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WOOD-PARTICLE BOARDS OF INTENSE WATER RESISTANCE BASED ON HYDROPHOBIC UREA-FORMALDEHYDE RESIN

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ABSTRACT

Research work has been carried out in view of establishing the possibilities of obtaining particle boards with intensified water- resistance on the bases of urea-formaldehyde resin and hydrophobic composition of hideglue-paraffin emulsion. The results of the research prove that the hydrophobic emulsion used is compatible with the urea resin and that it guarantees a high degree of hydrophobization of the particle boards /water- sorption below 25 %, thickness of swelling below 4 %/ under relatively high strength indicators /bending strength above 18 N/mm², internal bond strength above 0,45 N/mm²/. On the basis of a planned experiment the impact of the following technological factors has been established: content and concentration of the hydrophobic solution, pressing temperature and pressing time on the properties of particle boards based on hydrophobic urea-formaldehyde resin. The following values have been defined as optimal: content 2 %, concentration 30 %, pressing temperature 177,5 ^{o}C and pressing time 0,5 min/mm.

Key words: particle boards; intensified water- resistance; urea-formaldehyde resin; hydrophobic emulsion; technological factors

INTRODUCTION

The permanent intensification of the utilization of wood-particle boards (WPBs) has been determining and stimulating as the development of technique and technologies, so the adoption of more effective adhesives which are important for the qualitative features and cost price of the finished product. In each particular country, the choice of adhesives is determined mainly by the level of the technical-and- economic development of this same country and by the availability of the necessary raw materials.

The properties of WPBs are determined, to a great extent, by the kind and amount of adhesive. Technologies using adhesives based on melamine- formaldehyde resin or on urea- formaldehyde, isocyanate, and other resins, have been applied to, and widely used in the world practice, for production of boards of intense water resistance. Finding the adhesive which is economically most expedient for the production of WPBs of intense water resistance while guaranteeing high values of the strength parameters of any environmentally sound production, is of interest to practice. The results from the experiments with various adhesives such as urea – formaldehyde resin (UFR), melamine-formaldehyde resin (MFR), phenol-formaldehyde resin (PFR), and isocyanate resin [3, 4, 6, 8], which have been made so far, give a reason for concluding that producing water resistant WPBs with comparatively high values of their strength parameters, can be achieved while using isocyanate and melamine-formaldehyde resins. It should be noted, however, that these adhesives are still deficit and expensive.

Urea-formaldehyde resin (UFR) is the adhesive which is most widely used in the production of WPBs. It is comparatively cheep, it guarantees that the boards will have the necessary strength, but it doesn't make them water resistant enough. It has been found that mechanical mixtures of UFR with MFR, PFR or isocyanate resin (ICR) [1, 3, 5, 8] can be successfully used for intensifying the water resistance of WPBs. Besides, the mixtures of UFR with ICR and of UFR with MFR, have appeared to be more efficient from the technological and economic points of view. Studies of the possibility for intensifying the water resistance of WPBs which have been glued with emulsions of UFR and hydrophobic additions of bone- glues and paraffin [2, 7, 9], show that WPBs glued with UFR and the bone– glue– and- paraffin addition, called EMULGEN, have intense water resistance and comparatively high values of their strength parameters. Besides, when using EMULGEN as a UFR-modifer, boards of lower proportion of free formaldehyde are produced.

Investigating the effects of technological factors on the properties of water resistant WPBs in view of finding the optimum values of the temperature and duration of pressing, as well as the optimum concentration of the hydrophobic solution, is of substantial importance for practice. This is why the purpose of the present study is to find and optimize the effects of the percentages of the hydrophobic agents and of the concentration of the solution in the adhesive of UFR and EMULGEN. On the other hand, the parameters of the pressing regime, i.e. temperature and duration, are to be found and optimized, too.

MAKING REGRESSION MODELS

Optimizing the composition of the adhesive of UFR and EMULGEN, for the production of WPBs of intense water- resistance, as well as the pressing regime, is to be done while using a chosen, suitable mathematical model. A D-optimum plan was accepted for carrying out the experimental studies. The plan involved a complete, quadratic polynomial and a cube- like space of changes of the factors of fundamental importance for the production of WPBs f intense water resistance and guaranteed standard strength parameters and low toxicity. The criteria of optimum are definitely connected with the parameters of water resistance (water absorption and thickness swelling). Besides, there are requirements to the boards (as to a building material used in furniture industry), with respect to their mechanical properties, i.e. bending strength (G'_b), and tensile strength perpendicular to the plane ($G_{T\perp}$). So, a multipurpose optimization was carried out in this case, with respect to the target parameters, i.e. water absorption and thickness swelling which are limiting conditions of bending strength and tensile strength perpendicular to the plane.

