ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 8, Issue 10 , October 2021

Study of modified urea-formaldehyde resin properties

A. A. Abdurahimov, M.E. Mavlanova

Associate professor of department "Construction materials and chemistry" of Tashkent Architecture and Construction Institute, Republic of Uzbekistan
Senior lecturer of department "Construction materials and chemistry" of Tashkent Architecture and Construction Institute, Republic of Uzbekistan

ABSTRACT: In this paper we consider some issues of creating new modified polymeric binders for particle board materials. Local raw material resources are used as a modifier. The optimum amounts of introduced modifier and its influence on physical and chemical properties of urea-formaldehyde binder have been revealed. As a result of the research, the optimum amount of the inoculant was found, where high physico-chemical properties of the binder and products based on it are achieved. The obtained wood boards fully meet the standard requirements for board materials.

KEY WORDS urea-formaldehyde binder, modifier, curing time, viability, viscosity.

I. INTRODUCTION

Intensive development of polymer technology has led to the creation of a variety of materials based on them. Thermosetting polymers in large quantities are used in the production of chipboard and fibreboard, plywood, furniture industry.

The economic program of social development of the country provides the rational and economical use of all kinds of resources, reducing their losses, rapid transition to resource-saving and wasteless technologies, as well as the significant improvement of the use of secondary resources [1,2].

In this case, an important economic task is the mobilisation of secondary resources. This task can be considered as a part of environmental protection.
The Republic of Uzbekistan will need more than 250 thousand m3 of chipboard annually, of which more than 92% is imported from other countries.

As a polymeric binder for the production of chip boards, scarce carbamide-formaldehyde resins are used, the share of the cost of which in the cost of the boards is about 45% [5]. Therefore, the problem of consumption of these resins and improving the quality of wood boards becomes relevant. In the oil and fat enterprises of the country the multi-tonnage wastes of production are formed. Very promising is the use of gossypol resin for modification of urea-formaldehyde resins. The above-mentioned circumstance and urgency of the problem have determined the direction of research.

II. SYSTEM VALUE

The article focuses on improving the quality of urea-formaldehyde binder used for making chipboard. It is achieved by the introduction in the binder composition of secondary waste oil and fat production, which is ecologically and economically feasible. The literature review is presented in section III, the methodology is explained in section IV and experimental results are discussed in section V. And section VI discusses the future study and conclusion.

III. LITERATURE STUDY

Polymeric binders used in the wood industry to produce materials and products operated in atmospheric conditions have higher requirements in terms of hydrophobicity and moisture resistance. It is known that of all amidoaldehyde polymers urea-based polymers are the most moisture-sensitive [1-3]. This is thought to be primarily due to the low

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International Journal of Advanced Research in Science, Engineering and Technology
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hydrolytic resistance of amide and methyleneether bonds, a low degree of cross-linking during curing, and the hydrophilicity of the methylene groups present in the cured polymer. Elimination or reduction of these disadvantages can be achieved by modification of amidoaldehyde resins with compounds containing reactive groups. As a modifier we chose gossypol resin (tar), which is a waste product of the oil and fat industry [4]. This substance is inert to water and contains various functional groups (-OH, -COOH etc.) which can react with reactive groups of urea polymer resulting in shorter urea polymer curing time due to increase of its molecular weight and degree of structuring.

IV. METHODOLOGY

Urea-formaldehyde resin was modified in a three-neck flask equipped with an agitator, a thermometer and a refrigerator at different ratios of resin-modifier (temperature 70 °C, reaction time 3 h). The cured resins were hydrolyzed in aqueous medium at 60°C. The mass loss was determined according to the formula

$$Q = \frac{Q_2 - Q_1}{Q_1} \times 100\%,$$

where Q is mass loss, Q_1 is mass before hydrolysis, Q_2 is mass after hydrolysis.

To determine the optimum gossypol resin content the urea-formaldehyde resin was modified with different ratios of resin-modifier. It was found that the introduction of the modifier up to 10% increases the resistance to hydrolysis. A further increase in gossypol resin content markedly reduces hydrolytic resistance. Therefore, for further investigations the following was chosen

Urea-formaldehyde resin - modifier ratio of 90:10.

