Development of an effective technology for producing composite wood-plastic board materials for construction and furniture purposes

Dilafruz Kholmurodova[1*], *Sohiba* Pardaeva[1], and *Abdikhakim* Kardzhavov[1]

[1]Samarkand State Medical University, Republic of Uzbekistan, Samarkand, Uzbekistan

Abstract: This article presents the results of research in the development of an effective technology for obtaining composite wood-plastic board materials for construction and furniture purposes based on fillers from cotton stalks, which are agricultural waste, and polymer binders based on modified urea-formaldehyde and gossypol resins, epichlorohydrin, benzyl chloride, and polyvinyl chloride. The study revealed a correlation between the ultimate bending strength, tensile strength and water absorption with the parameters of pressing polymer-fillers of the mass. At the same time, to obtain composite wood-plastic board materials, it is recommended to use a urea-formaldehyde resin modified with reactive structuring additives as a binder. It has been established that the optimal technological mode for pressing the mass of polymer fillers and cotton stalks is: specific pressure 35 kg/m², pressing temperature 168-170°C, heating duration 7-10 minutes.
Key words: technology, composition, modified urea-formaldehyde resin, cotton stem filler, wood-plastic board, specific pressure, pressing temperature, heating duration, water absorption, tensile strength.

1 Introduction

Today, all over the world, special attention is paid to the development of an effective technology for producing composite wood-plastic materials that provide high physical and mechanical properties [1-7]. In this aspect, the development of composite wood-plastic materials and boards based on fillers - stems of annual plants that replace wood, and chemically modified polymer binders - is an urgent task.

In this regard, the goal of this work is to develop an effective technology for producing composite wood-plastic board materials for construction and furniture. appointments.

* Corresponding author: author@email.org

2 Methods

As an object of research for the production of wood filler, cotton stems of the Tashkent-1 variety were chosen, with a shelf life of up to 1 year, with a bulk weight of 0.38-0.40 g/cm 3 and a static bending strength of 60.0-88.0 MPa.

The method for producing composite wood-plastic board materials based on wood fillers from the stems of annual plants and polymer binders was carried out according to the method given in [8-9].

3 Results and discussion

Let us first consider the results of studies of the physicochemical modification of urea-formaldehyde resin with reactive compounds, which present experimental studies on the modification of urea-formaldehyde resins with reactive compounds and their hardening under pressing conditions.

The modifiers studied were benzyl chloride, epichlorohydrin , polyvinyl chloride and waste from the oil and fat industry in the form of gossypol resin. Using various methods of physicochemical analysis, additional structuring of the KF-MT resin was established due to interaction with modifiers.

It has been determined that the rate and degree of curing of the resin largely depend on the modification conditions, which include the content of the modifier, temperature and duration of modification. As can be seen from Table 1, a reduction in curing time is observed up to 10% modifier content. This indicates their catalytic role and increased activity of the functional groups of the polymer.

Based on the results of experiments for further use, gossypol resin was chosen as a modifier , as it is the most effective in terms of technological characteristics, availability and low cost. A study of the properties of gossypol resin showed that it consists of phenolic, fatty acid and unsaponifiable parts. It has been established that the IR spectra of the modifier contain COOH, -CH, -C=0 and other active reactive groups that chemically interact with the reactive groups of the resin and constituent parts of cotton stems.

Table 1. Dependence of the curing time of the KF-MT binder on the content, nature of the modifier and modification temperature (Modification time 3 hours)