It was found for the factors of fundamental importance for WPBs' water resistance, that they could be divided into two groups- factors determining the adhesive's composition, and technological factors of board pressing. The main factors were accepted to vary in broad ranges in accordance with the targets of the optimized task. They are presented in Table 1. the rest of the factors, i.e. amounts of resin in the surface (RSL) and intermediate (RIL) layers of the boards, the concentrations of the adhesive solution in the surface (C_{SL}) and the intermediate (C_{IL}) layers, had stable values, at an intermediate level, as follows: RSL=12 %, RIL= 8,5 %, C_{SL} = 49,5 %, and C_{IL}= 52,5 %.

Table 1: Investigated factors and levels of varying

Names of factors	Symbols	Level of varying

	Symbol	Code	Lower (-1)	Intermediate (0)	Upper (1)
Proportion of hydrophobic agents, (%)	P_{ha}	X_1	1	2	3
Concentration of hydrophobic Solution, (%)	C_{ha}	X_2	25	30	35
Pressing temperature (^oC)	T	X_3	170	185	200
Pressing time, min/mm	τ	X_4	0,35	0,50	0,65

Based on the result from the production of unilayerous WPBs of a density of 780 kg/m^3 and of a thickness of 16 mm which were made of beech particles (industrial residues chipped) and an adhesive of UFR and EMULGEN, under laboratory conditions by a matrix of a planned, multi-factor experiment, regression equations were worked out for the physico-mechanical properties: water absorption (A), thickness swelling (α_δ), bending strength (G_b) and internal bond strength ($G_T\perp$). The values of their coefficients are presented in table 2.

Table 2: Values of the coefficients in the regression models of the WPBs' properties

№	Symbols of coefficients	A (%)	α_δ (%)	G_b (N/mm²)	$G_T\perp$ (N/mm²)
1	B (0 0)	21,47	3,10	19,91	0,580
2	B (1 0)	-2,20	-1,41	-0,38	-0,010
3	B (2 0)	0,31	0,32	0,0	-0,002
4	B (3 0)	-3,17	-0,58	0,05	0,002
5	B (4 0)	1,54	0,19	-0,83	-0,020
6	B (1 2)	-0,91	-0,09	0,81	0,031
7	B (1 3)	-1,64	-0,37	0,07	0,002
8	B (1 4)	-3,01	-0,86	0,29	0,016
9	B (2 3)	0,00	-0,64	0,0	0,010
10	B (2 4)	2,25	0,46	0,09	0,007
11	B (3 4)	-2,63	-0,48	0,08	0,001
12	B (1 1)	-0,25	-0,04	1,70	0,044
13	B (2 2)	2,32	0,00	0,11	0,023
14	B (3 3)	-4,72	-1,20	0,85	0,018
15	B (4 4)	- 1,64	0,92	-1,46	-0,060

The unidimensional sections of the models have been graphically presented for each factor scanned at five levels while keeping the rest of the factors at their constant lower, intermediate and upper levels.

EFFECTS OF THE AMOUNT OF HYDROPHOBIC AGENTS AND OF THE CONCENTRATION OF THE HYDROPHOBIC SOLUTION ON THE PROPERTIES OF WPBS.

The effects of the amounts of the hydrophobic agents (P_{ha}) on the water absorption and thickness swelling of WPBs, are presented by graphs, on Fig. 1 (a and b). As the studied factor is significant for the indices characterizing boards' water resistance, the relation of these properties at three different levels of scanning (-1; 0; 1) have been depicted by the graphs. They show that water absorption decreases from 35 % down to 19 %, and thickness swelling- from 8,8 % down to 1,2 %, with the increase of the amount of the hydrophobic solution. When scanning the factors at the lower level, high values are obtained as of the determinant factor, so of water absorption and thickness swelling. At constant upper and intermediate levels of factors, the values of A are lower than 25 % and those of α_δ are lower than 6,5 %.The graphs also reveal that the most favorable amount (in per cent) of the hydrophobic agents is a total of 2 %, at constant intermediate (0) levels of the rest of the factors with which the WPBs' water-resistant properties have the following values: A= 21,5%; α_δ= 3,1 %.

