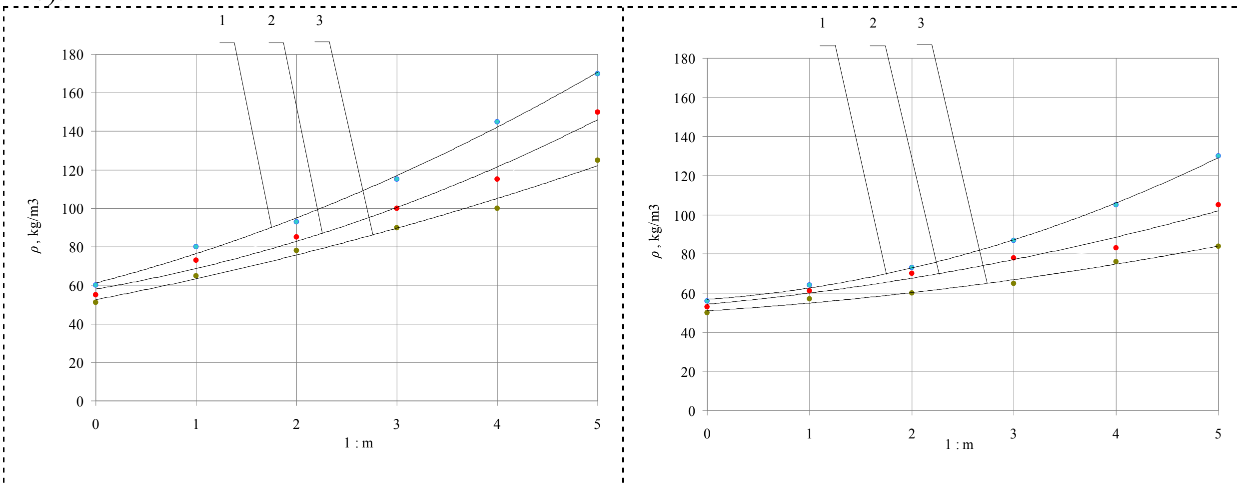
Currently when the thermal insulation of buildings and structures mainly mineral thermal insulation (fiberglass, rock wool, etc.) and gas-filled polymeric insulation materials (polystyrene, polyurethane foam, etc.) with high costs are used [2, 6, 7]. In recent years, there are insulation materials obtained by processing of unmerchantable wood – wood-fiber insulation, particleboard, cement particle boards that rapidly become very popular [8, 9, 10, 11]. However, from the point of modern requirements, they do not have sufficient heat-shielding properties and a level of hydrophobicity. In addition, nowadays there are no clear recommendations what should be the composition, conditions and technology of production of efficient thermal insulation materials, produced on the basis of shredded wood and wood waste [12, 13, 14].

Based on the above, the actual direction is the development and creation of new technologies for the production of thermal insulation materials in order to reduce their costs and improvement of the thermal insulation properties.

2. Case study

Given the high cost and unique properties of the polyurethane foam as insulation material, as well as a large amount of wood waste from wood processing complex, it was asked to fill polyurethane organic fillers, which are selected as shredded wood waste [15, 16]. The result was a method of producing wood-filled with insulating material. The method consists in mixing the filler and binder, followed by molding and curing. The wood is used as a filler pulpchips thickness of 5 ±2 mm, length 10−35 mm. The polyurethane foam used as the binder obtained from two components − a polyol and a polyisocyanate. Previously, the binder components are mixed, then binder is mixed with filler by layering (binder - filler - binder) to form at a ratio of mixture components (wt. %): polyol 22−24, isocyanate 33−36, pulp chips 40−45. After complete feed of components, the form is fixed by latch and held for 15−20 minutes. By this method there were prepared samples of easy and effective thermal insulation material based on wood waste with a high density, but the thermal conductivity properties were inferior to the regular polyurethane foam slabs, resulting in increased thickness of the plates [17, 18, 19].

In order to reduce the density of wood-filled polyurethane foam while maintaining its fractional composition the experimental research on the basis of the laboratory of the department of wood processing materials of FSEIHE "KNRTU" was carried out. The results showed that exposure to a vacuum of 0.3 bar effectively affects the foaming process the wood-filled polyurethane. Figure 1 shows the results obtained by determining the density of material depending on the weight ratio of components of the composition at atmospheric pressure (figure 1a) and a vacuum of 0.3 bar (figure 1b).



a b

Figure 1. The density of the samples of wood-polymer thermal insulation material, depending on the mass ratio of the components "A − polyol:", "B − polyisocyanate" and the degree of dilution (ratio of "A" and "B" components: 1 − 1:1.1; 2 − 1:1.3; 3 − 1:1.5): a − 1 bar; b − 0.3 bar

The presented data show that the formation of the material at a vacuum of 0.3 bar with an increase in the proportion of wood filler densities increase (at a weight ratio of polyurethane to the wood filler 1:5 (ρ = 130 kg/m^3) − figure 1b, position 1), but one order less than the atmospheric pressure (at a weight ratio of polyurethane to the wood filler 1:5 (ρ = 160 kg/m^3) − figure 1a, position 1). From the data obtained it can be concluded that the introduction of wood filler in a polyurethane foam matrix, to achieve the desired density of the material, a necessary condition during its formation is the presence of vacuum.

