Upgrading the Technology of Chipboards Manufacturing from Softwood with Increased Biostability

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Abstract. Expansion of the raw materials base for building materials production is possible at the expense of soft-wooded broadleaved species little used nowadays. All these timber species are characterized by lower strength if compared with the strength of hard-wooded broadleaved species or pine-wood. They are also prone to cracking and decay. In construction industry, they could be used after special treatment by modifiers. High porosity facilitates the improved substances absorption. As the result, impregnated wood with porous structure would have improved technical properties. Thus, the use of soft-wooded broadleaved species as a renewable available source of raw materials for manufacturing construction products is regarded as the acute practical issue from the perspective of technology, ecology and economy.

The implemented experimental studies for treatment of broadleaved wood by the wood preservative “Ksilostat” have shown that the wood preservative has proved to 100% efficient to perform the task. The results of experimental tests are presented. The implemented work aimed at developing technological solutions for woodchip board production from broadleaved hardwood of improved biological stability allowed proposing technological scheme of manufacturing bio-retardant boards with introduction of timber preservation production unit followed by wood chip drying.

1. Introduction

Chipboard production has emerged and developed due to the urgent need to utilize subsidiary and low-quality wood as well as scrap wood including green waste and byproducts of woodworking industry. Chipboard manufacturing enables to use raw materials that have not found application in other industries [1-3]. Chipboard are produced in any size and thickness, are not characterized by wood flows and could be coated by film materials for enhancing the maximum texture finish. Due to this, the further development of chipboard and fiberboards facilitating complex wood processing are of the paramount importance [4, 5]. For example, for quality application of woodchip boards as a structural material, their quality should be adapted to conditions in service, in other words, it is required to increase their resistance to water and microbial corrosion [6, 7].
The Russian Federation possesses the world greatest timber volumes (more than 20% of world’s supply) and the largest forested areas. However, as far as forest resources are concerned, there exist numerous important and acute problems. In some regions of the European part of the country (e.g. Northern, Ural, Volga-Vyatka regions), as well as in Siberia, excessive soft wood deforestation and low interest in hard wood are observed. It is largely due to underdeveloped transport system in forested areas and immaturity of wood processing technologies [8-11].

In connection with this, development of technological solutions for chipboards manufacturing on the base of subsidiary and widely used softwood is of actual importance. In order to attain success in this sphere, it is required to overcome the problem of softwood low resistance to microbial corrosion. Softwood, free of resins and other extractive matters, is prone to biodegradability; in particular, fungi have the adverse effect on hardwood. In the present paper, the authors have attempted to solve this issue by using a modifier of complex impact on the base of boron-nitrogen compounds – “Ksilostat” developed in NRU MGSU [12]. Earlier, “Ksilostat” has demonstrated the impressive results on softwood – it enabled to guarantee 100% microbial corrosion for the period of no less 20 years [13]. It has not been tested on softwood so far. Therefore, the purpose of the present study is the enhancement of softwood microbial corrosion and development of technological solutions for manufacturing woodchip boards on its base. The priority task was researching the impact of a complex action modifier “Ksilostat” on biological stability of softwood. The second task was the development of technological solutions for timber preservation production unit, being the part of technological process in chipboard manufacturing.

Expansion of the raw materials base for building materials production is possible at the expense of soft-wooded broadleaved species little used nowadays. For this purpose, it is required to state the application areas for construction products from broadleaved softwood factoring in their environmental security. In the forested areas of the European part of the RF, among the soft-wooded broadleaved species, birch, aspen, alder, poplar and bass-wood are widely spread. All these timber species are characterized by lower strength if compared with the strength of hard-wooded broadleaved species or pine-wood. They are also prone to crackling and decay. In construction industry, they could be used after special treatment by modifiers.

Wood is considered a naturally occurring polymer. This fact determines its structural specific features directly reflected upon its properties. Broadleaved softwood of birch, aspen, alder, and poplar has increased porosity as compared with softwood that would guarantee the increase in quality of wood steeping by modifiers and antiseptics. High porosity facilitates the improved substances absorption. As the result, impregnated wood with porous structure would have improved technical properties [14-18]. Thus, the use of soft-wooded broadleaved species as a renewable available source of raw materials for manufacturing construction products is regarded as the acute practical issue from the perspective of technology, ecology and economy.