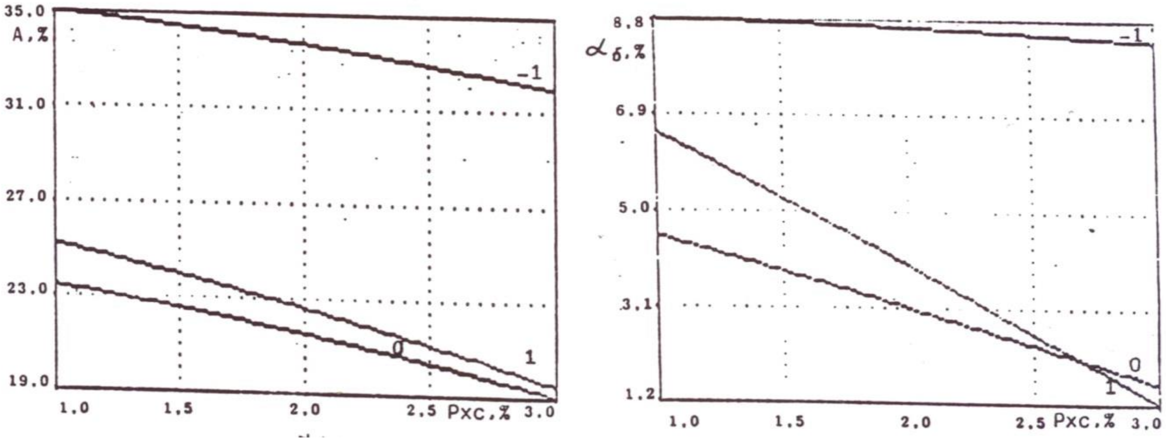

Figure 1: Effects of the amount of the hydrophobic agents (Pha) on the water absorption and thickness swelling of water-resistant WPBs' with X2=X3=X4 and levels of varying „-1", „0", „1".

The effects of the concentration of the hydrophobic solution in the UFR-based adhesive, on the water absorption and thickness swelling of WPBs, are presented on Fig. 2 (a and b). One can report from the graphs about A and α_δ, that at constant lower levels of scanning the rest of the factors, high values of the water absorption and thickness swelling of WPBs, are obtained. At constant upper and intermediate levels, and with increasing the hydrophobic solution's concentration, the values of the parameters of WPBs' water resistance diminish, too. This can be explained by the negative effect of the increased concentration of EMULGEN on the homogeneity of the adhesive's composition. Minimum values of water absorption (12,1 %) and thickness swelling (0,15 %) are obtained with a 25 % concentration of the hydrophobic solution, at constant upper levels of the rest of the factors investigated. Because of economic considerations, the optimum values of water absorption (21,4 %) and thickness swelling (3,15 %) should be those with a 30 % concentration of the hydrophobic solution.

The effects of the amount and concentration of the hydrophobic addition EMULGEN in the composition of the UFR-based adhesive, on the bending strength (G_b) and the tensile strength perpendicular to the plane, of WPBs, are positive at all the levels of varying of the factors, yet the values obtained, i.e. G_b= 18,6 up to 22,2 N/mm² and $G_{T\perp}$= 0,49 up to 0,65 N/mm², exceed those required by the Bulgarian state Standard of I (the best) quality. This inference has been confirmed as well after investigating the effects of the temperature and duration of WPB pressing.