Initially the density range of created wood-polymer insulation material is set as ρ = 60−80 kg/m^3. That means that in order to achieve the specified numbers, the following conditions must be observed during the formation of the composition:

- the weight ratio of polyurethane to the wood filler: from 1:2 to 1:4;
- the ratio of polyurethane foam components (polyol: polyisocyanate) from 1:1.3 to 1:1.5;
- the degree of vacuum: 0.3 bar.

Thus, foaming under vacuum enables cost reduction according to the standard slabs of polyurethane foam in 2.5 times.

Based on the research the pilot plant for wood-filled with polyurethane foam insulation material has been developed. The scientific novelty of this development is a patented method of layering components and the formation of plate products under vacuum (Pat. Russian RU2538004 (C1)).

3. Description of the developed object

The construction of pilot production unit is shown in figure 2.

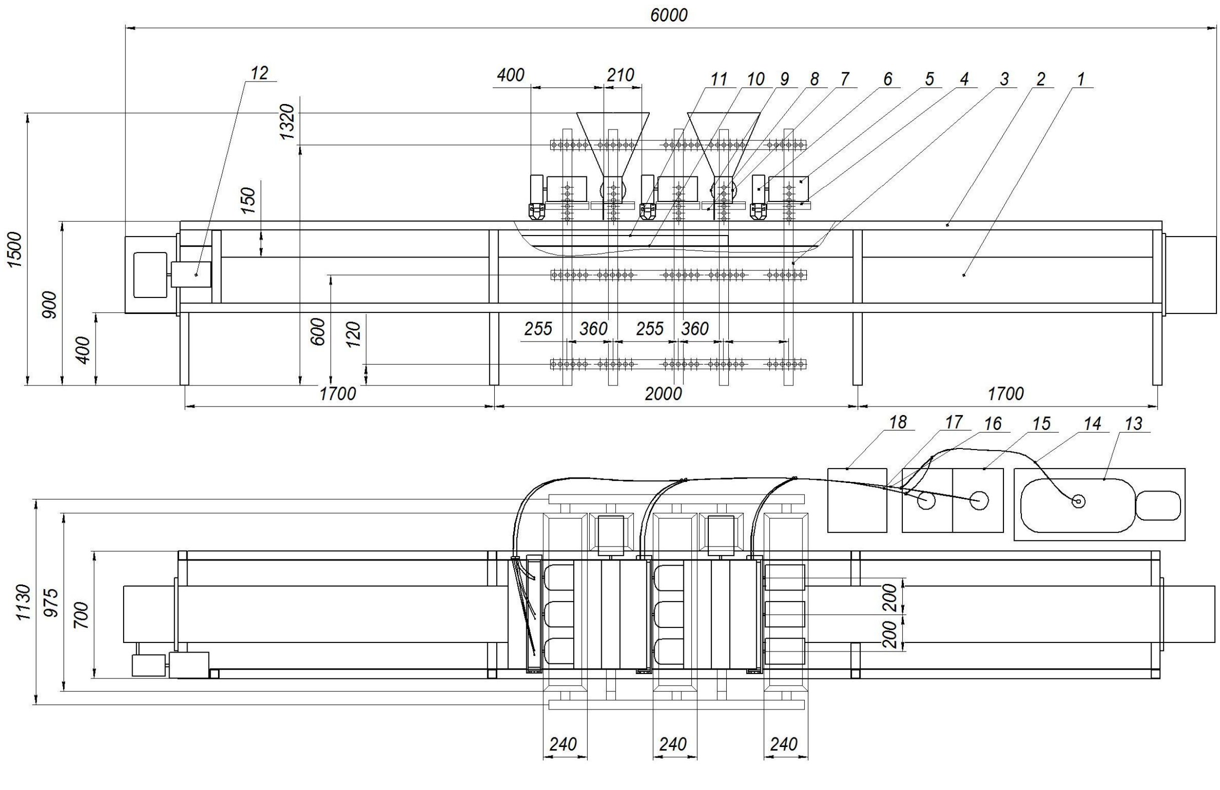


Figure 2. Sketch of the laboratory setup producing wood-filled thermal insulation material: 1 − conveyor, 2 − the conveyor frame, 3 − inlet unit frame, 4 − engine bearer, 5 − electric motor, 6 − filling head, 7 − chip batcher, 8 − batcher engine bearer, 9 − lock-gate hatch drive, 10 − conveyor belt, 11 − form, 12 − conveyor drive, 13 − compressor, 14 − compressed air hose, 15 − foamed polyurethane production machine, 16 − component "A" supply hose, 17 − component "B" supply hose, 18 − the vacuum pump.

