DEVELOPMENT OF WOOD-POLYMER COMPOSITE MATERIALS FOR SLIDING BEARINGS IN FRICTION UNITS OF SEED SCREW CONVEYORS

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Abstract*: This paper presents research results on the possibility of manufacturing sliding bearings for friction units of screw conveyors used in cotton seed transportation from wood-polymer composite materials. To develop a composite material for sliding bearings, the physical and mechanical properties of its main components were studied based on standard materials used in mechanical engineering. Willow wood, which is widely available in the Republic of Uzbekistan, is proposed as the wood component for composite materials.*

For impregnating the wood-composite material, a hot-cold bath method is proposed, and for wood compaction - an evaporation method with corresponding implementation technologies. It is noted that a portable hardness tester model MED UD was used to measure the hardness of samples.

The research results show the relationship between the physical and mechanical properties of wood and its degree of compaction. It was established that wood density is directly proportional to the degree of compaction, and this relationship has a linear character. The results also show the dependence of wood strength limit, its hardness, and modulus of elasticity along fibers on the degree of compaction.

The effect of wood saturation with polymer composite was studied, and comparative results are presented; if in the initial state, for example, willow has a density of 0.49 g/cm³ and hardness of 4.73 MPa, then after saturation with polymer composite, the density reaches 0.89 g/cm³ and hardness up to 8.05 MPa, while additional compaction increases these values to 1.01 g/cm³ and 10.17 MPa, respectively.

Keywords*: cotton ginning industry, screw conveyor, sliding bearing, friction unit, wood-polymer composite materials, physical and mechanical properties.*

In the cotton ginning industry of the Republic of Uzbekistan, along with many other mechanization tools, screw conveyors are widely used: for transporting and distributing raw cotton and cotton seeds across batteries of technological machines and removing separated trash impurities [1].

Screw conveyors are particularly effective for transporting cotton seeds from saw gins to linter machines (Fig.1).

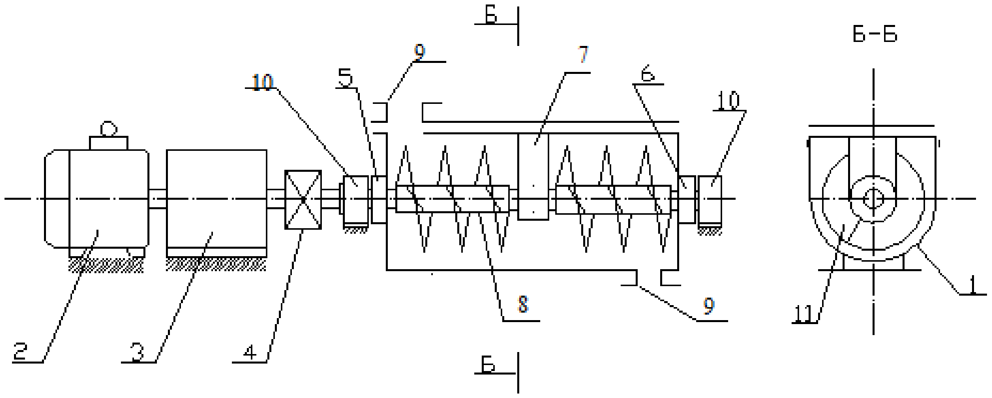

Figure 1. Screw conveyor diagram. 1-trough, 2-motor, 3-reducer, 4-coupling, 5,6-bearing, 7-suspended bearing, 8-screw shaft, 9-input and output openings, 10-bearing, 11-blade.

Taking into account the peculiarities of transported cotton seeds movement in the screw conveyor, where intensive separation of trash impurities occurs due to constant rolling of the total seed mass, a modernized screw conveyor with a cleaning section was proposed [2] in which the semi-cylindrical part of the trough is made in the form of a screening surface with holes (Fig.2).

