WOOD POLYMER COMPOSITE MATERIALS

E.A.Egamberdiev
Tashkent State Technical University named after Islam Karimov

B.B. Rakhimjonov
Tashkent State Technical University named after Islam Karimov

D.A.Khusanov
Tashkent Chemical-Technological Institute

Q.N.Khoshimov
Tashkent Chemical-Technological Institute
el.1909@mail.ru

Abstract: In this study, wood polymer composites were obtained using local poplar and paulownia tree flours and their physical and mechanical properties were analyzed. In addition, the effect of composite composition on the strength of composites was studied and analyzed. That is, the role of chemical bonds was studied and the results were presented.

Keywords: poplar, paulownia, tree filler, wood, poplar, polymer, secondary polyvinyl chloride, wood polymer composites, chipboard, fiberboard

Introduction. When producing WPC materials, two main aspects must be taken into account: production conditions, i.e. location and climate, selection of wood fillers introduced into their composition, depending on their mechanical properties. Because there are two types of wood: softwood and hardwood, in which hardwoods have higher mechanical properties than softwoods, and, in turn, the materials produced from them are relatively strong. In addition to the woodworking and furniture industries we know, wood materials in the construction industry of Uzbekistan are mainly imported. Deciduous tree species of Nina are quite difficult to grow in the climate of Uzbekistan, and this type of tree is of little industrial importance. Therefore, wood-composite materials (chipboard, MDF, plywood, etc.), widely used in the woodworking industry and production based on them, are imported.

Based on this, in the conditions of Uzbekistan, the creation and development of technologies for the production of composite materials based on local wood species and their mechanical properties is being carried out. Our previous studies examined the effect of wood fillers in wood-polymer composite materials on the compositional mechanical properties of waste chipboards (chipboards) and wood fiber boards (MDF, HDF), which are wood-composite materials widely used in the furniture industry. investigated.

Methods and materials: To obtain a new type of wood-polymer composite material in the laboratory, we used local poplar wood flour from the Tashkent region, recycled polyvinyl chloride from polyvinyl chloride suspension grade C-6346 of the NavoiAZOT chemical production complex in the Navoi region, samples of the composite material were obtained by extrusion based on recycled polyvinyl chloride and auxiliary chemical fillers made in China from the WOODWIN enterprise operating in the city of Tashkent, according to several developed recipes.

Experimental part: Modification of the filler is one of the ways to regulate the properties of wood-polymer composites. Shredded poplar and paulownia wood were used as a filler for wood-polymer composites. The granulometric composition of wood flour particles corresponded to the brand and was ensured by sieving on a sieve separator. The particle size distribution diagram for wood flour is shown in Fig. 1.