2. Methodology

The proposed chemical and mechanical method of modifying treatment of broadleaved softwood timber blanks would enable to improve their physical, mechanical and aesthetical properties as well as their hydrophobic behavior, and in consequence, to enhance the customer appeal of the products and performance characteristics such as abrasion resistance, strength, hardness, shape and size stability, etc. Along with that, there would be obtained a monolithic material with designed properties that could successfully replace valuable hard-wooded broadleaved species. Moreover, thanks to hydrophobic behavior and pleasant physical configuration after pressing (color and gloss), it becomes possible to omit a complicated and labor-consuming process of varnish coating from the technological process.

For the study of biological stability and water absorbing capacity of broadleaved softwood, the samples of aspen, poplar and birch have been tested. For studying biological stability, the samples have been made in the cube shape with the dimensions of 50x50x10 mm. In order to research the parameter of water absorbing capacity, the samples have been shaped as rectangular prisms with the base 20x20 mm and the height of 10 mm longwise the fibers. Along with that, the tested batch of the
samples has remained non-modified while the remaining samples have undergone volume modification by “Ksilostat”. The volume modification has been implemented by soaking the samples in a modifier for three hours. Then, the samples have been air-dried before reaching constant mass. Fungal resistance of samples has been carried out in the laboratory of tropic technologies of the Institute of Ecology and Evolution of the Russian Academy of Sciences in compliance with the All-Union Standard GOST 9.048-89. The test results are presented in the table 1. Water absorbing capacity has been evaluated under the All-Union Standard GOST 16483.20-72* “Wood. Determination method of water absorption”. The results of measurements are presented in the table 2.

3. Result and discussion
The table 1 clearly demonstrates that the wood preservative “Ksilostat” has performed very effectively. This statement is plausibly proven by 100% absence of conidium and sprout spores on the treated samples.

| N  | Type of wood          | Sample number | Physical configuration after testing | Grade | Biological stability, % |
|----|-----------------------|---------------|--------------------------------------|-------|------------------------|
| 1  | Non-modified birch    | K1            | 80% of the surface is taken by fungal mycelium and sprout spores | 4     | 20                     |
| 2  | Non-modified aspen    | K2            | 85% of the surface is taken by fungal mycelium and sprout spores | 5     | 15                     |
| 3  | Non-modified poplar   | K3            | 85% of the surface is taken by fungal mycelium and sprout spores | 5     | 15                     |
| 4  | Birch modified by “Ksilostat” | 1 | Visual and under the microscope check show the absence of conidium and sprout spores | 0     | 100                    |
| 5  | Aspen modified by “Ksilostat” | 4 | Visual and under the microscope check show the absence of conidium and sprout spores | 0     | 100                    |
| 6  | Poplar modified by “Ksilostat” | 8 | Visual and under the microscope check show the absence of conidium and sprout spores | 0     | 100                    |

The average results of water absorbing capacity tests are given in the table 2 for control and modified samples of three timber species. The table reflects the volume of absorbed water expressed in percentage. The presented data demonstrate clearly that non-modified samples, or control samples, have much higher water-absorbing capacity than treated or modified samples. Thus, the authors could draw a conclusion that the applied wood preservative “Ksilostat” performs effectively against active water absorbing. This guarantees synergistic effect for the control of microorganisms in the partridge softwood. In addition, it could be stated that the poplar samples undergone timber preservation process have demonstrated the best performance. The water absorption of these samples is by 80% lower than of non-modified control samples for poplar, and correspondingly, by 20% lower form non-modified samples of birch and aspen.
Table 2. Water absorbing capacity of modified and native timber.

| Sample          | Δm average, % |
|-----------------|---------------|
|                 | 2 hours  | 1 day   | 3 days  | 6 days  | 9 days  | 13 days | 20 days | 30 days | 40 days |
| Birch control   | 60       | 86      | 105     | 120     | 126     | 129     | 130     | 131     | 131     |
| Birch modified  | 21       | 50      | 65      | 77      | 81      | 85      | 89      | 89      | 90      |
| Aspen control   | 45       | 78      | 97      | 116     | 126     | 134     | 147     | 158     | 16      |
| Aspen modified  | 12       | 38      | 46      | 59      | 66      | 73      | 83      | 93      | 94      |
| Poplar control  | 26       | 57      | 79      | 100     | 111     | 121     | 138     | 153     | 155     |
| Poplar modified | 13       | 31      | 40      | 51      | 55      | 60      | 64      | 69      | 69      |