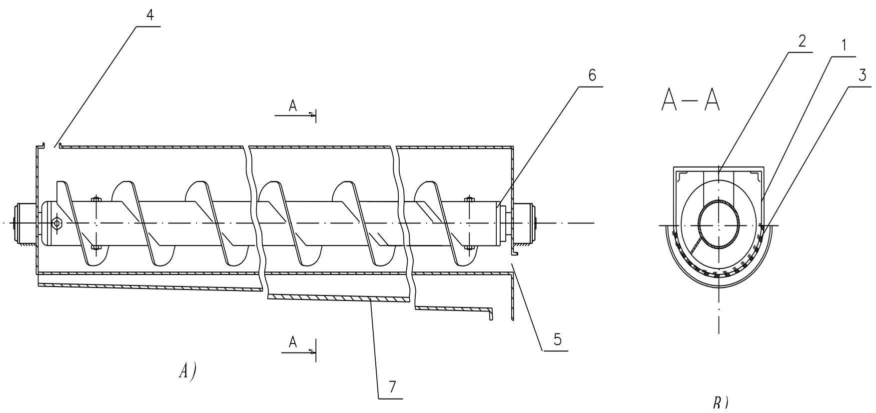

Figure 2. Diagram of screw conveyor with cleaning section. 1-trough, 2-cover, 3-mesh surface, 4-input opening, 5-output opening, 6-screw shaft.

Research has shown that using a screw conveyor with a cleaning section for cotton seed transportation achieved resource and energy savings, due to reducing waste in seeds by 2-3 times, increased lint purity by 22-24% (rel.), ensured the transition of lint from 1st grade "Urta" to 1st grade "Oliy" and increased seed oil content by 16-18% (rel.).

In principle, today, as a result of conducted scientific research, the process of cotton and seed transportation using screw conveyors has been justified, and equipment designs have been developed for their effective implementation. The possibilities of effective cleaning of cotton seeds from waste to obtain quality products (fiber and oil) during transportation by screw conveyors have been studied, thereby transforming mechanization tools into technological machines [3,4,5].

At the same time, issues of optimizing the design of friction parts of the screw conveyor for cotton seed transportation have not been sufficiently studied.

Currently, rolling bearings (RB) are used in the friction units of cotton ginning machines. They have rather large dimensions in the radial direction and are manufactured from high-quality steel grade ShKh-15, their performance in dusty and neglected environmental conditions is low. These bearings are non-separable, non-adjustable, and therefore their frequent replacement involves large material and labor costs [6,7,13,14].

Analysis of friction units operation in screw conveyors at Uzbekistan, Yangiyul, and Karasuy cotton ginning plants showed that most rolling bearing failures are associated with unfavorable operating conditions of the unit. In addition to misalignment of axes and working shafts, improper installation of the unit, there is a problem of large amounts of cotton lint, which, penetrating through the protective device into the RB, intensively thickens the lubricant and the process of abrasive wear increases multiple times (Fig.3).

Figure 3. Bearing operating conditions in contaminated environment.

Currently, in many friction units of machines and mechanisms, in addition to standardized RBs, sliding bearings are used primarily made of materials such as: antifriction cast iron, tin bronze, as well as sliding bearings based on other non-ferrous metals. They work under boundary lubrication conditions and wear intensively when abrasive particles enter.

Domestic and foreign mechanical engineering experience shows the effectiveness of composite materials in certain operating conditions of machine friction units. The applicability ranges of such materials are determined by the specifics of processes occurring during friction and the physical-mechanical properties of composite polymer materials.

METODS

To develop the necessary composite material with appropriate operational characteristics, it is necessary to consider the intended purpose of the product and the requirements for the bearing material.

Therefore, initially, the physical and mechanical properties of wood, polymers, and fillers (density, crushing stress under compression, Brinell hardness, impact strength, elastic modulus, heat resistance, melting temperature, water resistance) were studied according to the methods specified in the corresponding GOST standards adopted in mechanical engineering [10,15].

The method of filling the wood-polymer composite material for manufacturing rolling bearings plays an important role and was performed as follows: according to the hot-cold bath method for filling wood without pressure, the wood was first heated to 95-115°C in a hot bath, during which air expansion occurs in the capillary porous system. Then the wood is placed in a bath with cold filling composition, during which the volume of remaining air decreases, vacuum is formed, and the modifier fills the wood [11,16,17].

