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BRIEF COMMUNICATIONS

Combined Action of Acid Hardener and Constant Magnetic Field on the Process of Hardening Carbamide-Formaldehyde Resins

S. S. Nikulin, V. M. Popov, and A. V. Latynin

Voronezh State Forestry Engineering Academy, Voronezh, Russia

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Abstract—Combined action of an acid hardener and a constant magnetic field on the process of hardening carbamide-formaldehyde resins and on the strength of a glue line was studied.

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At present carbamide-formaldehyde resins (CFR) are widely used in Russian woodworking industry. Ammonium chloride is widely applied in the hot glueing with the use of CFR. For glueing without heat (cold hardening) oxalic or orthophosphoric acid is applied [1]. However thus obtained glued wood does not possess a full complex of required properties. Frequently adhesive-bonded joints in wood articles have low strength characteristics. Therefore a search for new glue compositions and hardening modes, which allow increasing strength of adhesive joint is of a great importance.

Chemical industry waste products are promising in this respect as they contain reactive compounds, which have a complex of positive properties and are capable to give new properties to a glueing material. Precisely of this sort is the waste product of the phthalic or maleic anhydride production [2] containing maleic acid as the main component, which can be an active structure-forming agent for cold hardening CFR instead of oxalic acid. Therewith it is important to note that even to date this waste product does not find application and pollutes the environment.

In last years enhanced attention is paid to the use of a constant magnetic field in glueing, in particular, glueing of timber-based materials [3]. The interest to the use of a magnetic field in the processes of glueing timber-based materials is based on the fact that its action makes possible a directed formation of a glue line, which allows strengthening of surfaces glued together [4].

The aim of this work was to consider the action of a constant magnetic field in combination with acid agents used in cold hardening glues on the strength of adhesive joints.

EXPERIMENTAL

We used oxalic acid (GOST 22180-76), maleic acid (GOST 14231-88), and a waste products of the phthalic anhydride production containing 80% of maleic acid as acid agents.

The waste product of the phthalic anhydride production used in the work had the following characteristics and composition: density at 40°C 1.11 g cm^3, contents of maleic acid 34.5, citraconic acid 1.76, phthalic acid 2.78, benzoic acid 1.72, phthalide 0.34, and *o*-toluic acid 0.024 wt %; the total acidity in terms of maleic acid was 362 g l^{-1}.

The glueing together of timber-based materials was carried out as follows. A carbamide-formaldehyde resin, containing from 0.7 up to 3.0 wt fractions of an acid cold hardener per 100 wt fractions of the resin, was laid on the surface of standardized oak wood samples (GOST 15613-84). The hardener consisted of oxalic and maleic acids and the waste product of the phthalic anhydride production. Glue consumption was 180–190 g m^{-2}. Glued surfaces were put between poles of a constant electromagnet so that magnetic force lines were directed perpendicularly to a glue line. The pressure on glued together surfaces while hardening was 0.03 MPa during treating samples in a magnetic

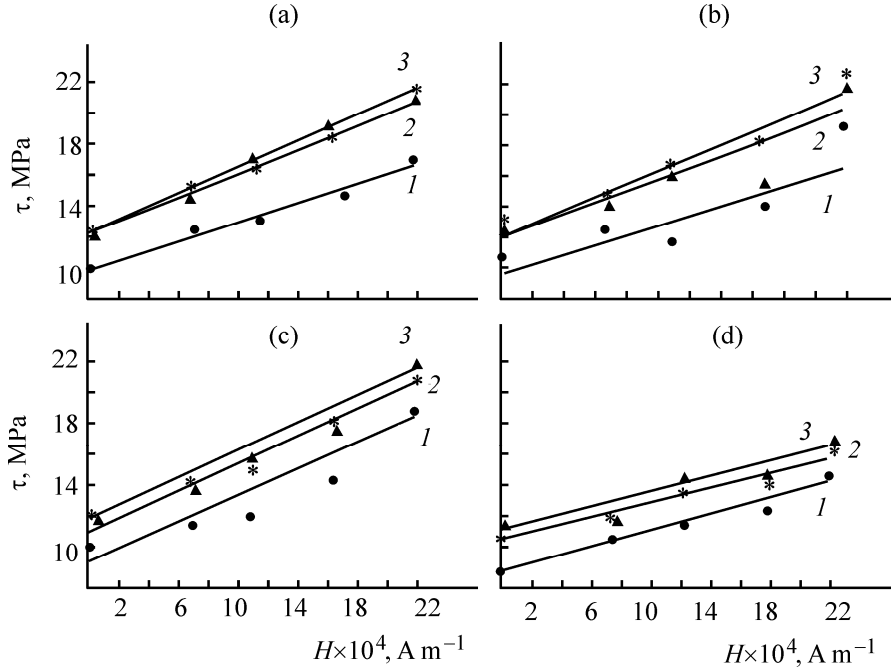

Fig. 1. Effects of the type and content of a hardener (wt fractions per 100 wt fractions of resin) and also of magnetic field intensity H on the chipping strength τ. Hardener: (*1*) oxalic acid, (*2*) maleic acid, and (*3*) phthalic anhydride waste product. Hardener content (wt fractions per 100 wt fractions of resin): (a) 0.7, (b) 1.0, (c) 2.0, and (d) 3.0.

field, the duration of the treatment 20 min at 20±2°C. Then the glued together samples were tested for chipping resistance on a testing machine MI-20. The effect of the hardener content and the magnetic field intensity on the chipping strength determined according to GOST 15613.1-84 is given in Table 1.