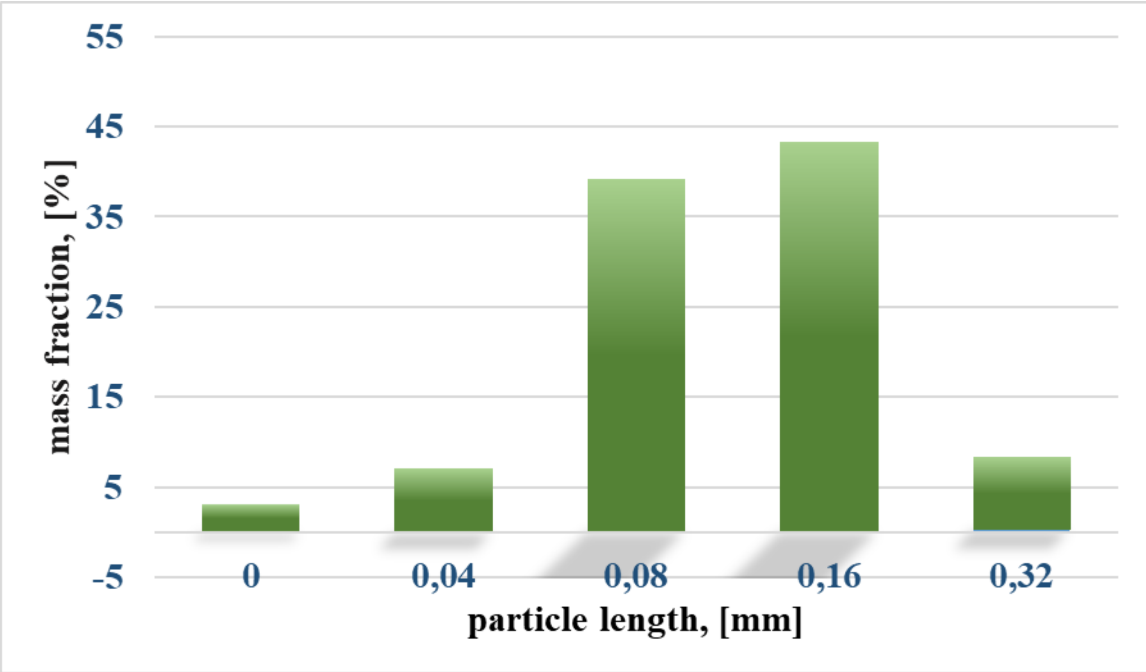

Figure 1 - Diagram of particle size distribution of poplar and paulownia wood flour (“0” - the remainder of particles is less than 0.04 mm at the bottom of the sieve separator)

Torrefaction of wood flour was carried out on an installation whose operating principle is described. During the thermal decomposition of lignocellulosic biomass, the polymers that make up wood, in most cases, behave as an additive mixture of the three high-molecular compounds (Table 1).

Table 1

Main components of wood

Wood type	Component content, %		
	Cellulose	Hemicellulose	Lignin
Poplar	45-48	17-23	33
Paulownia	40-45	15-24	23-25

In particular, it is known that during thermal modification of wood in the temperature range of 200-300°C, the most significant changes occur in connecting glycans, as the least heat-resistant biopolymers. Moreover, the least thermally stable of them is xylan.

As the temperature increased from 200 to 3000C, the yield of the thermally modified filler decreased, and the color darkened from natural color to dark brown. Moreover, for samples from pine, the weight loss was more uniform up to 55% at 300 °C, and for samples from poplar samples there was a characteristic fracture at processing temperatures above 250 °C, while the yield at 300 °C was 43%.

These differences are most likely due to the mechanism of thermal decomposition of hemicelluloses and lignin in the poplar and paulownia samples. A decrease in filler weight during thermal modification is an undesirable characteristic, so it was necessary to determine the temperature at which the change in sample weight would be minimal while maintaining the required level of filler characteristics.

One of the main goals of thermal modification of samples is to reduce the ability to absorb moisture and water. The lower the equilibrium moisture content of the material and the higher its hydrophobicity, the more likely it is to increase the performance characteristics of the filled composite (due to the absence of hidden pores, a nutrient medium for microorganisms, dimensional stability, etc.).

For this purpose, the moisture content of the treated samples was assessed. The presented dependence of the humidity of heat-treated wood on the torrefaction temperature shows that the most significant change in humidity for both samples lies in the range of 200-225°C with its subsequent stabilization.

Also, in this range of processing temperatures, hydrophobic properties begin to appear in both types of wood. Wood filler does not absorb water for a long time.

It is also quite possible to form water-stable high-molecular compounds as a result of the polycondensation interaction of dehydrated xylose monomers (furfural) with lignin monomers, which already at these temperatures undergo thermal decomposition due to the cleavage of alkyl-aryl and ether bonds.

As a result, it is possible to obtain water-resistant, brittle, resin-like products that are localized on the surface of microfibrils. These resins encapsulate cellulose microfibrils, which largely explains the increase in hydrophobic properties, increased water resistance and fragility of torrefied wood.

The formation of water-resistant resins and reactive oligomers during thermal modification explains the hydrophobic properties of torrefied wood.

Information about changes affecting various functional chemical groups in a sample that occur as a result of heat treatment can be obtained using IR spectroscopy. This statement is confirmed by the results of the IR spectra, which clearly show a decrease in the intensity of the bands at 3600-3200 cm-1, which are responsible for O-H stretching vibrations with a maximum at 3350 cm-1, involved in the system of hydrogen bonds.