For wood compaction, the evaporation method was used, the essence of which is that wood with 8-20% moisture content is thermally treated in motor oil at a temperature of 140-150°C for 30-90 minutes, then cooled in oil and compacted in a mold under pressure with a hold time of 3-10 minutes.

Hardness measurements of samples were performed using a portable hardness tester model MED UD (Fig.4), sample pressing was carried out using a specially developed mechanical press (Fig.5).

Figure 4. General view of portable hardness tester.

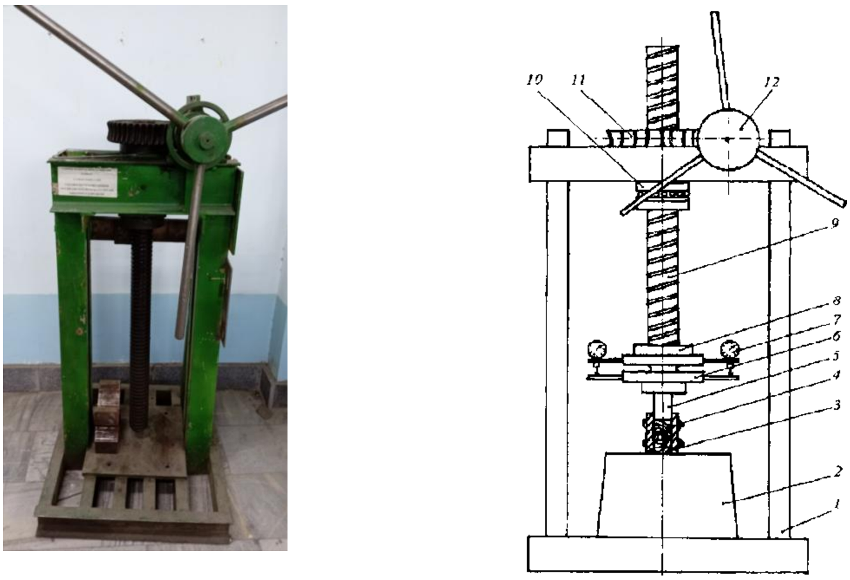

Figure 5. Diagram and general view of mechanical press.

RESULTS AND DISCUSSION

The dependence of the main physical and mechanical properties of wood on its degree of compaction was studied, the results of which are presented in the graph in Fig.6.

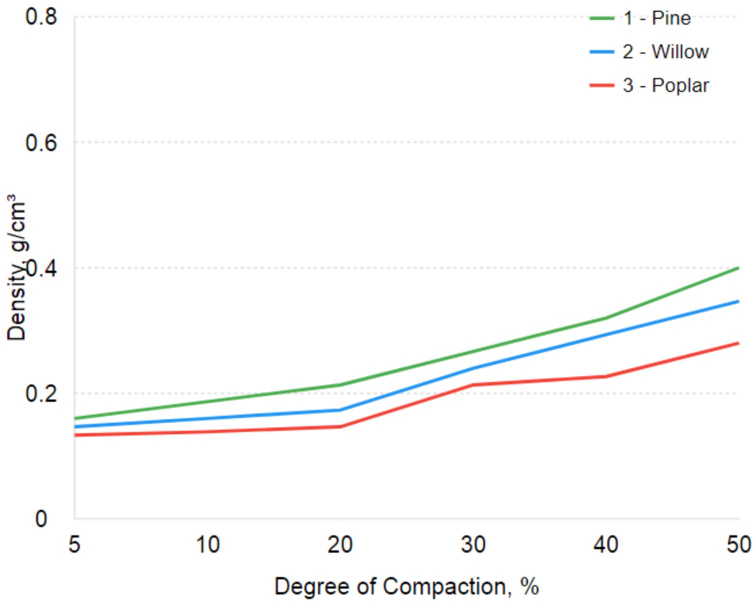

Figure 6. Dependence of wood density on compaction degree. 1-pine, 2-willow, 3-poplar.]