Technological process of woodchip board manufacturing involves certain sequential operations. The number of these operations could be rather extensive, and the process itself could vary in the number and type of such operations, as well as in their sequence depending on raw materials, the size and type of produced chipboards, production line mechanical outfit, material transport connection and the shipment of produced boards to consumers [19, 20]. From the total number of technological operations, there could be distinguished the main ones, determining the principal conditions of boards manufacturing and the operations sequence.

The particular feature distinguishing standard production of woodchip boards from manufacturing bio-retardant woodchip boards is the introduction of wood preservative into the board structure, in this specific case, of wood preservative into wood chips. In connection with this, it is required to upgrade the technology by means of insertion additional stages of woodchip boards’ production. Thus, technological process comprises the following principal operations: 1) raw timber preparation; 2) raw wood feed to production and conversion; 3) wood disintegrating into chips and wood chip grading; 4) production of wood particles; 5) drying of wood particles; 6) wood particles grading and grinding of a coarse fraction; transporting and storing of resins and chemicals; 7) woodchip coating with wood preservative; 8) drying of preserved woodchips; 9) binder’s preparation; 10) batching and mixing of wooden particles with the binder; 11) chip mat formation and its separation into packs; 12) pressing of woodchip boards; 13) boards’ cooling and cutting; 14) surface grinding and grading, packing and storage. Each operation is executed in the specific technological sequence and is accompanied by formation of by-products and semi-finished goods. From there, the description of newly introduced technological operations related to the insertion of wood preservation unit into the technological production scheme is given.

Woodchip drying is carried out in drum dryers at the temperature of 105-350°C until they reach the moisture level of 3-6%. Wood dust formed during the process of various technological operations is used as the fuel and is burnt in the furnace unit. The dried woodchip passes through the cyclonic separator where it is separated from the air; then the settled woodchip is fed to the bunker. Before entering preservative treatment stage, woodchip is graded at the chip screeener, and the particles, which have not passed the grading process, are ground second time at the mill and resent to grading.

The wood preservative “Ksilostat” is delivered by rail in tank cisterns, pumped to the warehouse and further pumped to the supply tank. Coating the broadleaved woodchip surface with the preservative is executed by soaking in the modifier’s solution in the tub during three hours, along with that, modifier’s consumption accounts for 200 g/m². Having completed the preservation stage, it is required to redry preserved woodchip until it reaches the moisture level of 4-6%. Woodchip drying is also carried out in the drum dryer. In the dryer’s furnace unit, gas or black oil is burnt; the temperature in the furnace is 900-1000°C. At the drum’s input point, the temperature of the drying agent reaches 300-350°C, while at the output point, it is within the range of 90÷120°C. The drum has a diameter of 2.2 m and the length of 10m, it is fixed with the slope of 2-3° in the direction of raw woodchip input.

The dried woodchip is separated from air in the cyclonic separator and further on fed to the vertical bunker. In order to feed woodchip to the mixer for its blending with the binder, it passes through the
grading process on the chip screener. The woodchip that has not passed grading is sent to the mill for additional grinding.

4. Conclusion
The implemented experimental studies for treatment of broadleaved wood by the wood preservative “Ksilostat” have shown that the wood preservative has proved to 100% efficient to perform the task. The results of experimental tests are presented. The absence of a sanitation and hygiene certificate for “Ksilostat” for indoor use in the residential premises. So far, now we can only speak about modified wood application for indoor use in non-residential premises (for example, attics) or outdoor use.

The implemented work aimed at developing technological solutions for woodchip board production from broadleaved hardwood of improved biological stability allowed proposing technological scheme of manufacturing bio-retardant boards with introduction of timber preservation production unit followed by wood chip drying. The production unit for manufacturing woodchip boards with annual productive capacity 30 000 cubic meters has been designed. The principal production methods have been considered and the general overview of standard technological units has been done. The project includes technological elective scheme with the detailed description, the production units’ layout with equipment’s layout diagram, operation cyclogram of the plant.

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