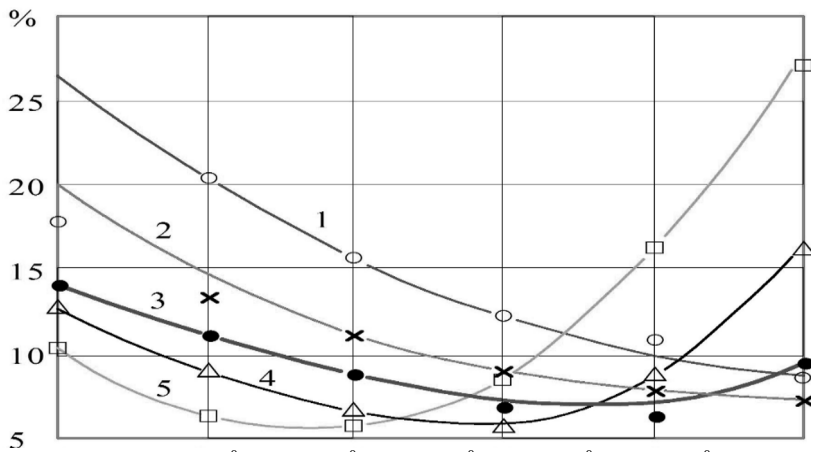
Modification temperature T ^{0}C	Contents _ modifier -tor, %	Curing time, sec			
		Epichlor hydride	Benzyl chloride	Polyvinyl chloride	Gossypum resin
	Control KF-MT-107				
50	5	74	91	68	97
	10	61	82	54	77
	15	180	149	112	109
	20	310	296	192	170
60	5	70	88	60	80
	10	102	107	97	84
	15	122	128	108	88
70	5	66	80	62	58
	10	70	93	74	62
	15	99	155	102	70

Thus, the improvement in the physical and mechanical properties of modified resins is associated with an increase in the completeness of curing of the resin, as well as with a

more complete realization of the chemical similarity between the urea-formaldehyde polymer and the modifier.

In order to identify the picture of the curing process under pressing conditions, studies were carried out in a wide temperature range of 150 – 200 0 C (Fig. 1).

A study of the dependence of weight loss after hydrolysis of resins on temperature and curing time showed that with increasing curing temperature, weight loss at all times initially decreases, reaching a minimum value, then weight loss rises again, with the exception of samples cured at 100 0 C (Fig . 1). In this case, the weight loss decreases significantly depending on the curing time and tends to be stable at the time values studied. In samples cured at 180 0 C due to the higher curing speed, weight loss decreases faster to the optimal value.



1 – 100 ^{0}C; 2 – 120 ^{0}C, 3 – 140 ^{0}C, 4 – 160 ^{0}C, 5 – 180 ^{0}C.

Fig.1. Dependence of weight loss during hydrolysis of the modified KF-MT resin on curing time at different temperatures

As can be seen from Figure 1, an increase in curing time at 180 0 C leads to a sharp increase in weight loss, which indicates destructive changes in the resin. The optimal value of the degree of curing for such samples is achieved at 5 minutes, but this time is not enough for the formation of a particle board during the pressing process.

Therefore, destructive phenomena in the resin can be prevented by lowering the temperature to 150-160 0 C, while the curing time increases to 7 minutes.

A comprehensive analysis of the results of experiments to determine optimal conditions (temperature and curing time) showed that for urea-formaldehyde resin modified with gossypol resin in a ratio of 10:1, the best curing temperature is 170-180 0 C and time 6-7 minutes.

Compared to the unmodified KF-MT resin, the curing time was reduced by 2-3 minutes, which indicates a more intense polymerization of the modified resin and an increase in its heat resistance.

Next, the influence of various technological factors (composition humidity, bending strength, water absorption , pressing pressure) on the physical, mechanical and other properties of the resulting wood-plastic board materials is considered.

The humidity of the package has a direct impact on the pressing mode. Particles with low humidity are not sufficiently plastic and do not ensure maximum convergence of contact surfaces during pressing, which requires increasing pressure and pressing time. With an increased moisture content, its evaporation prevents the

chemical interaction of filler particles and resin, and delamination of the slab also occurs, which also requires a change in the pressing mode.

The optimum moisture content of the package was found to be 8-10% from the point of view of manufacturability and efficiency of the pressing process.

As can be seen from Figure 2, with an increase in pressing pressure to 3.5 MPa, the density and strength properties of composite wood-plastic board materials improve dramatically. From graph 1 of Figure 2 it is clear that with an increase in compaction pressure from 1.9 to 4.5 MPa, the density increases sharply from 460 kg/m 3 to a limit equal to 920 kg/m 3 , and then stabilizes and with a further increase in compaction pressure does not is changing. The dependence of the ultimate bending and tensile strength perpendicular to the face on the pressing pressure is almost the same. With increasing pressing pressure, bending and tensile strength increases monotonically: at pressing pressure from 1.8 to 6 MPa, bending strength increases from 17 to 35 MPa, tensile strength from 0.4 to 0.9 MPa.