Analysis of the results shown in Fig.6 demonstrates that at the same degree of compaction, for example at 20%, the density for pine, willow, and poplar is 0.72 g/cm³, 0.65 g/cm³, and 0.53 g/cm³ respectively, i.e., their density is directly proportional to the degree of compaction and this relationship has a linear character[18,19,20].

The ultimate tensile strength along wood fibers also depends on the degree of compaction, and the results of studies conducted in this direction are presented in the graph in Fig.7.

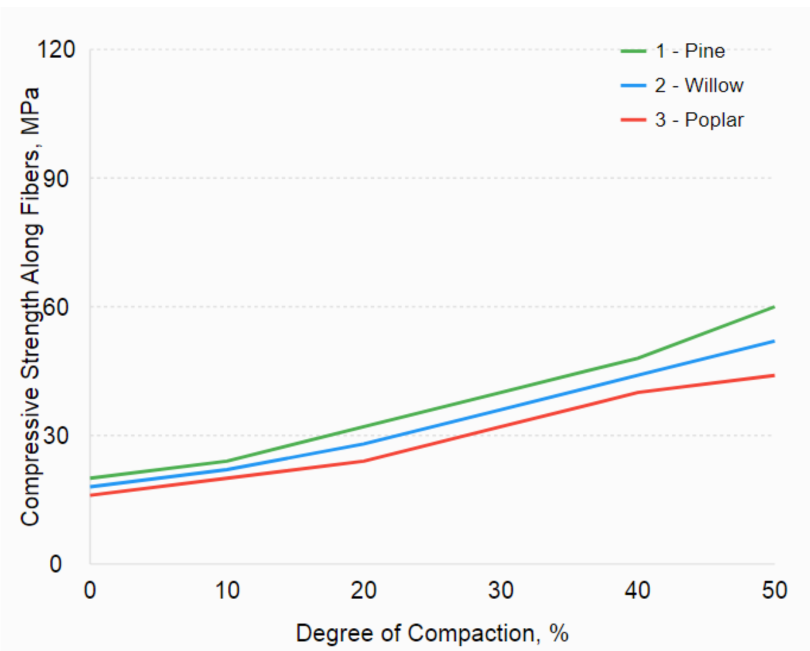

Figure 7. Dependence of compressive strength along wood fibers on compaction degree. 1-pine, 2-willow, 3-poplar.

Analysis of the results shown in Fig.7 shows that at the same degree of compaction, for example at 20%, the ultimate strength for pine, willow, and poplar is 70.2, 63.3, and 57.8 MPa, respectively, and this relationship also has a linear character.

The dependence of the elastic modulus along wood fibers was studied, the results of which are presented in the graph in Fig.8.

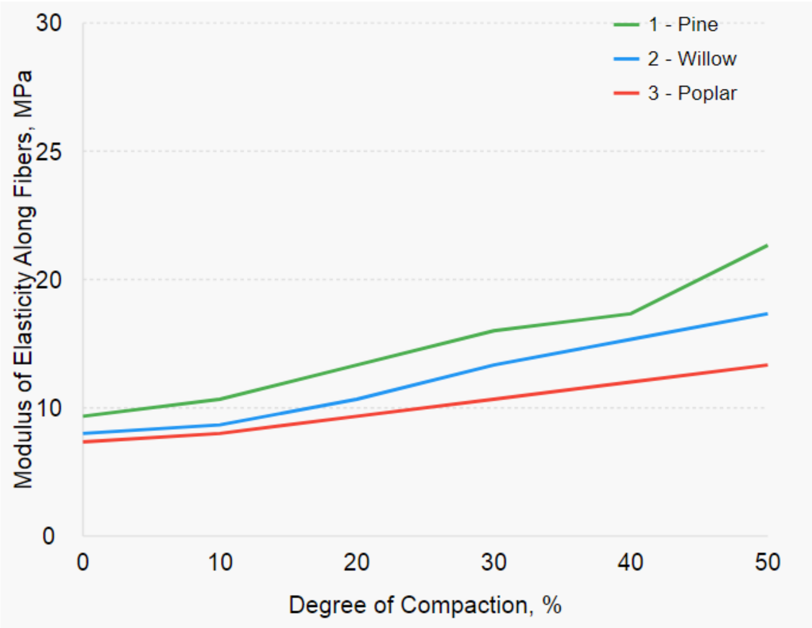

Figure 8. Dependence of elastic modulus along wood fibers on compaction degree. 1-pine, 2-willow, 3-poplar.