The principle of operation of the unit is to organize the sequential process steps in the following order: a special form 11 for slabby samples of wood-filled polyurethane foam is placed on the belt 10 of conveyor 1, mounted on a frame 2 with boards to organize the movement of forms. The conveyor runs from the actuator 12. The form 11 is moving on the conveyor belt from left to right. At the beginning and end of the form the laser sensors are set for transmitting the response on signal sensors mounted on the filling heads 6 and lock feeders 7. The filling heads for feeding a mixture of polyurethane components operate from the actuator 9 and mounted on a support 4. The lock feeders are mounted under at the chip storage bins, placed on a support 8. The overshot assembled unit is placed on the frame 3. With the passage of the form under a first sealing head as a result of operation of sensors the compressor 13 supplying compressed air through a hose 14 to the infusion head is activated. At the same time with the compressor the pump of foam generator 15, the supplied component "A" through the hose 16, the component "B" through the hose 17 are turned on. The foaming in forms is carried out under an exhaustion of vacuum pump 18. The regulation of the flow of components and compressed air is carried out by automatic valves installed on the supply hose, and receiving signals from the sensors. Components fall in the filling head together with the compressed air, wherein are mixed by working from actuators mixers in the contact area. The mixer drives are switched simultaneously with the pump and the compressor. Since the mixing of the components in the filling head the countdown of polyurethane induction begins. The compressed air pressure pushes a liquid mixture of polyurethane components out through opening of the filling head in to the form of a continuous strip of a given thickness, which is given by the size of the flow cross section of the filling head. Thus, the first layer of polyurethane foam is filled in the form, the foaming start time is regulated by the equivalence ratio and its mixing speed in the contact zone of the head. When the form completely passes under the head, closing sensors are triggered, and the supply of component in the first filling head is stopped by closing the valve. The chip lock feeder works similarly, it is installed after the first filling head and performs the feeding of wood filler in to the form as a second layer. Likewise the second filling head is activated, the second chip lock feeder and the third filling head, which are switched off in the same order when passing beneath a laser off sensor, the latter off sensor doesn't only provide a signal to close the supply valves of the third filling head, but also disables pump of foam generator and compressor.

Thus there is a continuously layering of components of wood-filled polyurethane foam in a special form. The whole process of the technological cycle of layering is done during the induction of the polymer, that is, until the foaming of compositions starts spontaneously and a free volume remains in the form that will be filled during the time of foaming. After placing the components into the form, the form closing is performed with a special lid with the valve hole for supplying the vacuum pump hose, which performs the foaming and lifting of the composition till the predetermined volume is defined by the form after evacuating of air and creating of a vacuum in the form. After vacuuming of the form the cover valve hole is sealed and the form is sent to holding until test sample of wood-filled polyurethane foam thermal insulation material is fully cured.

The automatization of setup is presented by laser sensors mounted on the ends of the form, filling heads and chip lock-feeder. The optical position sensor with integrated microprocessor control system is made for use in monitoring of the alignment control and collocation of distant objects systems. It allows you to accurately measure the movement of the object under control without mechanical contact. Also the automation system includes the system of maintaining at a given temperature of components "A" and "B". It is possible to adjust the parameters that affect the final properties of the resulting thermal insulation material on the developed setup.

The experimental study on separate laboratory benches allowed to establish the boundaries of an experimental study of the parameters of the process and the final physical, mechanical and performance properties of wood-filled polyurethane foam, suitable for the manufacture of thermal insulation slabs [20].

The ranges of variation of process parameters on the setup are determined based on the allowable range of property variation of the resulting material. When you create a pilot plant to produce wood-filled insulation material it is necessary to set the allowable range of the basic physical, mechanical and performance properties of wood-filled polyurethane foam insulation material [21, 22, 23]:

- Thermal conductivity: 0.025−0.035 W/m·K;
- Density: 60−80 kg/m³;
- Flexural strength: 0.55−0.65 MPa;
- Absorption of water by volume: 1.4−1.6 %;
- Damaged length in combustion: 70−85 %;
- Flue gas temperature in combustion 150−200 °C;
- Damaged weight in combustion: 43−58 %;
- Time of independent combustion: 20−30 sec.

The ranges of variation of process parameters on the setup based on the results of the research were determined on a given range of properties of wood-filled polyurethane foam:

- the ratio of polyurethane foam components: chips − from 1:2 to 1:4 (governed engine RPM airlock feeder 9);
- the ratio of components a polyol : polyisocyanate − from 1:1.2 to 1:1.5 (adjusted in foam generator 15);
- vacuum - from 0.2 to 0.4 bar (regulated by the processing of vacuum pump 18);
- fire retarder flow − from 0.7 to 0.1 l/kg (regulated by engine speed of the fire retarder feeder);
- time of filling mixture to forms- from 22 to 37 sec (is regulated by capacity and the pressure of compressor 13).

4. Conclusions

Thus, the development of technology for wood-filled thermal insulation material is to determine the allowable range of process parameters that determine the rules of experimental studies on the experimental setup. These ranges allow to run the numbers in a right way, establish the limits of experimental variation and to carry a number of other research studies on the setup, purpose of which will be to determine the optimal regime parameters of the process of obtaining slabby wood-filled thermal insulation material.

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