In the region of 3000–2800 cm–1 there are bands of stretching vibrations of C–H bonds. This region is characterized by symmetric and asymmetric C–H stretching vibrations in methyl and methylene groups. The intensity of these bands also decreased with increasing sample processing temperature.

The absorption band 1240-1230 cm-1, correlated with vibrations of C=O and C-O bonds in acetyl groups, possibly connected with polysaccharides, was present in the spectrum of birch before heat treatment and gradually decreased in intensity in the case of torrefaction at 200 and 225°C, then disappearing. This band was not detected in the spectra of pine wood samples.

The absorption band with a maximum at 1033 cm-1, correlated with deformation vibrations of the C-O bond in cellulose I and II or hemicelluloses, is equally strongly expressed in the spectra of the original birch and pine samples. Heat treatment at 225 °C reduces its intensity by approximately half.

Therefore, for further research, it was decided to use wood filler processed at a temperature of 225 °C. In this case, the conditions for maximum output with its desired characteristics are met. The effect of heat treatment of fillers on the physical and mechanical properties of WPC compositions with fillers (50 and 60 wt. %) poplar and thermally modified (T) poplar and paulownia and thermally modified (T) paulownia rocks are presented in Fig. 2.

a b

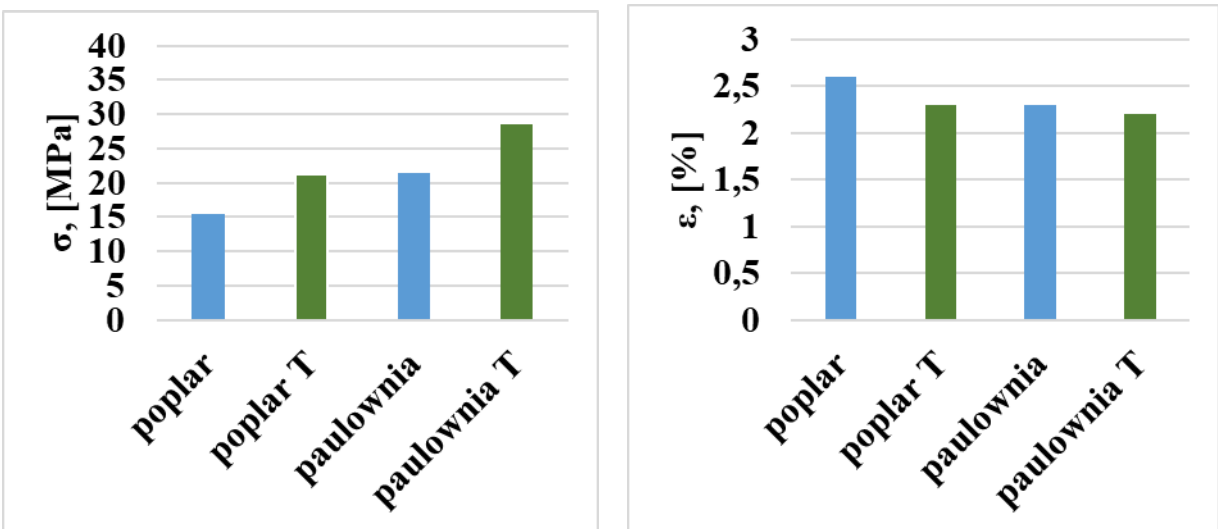

Figure 2 – The influence of thermal modification of different types of WF on the physical and mechanical properties of WPC, dosage of WF 50%: a) σ – tensile strength, MPa; b) ε - elongation at break, %

As can be seen from Fig. 2, for compositions with heat-treated hardwood filler there is a slight decrease in tensile strength and elongation at break in comparison with the original filler. At the same time, for compositions with heat-treated poplar filler, an increase in strength by 38% is observed with a decrease in elongation at break by 12%.

To assess the influence of particle size and the method of modifying wood flour on the physical and mechanical properties of WPC, wood flour WF 180 was subjected to thermal and mechanical treatment (WF 180T and WF 180*). At the same time, the decrease in the average particle size during mechanical activation ranged from 0.17 to 0.11 mm. The physical and mechanical properties of the compositions are presented in Fig. 3.