Analysis of the results shown in Fig.8 shows that the elastic modulus along wood fiber also depends on the degree of compaction and, for example, at 20% compaction, the elastic modulus along wood fiber for pine, willow, and poplar is 17.9, 12.1, and 10.7 MPa, respectively.

Of particular interest is the dependence of wood hardness on the degree of compaction. The results of the performed studies are presented in the graph in Fig.9, which shows that at the same degree of compaction, for example at 20%, the Brinell hardness of pine is 50.0 MPa, while for willow and poplar it is 35.3 and 32.9 MPa, respectively.

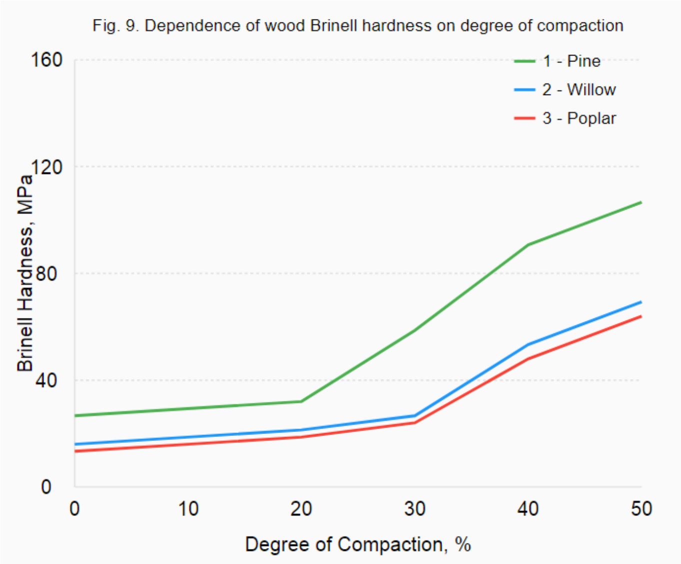

Figure 9. Dependence of wood Brinell hardness on compaction degree.

Based on the performed research, wood-polymer composite materials were developed, and their main physical and mechanical properties were also determined[12].

As a result of measuring the density of samples made from composite materials based on poplar and willow, it was determined that if in the initial state the density of poplar is 0.59 g/cm³, then after oil saturation this value increases to 0.66 g/cm³, and for willow these values are 0.49 g/cm³ and 0.89 g/cm³, respectively (Fig.10).

