**Analysis of Current Polymer Binders in Chipboard and Wood-Plastic Board Production and Their Disadvantages**

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**Abstract.** This research investigates how various reactive agents affect the curing of urea-formaldehyde resin (both pure and modified) in the production of wood-plastic composite board. We aimed to explore the ideal curing conditions for enhanced mechanical strength, durability, and environmental-friendliness of the materials attained. Using myriad modifiers, including epichlorohydrin, polyvinyl chloride, gossypol resin and more, we conducted testing and found certain compounds could significantly shorten the cure time and improve the performance of the resin. This is particularly important for the manufacturers who are looking for more energy saving and environmental friendly replacement for the existing binders that they are utilizing. Additionally, the study highlights the local resources that can be retrieved from locally available raw materials such as cotton stalks as an effective method for manufacturing high quality wood plastic composites. In summary, this work helps to produce more robust, fast-curing, and environmentally friendly materials, in line with contemporary industrial and ecological needs. This study increases understanding on the motivations for improving composite board production technologies.

**Keywords:** polymer, urea-formaldehyde resin, benzene chloride, epichlorohydrin, polyvinyl chloride, gossypol resin, lignin, composite wood-plastic plate material.

**INTRODUCTION**

Worldwide, the demand for wood products is increasing every day in the construction, furniture industry, and mechanical engineering. Currently, the demand for composite wood panel materials is increasing every day. The demand for organic composite materials based on modified binders is increasing. In this regard, there are no slab materials created on the basis of compositions in Uzbekistan. Lightweight materials will be of very high quality. Mainly on the basis of local raw materials and the use of secondary local products, very high-quality work is being carried out. This plays an important role in obtaining high-quality and environmentally friendly products. They are resistant to various influences in the production of composite wood-board materials based on such modifiers as polycondensation, urea-formaldehyde, epichlorohydrin, polyvinyl chloride, melamine, gossypol, and benzyl chloride. Certain works have been carried out in the republic and certain results have been achieved in providing construction, furniture industry, mechanical engineering with wood-plastic materials (DPM) based on crushed cotton stalks and polymer binders, in particular urea-formaldehyde resin. The existing urea-formaldehyde resin is toxic, has a long curing time under the conditions of pressing plates and does not sufficiently provide high physical and mechanical properties of the resulting plate materials.

In this context, enhancing the physicochemical and operational characteristics of urea-formaldehyde resin by incorporating reactive chemicals that satisfy production criteria, the development of composite wood-plastic board materials derived from fibrous pulp of cotton stems is a pressing issue [1-3].

**METHODS**

To study and analyze the states of polymer binders used in the production of chipboard and wood-plastic materials and plates (DPPM), in this article we considered phenol-formaldehyde, urea-formaldehyde and other polymer resins [4].

For the study, we selected the following: as a polymer binder - urea-formaldehyde resin of the KF-MT brand; as reactive compounds: benzene chloride, epichlorohydrin, polyvinyl chloride, gossypol resin, which is a waste of fat-and-oil production, lignin, which is an alcohol production.

The results of the study and their analysis. Let's consider phenol-formaldehyde and urea-formaldehyde resins widely used in the production of chipboard and DPPM [5].

Phenol-formaldehyde resins are the main component of adhesive compositions that have a valuable set of properties and are widely used in various industries. They are used to produce plastics (cured resins are called recites, cured in the presence of petroleum sulfuric, acids - carbolated, lactic acid-neoleucorites), synthetic adhesives, varnishes, sealants, switches, brake linings, bearings, and are also widely used in the manufacture of billiard balls.

These resins are used to produce as a binding component in the production of filled press compositions with various fillers (cellulose, fiberglass, wood flour), fiber-wood and chipboard boards, adhesives, impregnating and filling compositions (for plywood, woven and fiber-filled materials) [6-8].

Phenol-formaldehyde resin is a synthetic resin that is used to make chipboard. When exposed to hot and warm water, phenol-formaldehyde resin makes adhesive junctions very strong and resistant. This is why it is called a resin with increased water resistance.