The results of the fulfilled experiments show that the magnetic treatment of any glue composition results in strengthening the adhesive joint. The best results were obtained in the case of using maleic acid or the phthalic anhydride waste product as a hardening agent. It is most likely that the observed effect is connected

Table 1. Effects of the type and content of a hardener and of magnetic field intensity on the chipping strength

Magnetic field intensity $H\times10^4$, A m^{-1}	Hardener content, wt fractions per 100 wt fractions of resin	Chipping strength, MPa		
		oxalic acid	maleic acid	phthalic anhydride waste product
0	0.7	9.9	12.2	12.3
6.4	0.7	12.0	13.5	14.1
10.7	0.7	12.4	16.1	15.9
16.0	0.7	14.4	17.8	17.2
20.8	0.7	17.9	19.0	19.7
0	1.0	10.8	12.3	12.9
6.4	1.0	12.5	14.8	14.8
10.7	1.0	12.9	16.2	16.7
16.0	1.0	15.1	16.1	18.6
20.8	1.0	19.5	21.9	22.3
0	2.0	10.7	12.2	12.4
6.4	2.0	12.0	14.3	14.4
10.7	2.0	12.6	15.8	16.0

Table 1. (Contd.)

Magnetic field intensity $H\times10^4$, A m^{-1}	Hardener content, wt fractions per 100 wt fractions of resin	Chipping strength, MPa		
		oxalic acid	maleic acid	phthalic anhydride waste product
16.0	2.0	15.0	18.2	18.2
20.8	2.0	18.8	20.6	21.3
0	3.0	8.7	11.8	11.0
6.4	3.0	10.6	12.6	12.5
10.7	3.0	12.0	14.7	14.0
16.0	3.0	13.3	15.4	15.5
20.8	3.0	15.7	17.7	17.6

with the fact that maleic acid is less active than oxalic acid because carboxyl groups of maleic acid are separated by two carbon atoms and their mutual acceptor influence is attenuated in comparison with oxalic acid where carboxyl groups are directly linked with each other. Therefore maleic acid, possessing a lower acidity constant, is a "milder" structure-forming agent. Furthermore such glue composition retains a greater viability and allows a ready glue composition to be longer used in a technological process. It can be considered as a positive factor for using maleic acid or the phthalic anhydride waste product in glue compositions.

It is also important to mention a positive effect of a constant magnetic field on the strength of a resulting glue line. Under the action of a constant magnetic field a more regular glue structure is formed. It leads to an increase in the strength of resulting glue joints. Mathematically the effect of a constant magnetic field on the strength of glue joints at various contents of an acid hardener is described by the first-order equations (see the figure).

Another important advantage of the offered glue composition is the fact that the replacement of oxalic acid by maleic acid or by the phthalic anhydride waste product allows obtaining a glue joint with a higher strength, especially in the case of using the phthalic anhydride waste product containing about 80% of maleic acid. It is most likely that the enhanced activity of the phthalic anhydride waste product is connected with the presence of phthalic, benzoic, and other acids in its composition, which activates hardening of a glue composition. A synergetic effect of components of the waste product on the hardening process also should not be ruled out.

For oxalic acid	For maleic acid	For phthalic anhydride waste product
$Y_{(0.7)} = 9.3932 + 0.3624x$	$Y_{(0.7)} = 11.9619 + 0.3672x$	$Y_{(0.7)} = 12.0880 + 0.3481x$
$Y_{(1.0)} = 9.9790 + 0.3878x$	$Y_{(1.0)} = 12.0682 + 0.3980x$	$Y_{(1.0)} = 12.3340 + 0.4384x$
$Y_{(2.0)} = 9.8136 + 0.3717x$	$Y_{(2.0)} = 11.8759 + 0.4030x$	$Y_{(2.0)} = 11.9354 + 0.4197x$
$Y_{(3.0)} = 8.5155 + 0.3270x$	$Y_{(3.0)} = 11.4000 + 0.2820x$	$Y_{(3.0)} = 10.7263 + 0.3148x$

CONCLUSIONS

(1) The application of a constant magnetic field in the process of glueing timber-based materials makes it possible to increase strength characteristics of glue joints.

(2) The best results are reached by using such acid hardeners as maleic acid or the waste products of phthalic anhydride production at their contents from 0.7 up to 2.0 wt fractions per 100 wt fractions of a carbamide-formaldehyde resin.

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