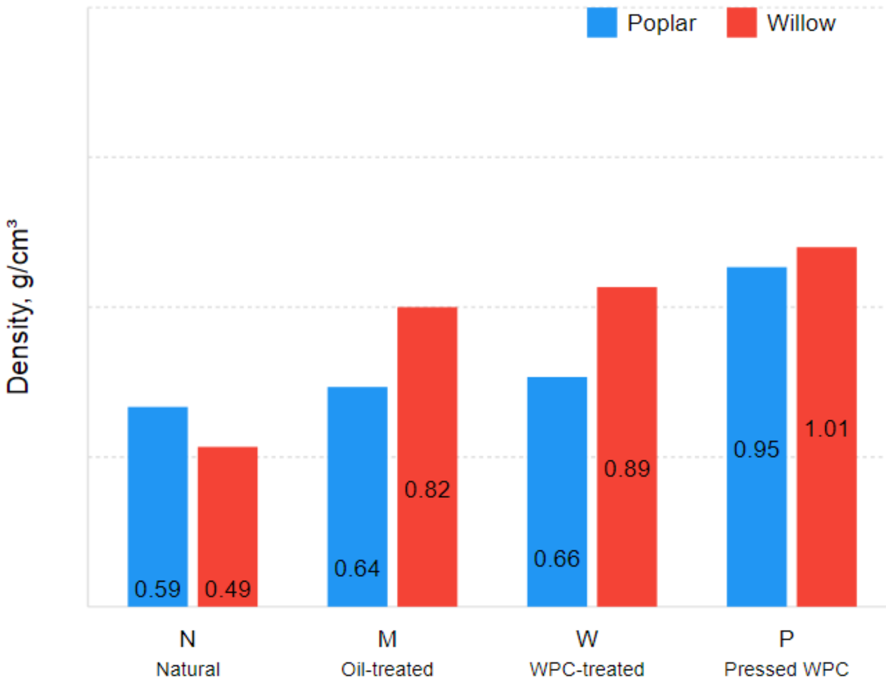

Figure 10. Diagram of sample density changes. N-natural wood, M-oil-impregnated wood, B-wood impregnated with WPCM, Pr-pressed wood impregnated with WPCM.

The density of samples increases when saturated with polymer composite - up to 0.64 g/cm³ for poplar, for willow - up to 0.89 g/cm³. Additional pressing of such samples leads to an increase in poplar density to 0.95 g/cm³, and willow to 1.01 g/cm³.

The hardness of samples made from polymer composite materials based on poplar and willow was also studied. The research results are presented in the diagram in Fig.11.

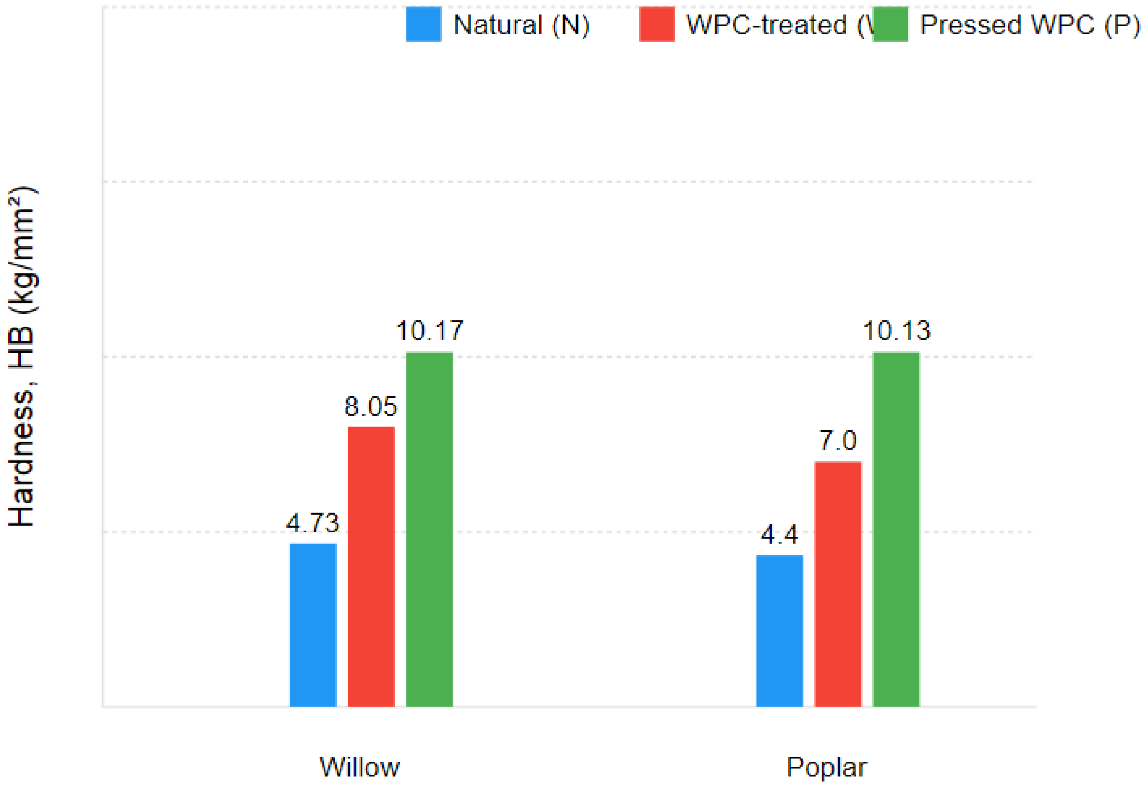

Figure 11. Diagram of sample hardness changes.