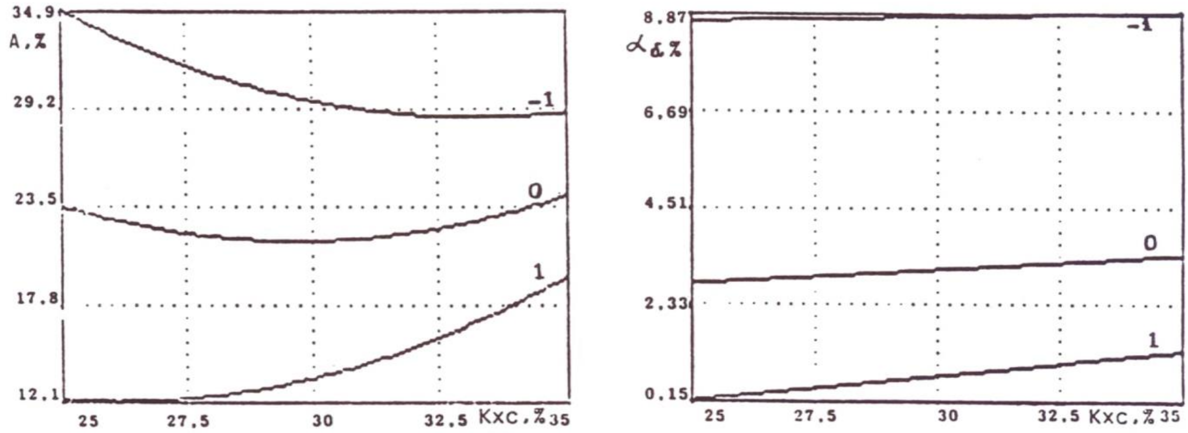

Figure 2: Effects of the concentration of the hydrophobic solution (Cha) on the water absorption and thickness swelling of water-resistant WPBs' with X1=X3=X4 and levels of varying „-1", „0", „1".

EFFECTS OF THE TEMPERATURE AND DURATION OF PRESSING ON THE PROPERTIES OF WATER-RESISTANT WOOD-PARTICLE BOARDS

Raising the temperature results in a decrease of the water absorption and thickness swelling of WPBs glued with an adhesive mixture of UFR and EMULGEN [Fig. 3, (a and b)]. At constant intermediate (0) levels of the rest of the factors, the differences in the values of water- resistant properties are negligible, yet minimum water absorption (13,6 %) and thickness swelling (1,3 %) occur at a pressing temperature of 200 ^{o}C. While scanning the factors at the upper level, one can report bigger differences in the values of A and α_{δ}. One can see that a temperature higher that 170 ^{o}C is more favorable for producing WPBs glued with the adhesive mixture of UFR and the hydrophobic solution EMULGEN. A temperature of about 185 ^{o}C is quite satisfactory from economic and practical points of view.

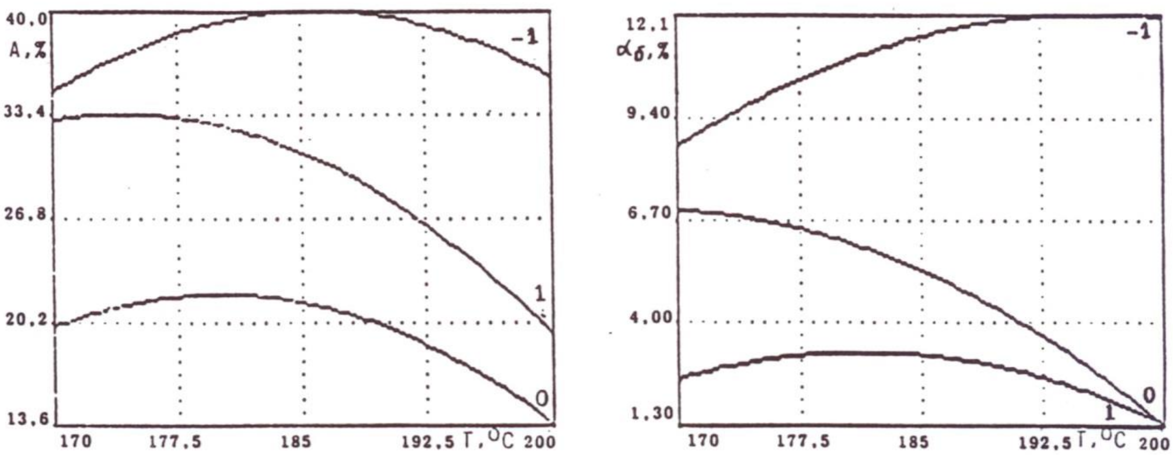

Figure 3: Effects ot the pressing temperature (T) on the water absorption and thickness swelling of water-resistant WPBs' with X1=X2=X4 and levels of varying „-1", „0", „1".

Fig. 4 presents the effect of relative duration of pressing (τ) on the water- resistant properties of WPBs, i.e. water absorption and thickness swelling. Prolonging τ from 0,35 up to 0,65 min/mm results in minimum changes in the value of water absorption. At constant intermediate (0) levels of the rest of the factors, A increases from 18,4 % up to 21,7 %, yet it decreases from 22,0 % down to 20,0 % at upper level of scanning the factors. Prolonging the duration of pressing, and after setting the factors at a lower levels of varying, the values of water absorption are of the order of 35,0 up to 43,6 %. A more complete polycondensation of resin is known to occur with a longer duration of pressing. In this case, the availability of hydrophobic agents in the adhesive's composition results in a higher responding capacity of resin, so that board of better, water- resistant capacities can be produced even with a shorter duration of pressing. The inference from the graph of α_δ, is similar. Minimum values of thickness swelling of WPBs (0,19 %), can be obtained with a pressing time of 0,5 min/mm and the values of this feature are very low when scanning the rest of the factors at constant, upper levels. When scanning the factors at intermediate levels, the values of thickness swelling slightly change – by about 3,5 % ± 2 % with the increase of pressing time, and they gradually increase when τ is longer that 0,5 min/mm. One can see on the graphs of the water absorption and thickness swelling that the time necessary for the production of water- resistant WPBs, is from 0,425 up to 0,5 min/mm, where A= 20,4 ÷ 21,56 % and α_δ = 3,3 ÷ 3,4 %, at a constant intermediate levels of the rest of the factors.