The most common usage of phenol-formaldehyde resin is to make and glue chipboard (chipboard). This resin dries rapidly, has a strong binding, and is a light colour. Chipboard boards, which are produced from phenol-formaldehyde resins, do a good job of withstanding variations in humidity and temperature in the environment. When gluing chipboard, a low-toxic resin of the SFJ-3014 brand is used, which corresponds to the accepted standard (GOST 20907-75\*).

**TABLE 1.** Physico-chemical properties of phenol-formaldehyde resin SFJ-3014

|  |  |
| --- | --- |
| **Name** | **Indicators** |
| **Content of non-volatile substances (dry residue), %** | 45-55 |
| **Viscosity according to VZ-4,** | 20-35 |
| **Alkali content %** | 6,8 – 7,8 |
| **The content of phenol free % is not more than** | 0,25 |
| **Free formaldehyde content, % not more than** | 0,18 |
| **After boiling for one hour in water, the tensile strength of the plywood layer during chipping is -MPa, at least** | 1,65 |

Phenol-formaldehyde resins in the cured state are very fragile products and therefore are used in modified form in most cases. Non-modified resins have found applications mainly in gluing wood, foam and some other porous materials. Phenol-formaldehyde resins are obtained by polycondensation of phenol with formaldehyde.

Some characteristics of phenol-formaldehyde resins are shown in Table 2.

**TABLE 2.** Characteristics of phenol-formaldehyde resins

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Name** | **Trade name** | **Molecular weightсса** | **Melting point, 0C** | **Density, kg/m3** | **The content of methyl groups, %** |
| **p-tert-Butylphenol is a formaldehyde resin** | Fenofor B | 500-600 | 70-80 | 1100 | ≥13 |
| **p-tert-Octylphenol is a formaldehyde resin** | Fenofor О | 900-1200 | 85-90 | 1040 | ≥10 |
| **Bromomethylated p-tert-butylphenol-formaldehyde resin** | Fenofor BB | 1000-1400 | 65-85 | - | ≥13 |

Phenol-formaldehyde resins of the resin type with a molecular weight of 710-1200 are mainly used to produce adhesives. Novo lactic phenol-formaldehyde resins are used much less frequently, mainly in modified adhesives. Resins from cresols and substituted phenols are of less interest for the production of adhesives.

It should be noted that phenol-formaldehyde resin is not produced in our republic, due to the lack of raw materials for the production of phenol. In addition, they are very expensive and, accordingly, scarce, they will need to be purchased for foreign currency.

But the main disadvantage of phenol-formaldehyde resin is its toxicity. Therefore, as noted above, it is necessary to modify the phenol-formaldehyde resin or replace it with another, more non-toxic resin, i.e., urea-formaldehyde (carbamide).

It should be noted that in our republic, mainly in the production of wood-plastic board materials, urea-formaldehyde resin is used as a polymer binder [9-10].

Urea-formaldehyde resin (M-type resin fastener) is a product of polycondensation of urea and formaldehyde in the presence of a catalyst.

It is colorless and easily stained in bulk in any color.

The first products of urea condensation with formaldehyde (carbamide resins) were obtained as early as 1896, but the production of urea-aldehyde resins was established only in 1925-1928.

Urea-formaldehyde resin is obtained by the interaction of urea and formaldehyde taken in the form of an aqueous solution - formalin. Synthesis is carried out in two stages: first, it is formed by the interaction of urea and formaldehyde in the presence of ammonia of dimethylolurea, which is not yet a polymer; then, when acid (for example, oxalic acid) is added, condensation occurs, leading to the formation of a polymer. In a porcelain cup, urea, formalin, and a small amount of ammonia solution are mixed together. Stir the mixture and let it simmer for 8 to 15 minutes. The mixture's viscosity is slowly getting thicker. After that, oxalic acid is added, mixed in, and the mixture is put into a test tube. Put the test tube in a thermostat and keep it there for an hour at 55–65 0C. In this situation, the material hardens and changes from viscous to vitreous.

You can make urea-formaldehyde resins for glue using either periodic or continuous techniques.

To harden the urea-formaldehyde resin, a 32% solution of ammonium chloride was added.

Butanolizing urea-formaldehyde resins works best in an atmosphere that is a little acidic. The polycondensation process is still going on at the same time.