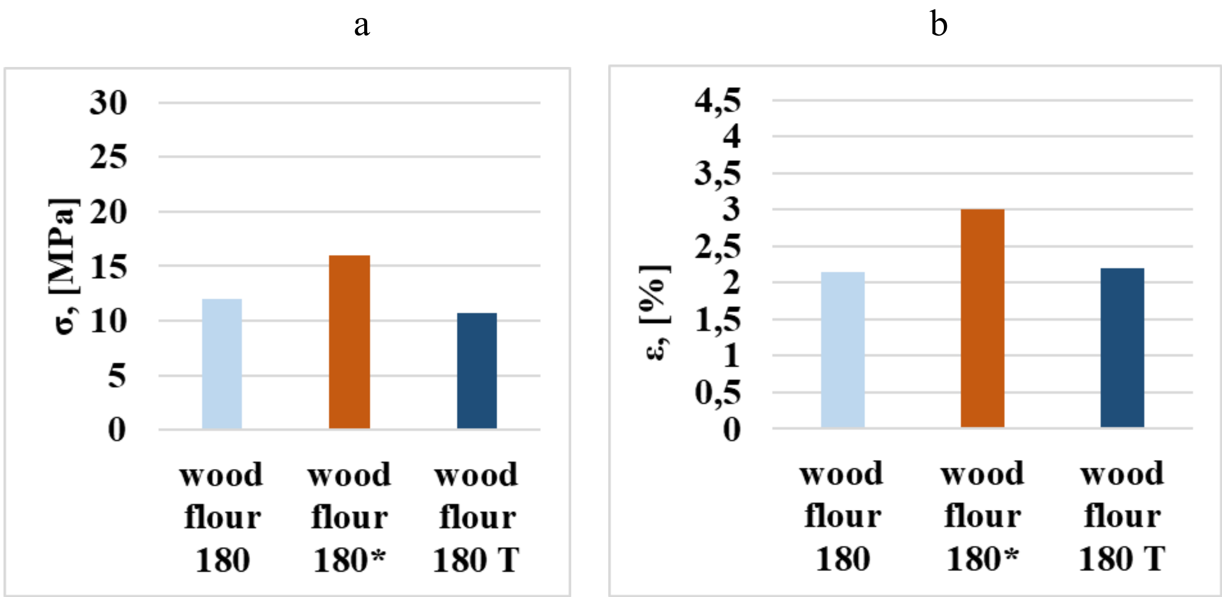

Figure 3 – Influence of the method of modifying wood flour WF 180 with a content of 50% wt. on the physical and mechanical properties of WPC: a) σ – strength at rupture, MPa; b) ε - elongation at break, %

As follows from Fig. 3, compositions with WF 180* have higher elastic-strength properties compared to WF 180 and WF 180 T. In this case, the increase in the surface area of interaction of WF 180* with the polymer matrix by reducing the size of filler particles is of greater importance.

Water absorption is one of the main indicators of the durability of WPC, since it allows you to evaluate the resistance of the material to aggressive weather conditions.

The dependence of the water absorption rate upon boiling for 2 hours in relation to the weight of the test sample for WPC containing wood flour modified in various ways is shown in Fig. 4.