The effect of temperature and curing time on the hydrolytic stability of the modified resins was investigated (Fig. 1 and Table 1).

The following types of work were carried out to obtain the chipboards: Preparation of gossypol resin by dissolving it in white spirit in an I:I ratio. The wood was chopped to a length of 2-3 cm and a width of 0.2-0.4 cm. The accepted dimension of the chips was determined from previous works. The total amount of binder was 10 % of the absolutely dry chips. The binder modification was carried out at a temperature of 60 °C for 3 hours. Binder concentration was 64%. Pressing temperature - 160 °C, pressing time - 0,30 mm/min, thickness of board - 16 mm, pressure - 2,5 MPa.

V. EXPERIMENTAL RESULTS

The study of the influence of gossypol resin on the physicochemical properties of urea-formaldehyde binder showed that the modifier positively influences the polymer properties, increasing the hydrophobicity, thermal stability, adhesion ability, etc. The introduction of the modifier has a positive effect on the hydrolytic stability of the cured polymer. The water resistance of the cured resin increases dramatically with increasing curing temperature. The modification of urea polymer and the curing process increases the curing depth and the molecular weight of the resin. In order to determine the optimum curing temperature and time where the most complete polycondensation is achieved, the dependence of the mass loss on the above parameters has been studied.

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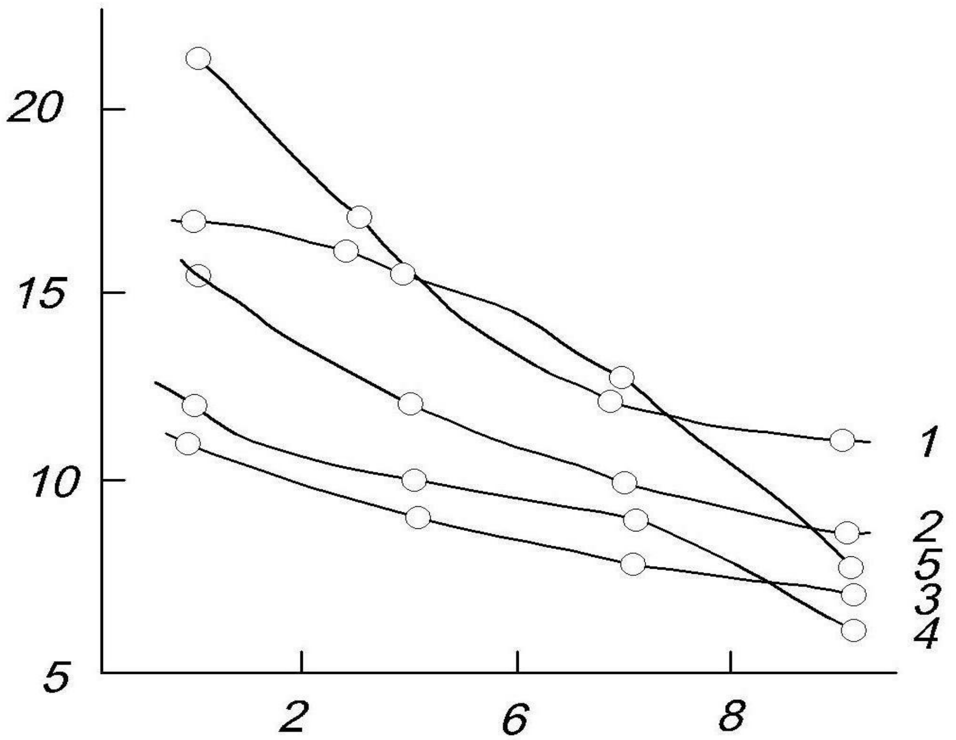

Fig. 1 Binder mass loss vs. curing time.
(1 at 100^{0}C, 2 at 120^{0}C, 3 at 140^{0}C, 4 at 160^{0}C, 5 at 180^{0}C,)