Making urea-formaldehyde resin is pretty much the same as what was just discussed. Fill the test tube with one-third of a saturated urea solution in formalin. Add 3 drops of 22% hydrochloric acid and heat the mixture over low heat until it boils. After that, it boils on its own, gets cloudy, and thickens quickly until it feels like rubber.

Urea-formaldehyde resins can also be used to make adhesives that don't decay, wood bugs, or light.

It can be only used pure urea-formaldehyde resins to soak paper if it is put a cover layer over the film's surface thereafter.

Urea-formaldehyde resins are used to make furniture, joinery, and other things that need to stick together. They are also used to make chipboard, fibreboard, and plywood.

Formaldehyde and carbamide condensation products are very common glues for wood, plywood, and other wood products.

To determine the effect of temperature and reaction duration on the content of galloidions and the curing time of the resin, were investigated the modification of urea-formaldehyde resin under various conditions (see Table 3).

**TABLE 3.** The dependence of the curing time of the compositions on the content, the nature of the modifier and the reaction temperature. The duration of the reaction is 3 hours

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Reaction temperature, 0C** | **Modifier** | **Мodifier content** | | | | | |
| 0 | 1 | 3 | 5 | 15 | 25 |
| 55 | Epichlorohydrin | 108 | 100 | 90 | 74 | 35 | 315 |
| Benzyl chloride | 105 | 102 | 96 | 91 | 85 | 290 |
| Polyvinyl Chloride | 108 | 95 | 81 | 68 | 54 | 195 |
| Gossypole resin | 105 | 100 | 92 | 78 | 35 | 305 |
| 65 | Epichlorohydrin | 106 | 93 | 83 | 70 | 52 | 310 |
| Benzyl chloride | 107 | 95 | 91 | 88 | 75 | 280 |
| Polyvinyl Chloride | 107 | 88 | 77 | 60 | 47 | 185 |
| Gossypol resin | 107 | 89 | 78 | 66 | 48 | 305 |
| 75 | Epichlorohydrin | 108 | 81 | 78 | 66 | 55 | 300 |
| Benzyl chloride | 108 | 89 | 86 | 80 | 75 | 270 |
| Polyvinyl Chloride | 105 | 73 | 70 | 52 | 44 | 180 |
| Gossypole resin | 108 | 78 | 74 | 61 | 45 | 290 |

Studies have shown that with increasing reaction temperature and duration, the yield of the modified resin increases, and the curing time of the resins decreases. The most optimal condition for modification is a temperature of - 60 0C, the reaction time is 3 hours. It was found that of the four selected modifiers, benzyl chloride has relatively little effect on the curing of urea-formaldehyde resin. Therefore, polyvinyl chloride and epichlorohydrin as modifying additives were mainly selected for further use in the production of plates.

Next, the influence of technological factors on the curing process of modified and initial urea-formaldehyde resins is considered (see Table 4).

**TABLE 4.** Dependence of the curing time of the CFMT binder on the content, nature of the modifier and modification temperature (modification time 3 hours)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Modification temperature**  **T, 0C** | **Modifier content 0%** | **Curing time, sec.** | | | | |
| **Epichlorohydrin** | **Benzyl Chloride** | **PVC** | **Gossypole Resin** | **Lignin** |
| **Control KFMT – 107** | | | | | | |
| 50 | 5 | 74 | 91 | 68 | 97 | 99 |
| 10 | 61 | 82 | 54 | 77 | 82 |
| 15 | 180 | 149 | 112 | 109 | 112 |
| 20 | 310 | 295 | 192 | 170 | 174 |
| 60 | 5 | 70 | 88 | 60 | 80 | 86 |
| 10 | 52 | 77 | 47 | 60 | 62 |
| 15 | 122 | 128 | 108 | 88 | 92 |
| 70 | 5 | 66 | 80 | 52 | 88 | 92 |
| 10 | 50 | 73 | 44 | 78 | 82 |
| 15 | 99 | 155 | 102 | 100 | 112 |

As can be seen from the table, a reduction in curing time is observed up to 10% modifier content. This indicates its catalyzing role and an increase in the activity of the functional groups of the polymer.