The optimum values determined for the temperature and duration of pressing, with respect to the hygroscopic properties of the boards, are quite satisfactory with respect to the strength parameters, as well (G_b > 18 N/mm² and $G_{T\perp}$ > 0.4 N/mm²).

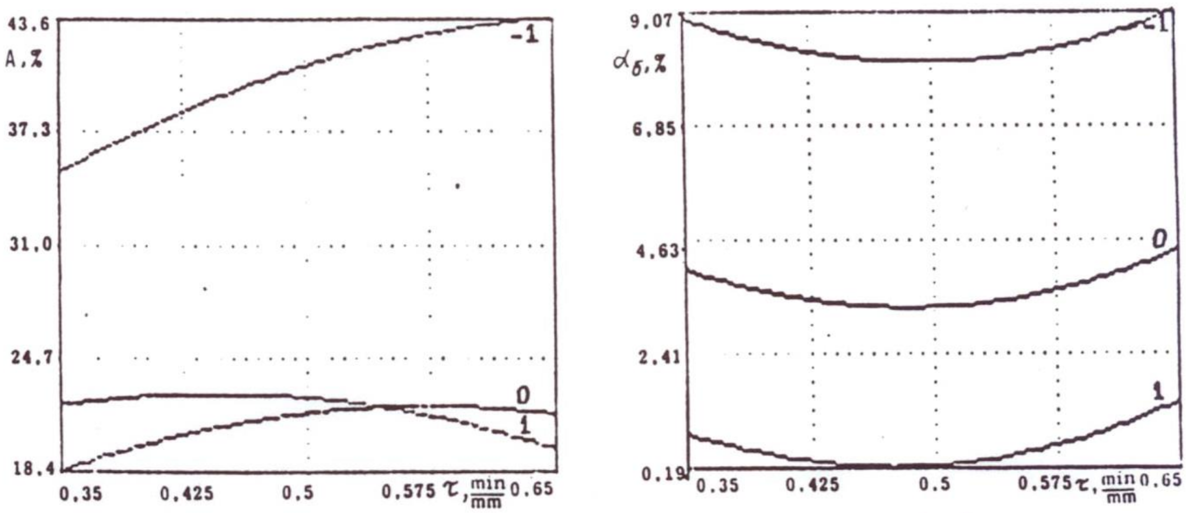

Figure 4: Effects of the pressing time (τ) on the water absorption and thickness swelling of water-resistant WPBs' with X1=X2=X3 and levels of varying „-1", „0", „1".

CONCLUSION

Based on experimental studies carried out in view of intensifying the water resistance of WPBs glued with UFR, the following, more important conclusions can be made:

1. A comparatively high water resistance (water absorption less than 25 % and thickness swelling less than 4 %) and good parameters of strength (G_b more than 18 N/mm² and $G_{T\perp}$ >= more than 0.4 N/mm²) of

the boards, can be guaranteed when using hydrophobic urea- formaldehyde resin mixed with EMULGEN (the emulsion of bone-glue and paraffin).

2. Adequate, regression equations have been worked out for the main physico- mechanical properties of the boards (i.e. water absorption, thickness swelling, bending strength and internal bond strength), in accordance with the technological factors (i.e. percentages of hydrophobic agents, concentration of the hydrophobic solution, and temperature and time pressing).
3. The values of the technological factors investigated, have been optimized based on the graphic relation resulting from the scanning of the equations about the main criteria of water resistance of the WPBs (i.e. water absorption and thickness swelling) while meeting the requirements for their standard properties of strength. These values are presented as follows: total proportion of the hydrophobic agents – 2 %, concentration of the hydrophobic solution – 30 %, temperature of the plots of the press – 177,5 ^{o} C, and pressing time – 0,5 min/mm.

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