Water absorption and swelling on pressing pressure is distributed completely differently . With an increase in pressing pressure from 2 to 4 MPa, water absorption decreases from 43 to 37%; with a further increase in pressure, water absorption increases (at p = 7 MPa, W = 60%).

Swelling decreases with increasing pressing pressure (at p = 2 MPa Δ S = 40 %, at p = 7 MPa Δ S = 27%).

The study established that with an increase in pressing temperature in the range of 140-180 0 C, the physical and mechanical properties of the plates improve. A further increase in temperature leads to a deterioration in the properties of the slabs. This is explained by the fact that under the influence of heat, heating of the chip mass causes intense evaporation of the moisture contained in it. Due to this, a large excess pressure is created, under the influence of which steam rushes into the package. In this case, the steam carries with it heat, which it transfers to the inner layer of the bag, which leads to accelerated heating and hardening of the binder.

As the experimental results showed, at a temperature of 170 0 C and a pressing time of 4-5 minutes, the ultimate strength during static bending increases from 1.6 to 2.3 MPa over a pressing time of 9 minutes. Further, the value of bending strength does not change. At a temperature of 210 0 C, the ultimate strength during static bending increases from 2.1 MPa (pressing time 5 min) to 2.4 MPa (over 7 min), and with an increase in pressing time to 15 min, the bending strength decreases to 2 MPa.

As for the dependence of the swelling and water absorption of the slabs on the pressing time, the following can be seen: at a temperature of 170 0 C, swelling in 5 minutes decreases to 40%, and in 11 minutes to 23%, then with an increase in time to 18 minutes, it slowly increases by 27%.

At a temperature of 210 0 C, swelling decreases from 33% in 5 minutes to 23 % in 7 minutes, with a further sharp increase to 37% in 18 minutes

At a temperature of 170 0 C, water absorption in 2 minutes decreases from 62% to 51% in 5 minutes, then the process stabilizes, and at a temperature of 210 0 C, water absorption decreases from 58% in 2 minutes to 51 % in 5 minutes, then sharply increases to 66 % in 15 min.

A pilot batch of boards produced in a specialized enterprise for the production of wood-plastic boards LLC "PROSPER ALL" using the developed technology has improved physical and mechanical properties compared to the requirements of GOST 10632-00.

Table-2. Physico-mechanical properties of chipboard and wood-plastic composite boards made from cotton stalks and polymer binders

Indicators of material properties	Properties of chipboard according to GOST 10632-00 at density . 720-800 kg/m ^{3}	Properties of DPKP at various densities, kg/m ^{3}		
		550-640	650-700	720-800
Bending strength, MPa for thickness 16 mm, not less	15-18	17-20	23-27	27-30
Tensile strength perpendicular to the plate face, MPa, not less	0.3-0.35	0.45-0.6	0.80-0.9	0.9-1.1
Swelling, % no more than normal water resistance	20-30	27-30	18-25	15-18
Hardness, MPa (approximately)	19.6-39.2	30-35	35-42	38-48
Modulus of elasticity at static bending, MPa	1770-4410	1500-2000	2200-3000	3000-4500
Specific resistance to holding nails, N/m	2.45-2.65	2.3-2.5	2.5-3.0	2.6-3.1
Resistivity pulling out screws N/m	58800-117700	60000-90000	90000-110000	110000-120000

4 Conclusion

A scientifically based approach to creating a technology of wood -plastic composite board materials based on local and recycled raw materials with high physical and mechanical properties has been developed. At the same time, gossypol resin, epichlorohydrin , benzyl chloride and polyvinyl chloride have been proposed as modifiers for urea-formaldehyde resin .

A correlation has been revealed between the flexural strength of slabs (σ u), tensile strength (σ p) and water absorption (Δ w) with pressing parameters.

An optimal technological pressing mode has been developed: specific pressure 35 kg/cm2 , pressing temperature 170 0 C, heating duration 7-10 minutes.

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