**RESULTS AND DISCUSSION**

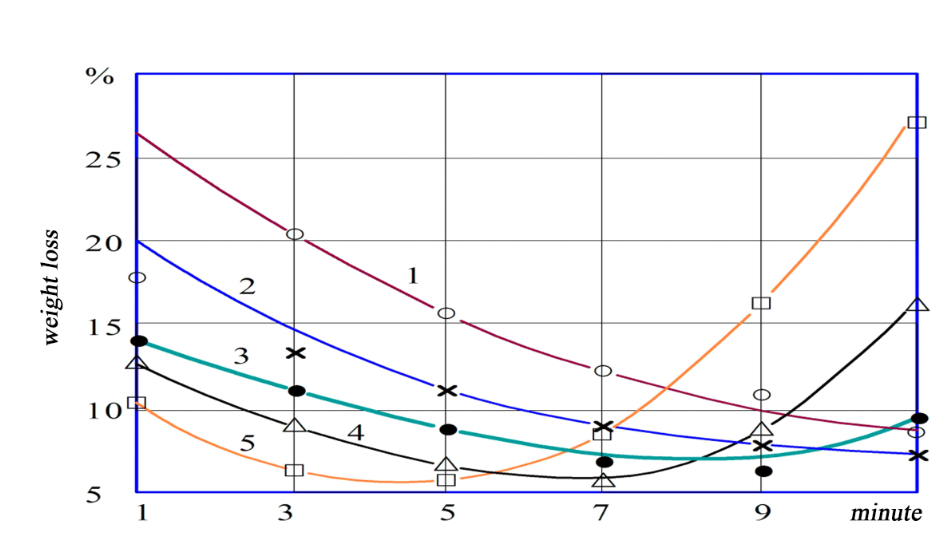
According to the results of experiments, gossypol resin was chosen as the second modifier for further research, and lignin was chosen as the third one, as the most effective in terms of technological characteristics, resin properties, accessibility and cheapness

The study of the properties of gossypol resin has shown that it consists of phenol, fatty acid, and unsaponifiable parts. The IR spectra of the modifier indicate the presence of -COOH, -OH, -C=0 and other active reactive groups in it, which chemically interact with both reactive resin groups and constituent parts of cotton stems.

Further experiments were carried out on the curing of the binder in a wide range of temperatures and time. The degree of curing of the modified resin was determined by several methods of chemical analysis: extraction in a sox let apparatus, hydrolysis, and thermal analysis. The study of the dependence of weight loss after resin hydrolysis on temperature and curing time showed that with an increase in the curing temperature, weight loss at all time values decreases at the beginning, reaching a minimum value, then rises again with the exception of samples cured at 100 0C (see Figure 1).

At the same time, weight loss decreases depending on the curing time and tends to be stable at the studied time values. In samples cured at 180 0C, due to the higher curing rate, weight loss decreases faster to the optimal value.

As can be seen from Figure 1, the duration of the curing process at 175 0C 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 to form a chipboard during the pressing process. Destructive phenomena in the resin can be prevented by reducing the temperature to 155-160 0C, while the curing time increases to 6.8 minutes.



**FIGURE 1.** The dependence of weight loss during hydrolysis of modified CFMT resin on the curing time at different temperatures: 1– 100 0S, 2– 1150 0S, 3– 135 0S, 4– 150 0S, 5– 175 0S.

It was found that modified resins cured at a temperature of 165-175 0C and a curing time of 6-7 minutes have the highest thermal stability. A further increase in temperature and time leads to an increase in weight loss during thermal decomposition, which is explained by destructive phenomena in the curing process due to the rupture of chemical bonds, which correlate with the above data.

**CONCLUSION**

Thus, it can be concluded that the physico-chemical properties of chipboard and wood-plastic boards using urea-formaldehyde resin are obtained with low properties, insufficiently durable and do not fully meet the requirements of GOST. In this regard, there is a need to modify urea-formaldehyde resin by physic-chemical methods and improve their adhesive and physic-mechanical properties in order to manufacture wood-plastic plates with high strength and performance properties and durability.

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