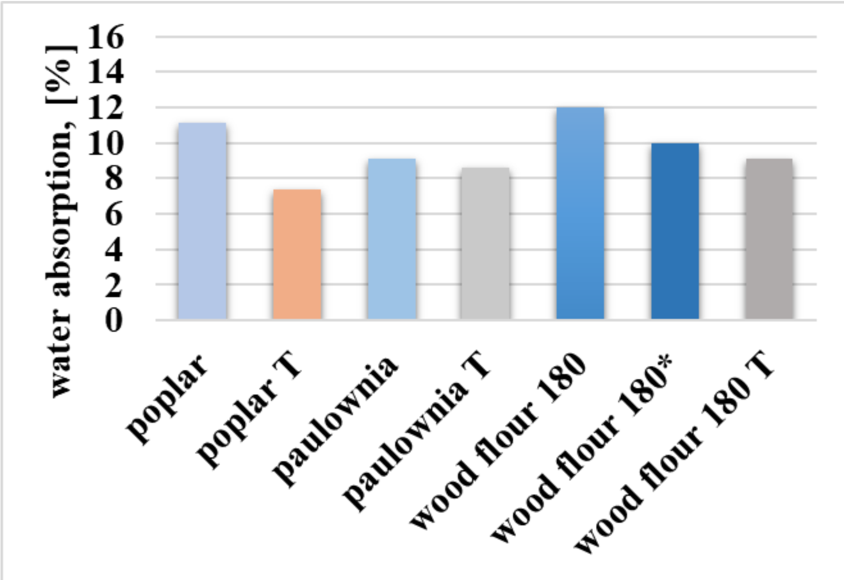

Figure 4 – Influence of the type and method of modification of wood flour on the water absorption of WPC

As follows from Fig. 4, thermal modification of wood flour leads to a decrease in water absorption for all samples, and this is most significantly observed for poplar species. Modification of the surface of flour WF 180 also leads to a decrease in water absorption, and this is most significantly observed for thermal modification. [128]

An important characteristic of wood-polymer compositions that affects performance properties is their density. In Fig. Figure 5 shows the density indicator of the resulting compositions.

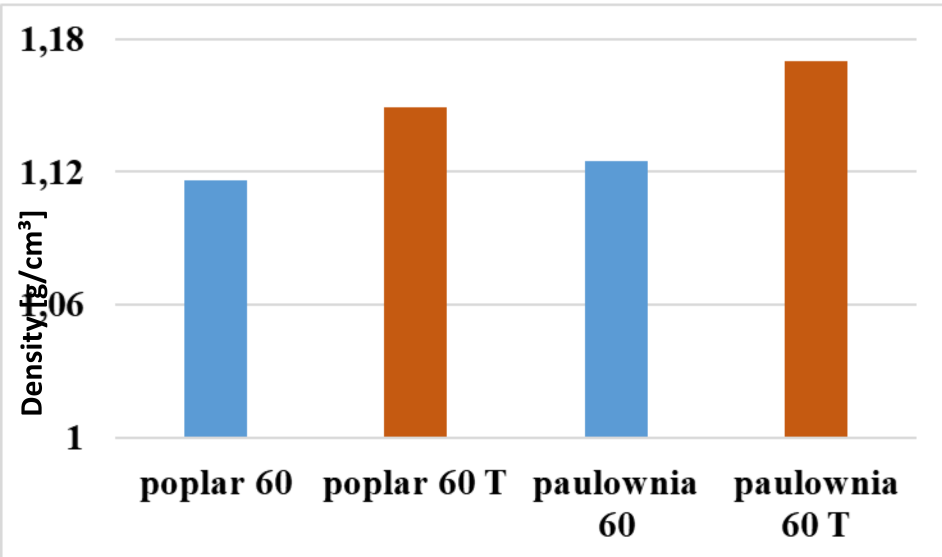

Figure 5 – Effect of thermal modification of wood flour on WPC density

From Fig. 5 it follows that the density of compositions with paulownia wood flour is slightly higher than with poplar. Thermal modification helps to increase the density of compositions with wood flour of both species. Moreover, this is more pronounced in compositions with hardwood wood flour. The increase in the density of compositions with thermally modified wood flour is explained by the removal of moisture during the torrefaction process of the filler. As a result of this, the possibility of the formation of air pores created by the effect of steam “explosion” during the extrusion process is sharply reduced in the composite.

Conclusion. Thus, mechanochemical modification of wood flour makes it possible to increase the physical and mechanical properties of WPC by 30% and reduce the degree of water absorption by 17%. Heat treatment of poplar flour leads to an increase in the tensile strength of WPC by 38%, a decrease in water absorption by 32%. Thermal modification of poplar flour, on the contrary, leads to a decrease in elastic strength characteristics by 5-10%. Apparently, modification of paulownium wood filler requires slightly different temperature conditions. But, at the same time, an increase in density is observed in compositions with thermally modified paulownia wood flour.

Thermal modification of poplar and paulownia wood flour does not have a significant effect on the change in the viscosity properties of the compositions under consideration.

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