Analysis of the results obtained in studying sample hardness showed that the highest hardness is observed in pressed materials impregnated with polymer composition. For example, if for natural willow wood the Brinell hardness is 4.73 MPa, then after impregnation with composite material, the Brinell hardness increases to 8.05 MPa, and after pressing it reaches 10.7 MPa. For poplar, these values are 4.47 and 10.13 MPa, respectively.

Based on the performed research, the main results of which are presented above, willow is proposed as the wood component for wood-composite material for manufacturing sliding bearings.

A working drawing of the proposed sliding bearing made from wood-polymer composite material was developed (Fig.12), and based on it, a manufacturing process was developed, which is proposed to be carried out in two stages.

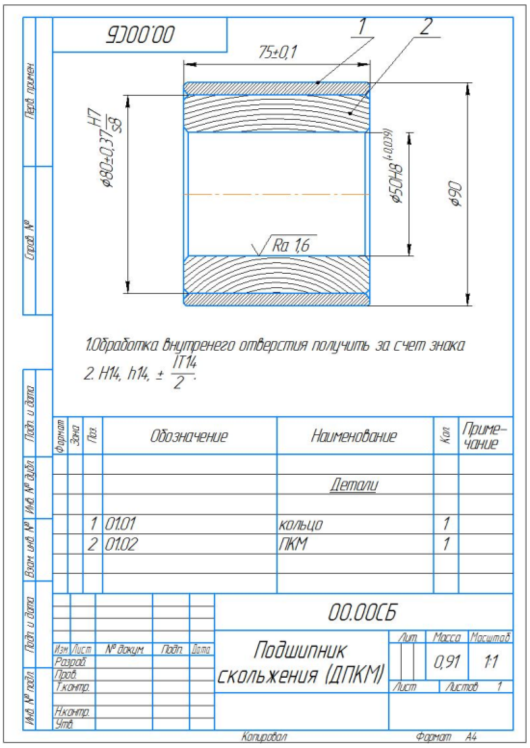

Figure 12. Working drawing of sliding bearing made from wood-polymer composite material..

In the first stage, the wooden bushing is immersed in an oil bath containing composite material. Composition: 92% oil, LDPE-5%, graphite-3%, saturation temperature -125-150°C, process duration-7-8 hours.

In the second stage, the wooden bushing impregnated with composite oil is pressed into a steel bushing, where the wooden bushing is taken with length *l=120 mm* and pressed to *l=80 mm*. The pressing device is mechanical. Pressing force-P=1000 MPa.

CONCLUSION

Based on the analysis of research results on determining the physical and mechanical properties of wood-polymer composite materials for sliding bearings in friction units of screw conveyors for transporting cotton seeds, it is proposed to use willow wood in such materials, which is widely distributed in the Republic of Uzbekistan, has low cost and favorable physical and mechanical properties, and is especially distinguished by a high degree of polymer composite absorption.

The developed sliding bearing design is distinguished by simplicity; it can be manufactured with minimal production costs and does not require separate production areas. Based on the obtained results, a sliding bearing was manufactured from the proposed wood-polymer composite material and underwent production testing at the cotton ginning plant LLC "Khorezm TEX" (Fig.13).

Figure 13. Sliding bearing installed in the friction unit of screw conveyor.

Sliding bearings made from WPCM were installed to replace existing rolling bearings No.1210 in the friction units of the seed screw of the linter line.

As a result of the conducted tests, it was established that the experimental samples of sliding bearings showed wear in the direction of load application averaging 0.2 mm in diameter. The bearing worked normally under a load of P=0.45 MPa and linear shaft speed V=0.31 m/s. No significant bearing damage was observed during their operation. These bearings are suitable for further use in the next season.

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