Table 1
Hydrolytic stability of urea resins

Curing temperature, °C	Mass loss, %							
	Curing time, min							
	1	3	5	7	1	3	5	7
	Source				Modified			
100	37,5	20,8	19,8	22,1	22,0	16,1	11,7	10,5
120	22,0	15,6	12,0	10,8	15,0	11,0	10,2	8,0
140	21,0	12,4	11,3	10,0	10,8	9,1	7,5	10,9
160	16,0	13,5	13,3	8,6	11,6	10,5	9,1	5,2
180	19,4	15,6	13,3	10,4	16,5	15,0	11,7	7,1

It was found that the introduction of the modifier significantly affects the hydrolytic stability of the resin (weight loss during hydrolysis corresponds to 30-40%). This indicates additional structuring due to chemical interaction accompanying the introduction of the modifier. The oligomers cured at 160°C and t_(off) = 5 min have a higher hydrolytic stability. When these parameters are entrained, the hydrolysis resistance decreases.
It was interesting to investigate the effect of additional heat treatment of cured resins on their hydrolytic stability. The results obtained indicate an increase in the hydrolytic stability of the modified resin with an additional heat treatment. The weight loss during hydrolysis is reduced by 20-25 % (Fig. 2, Table 2).

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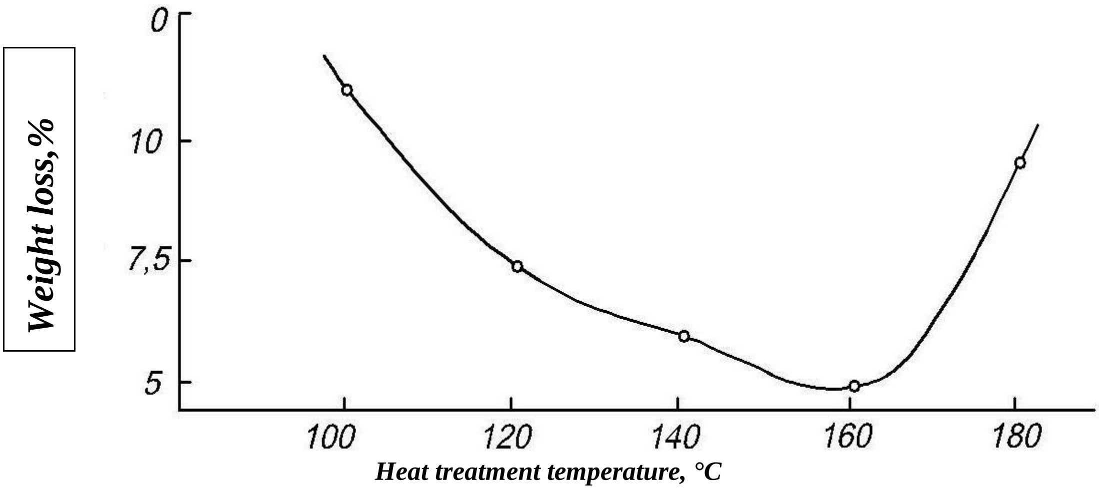

Figure 2. Dependence of the weight loss during hydrolysis of the modified resin on the heat treatment temperature.

Table 2
Effect of an additional heat treatment on the hydrolytic stability of urea resins

Heat treatment temperature, °C	Mass loss, %							
	Treatment duration, min							
	1	3	5	7	1	3	5	7
	Source				Modified			
100	25,1	17,5	14,5	14	17,8	12,5	11,0	10,6
120	14,2	12,2	11,3	10,8	8,5	7,2	6,8	8,8
140	21,0	11,7	8,4	7,2	7,8	6,3	6,0	5,5
160	12,7	12,0	11,0	9,6	6,6	5,2	4,0	4,8
180	13,5	11,2	9,8	9,0	11,5	10,2	9,8	9,1

Analyzing the experimental data obtained, it can be assumed that in the process of heat treatment at elevated temperatures (120-160 ° C), additional crosslinking of the modified resin deepens, which increases the resistance to hydrolysis. However, it is not possible to achieve a significant improvement in water resistance by heat treatment.

Thus, having various reactive groups in its structure, gossypol resin enters into chemical interaction with the urea oligomer.
This leads to additional structure formation, increasing hydrolytic stability. Heat treatment of the modified resin after curing increases its water resistance, since chemical transformations occur, which increase the frequency of intermolecular crosslinks.

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