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Investigation on polyesters for wood finishing

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Introduction

THE bulk of the expensive and medium-priced furniture and decorative panellings are presently coated with nitrocellulose lacquer. There is, however, a trend for greater use of conversion varnishes. These varnishes can usually be formulated to give a film of higher solid content than lacquers. Among these, unsaturated polyesters have excellent abrasion resistance and non-yellowing properties[1] In this system, the solvent presents cross-links with polyester resin. The solvent may be styrene, vinyl toluene or methyl methacrylate. An organic catalyst, benzoyl peroxide, and accelerator, cobalt naphthenate, are generally used for curing.

The main variables which control the properties of polyester resin are: type and amount of dibasic acids, alcohols, solvents (cross linking monomers) and the molecular weight of the resin. Mostly, the resins have their unsaturated group in the acid component of the polyester chain. Maleic and fumaric acids provide unsaturation. However, polyesters with these acids are very reactive and show high shrinkage on curing. Such resins produce non-flexible films and are not good for wood finishing[2]. A low and medium reactive resin appears most suitable. It is obtained by a blend of unsaturated and saturated acids. Normally maleic anhydride is partly substituted by phthalic and adipic acids. These saturated acids favour the formation of a linear and flexible resin[3].

Ethylene glycol, propylene glycol and diethylene glycol are generally used in the preparation of polyester resin. Water and heat sensitivity of the resin are greatly affected by the nature of these alcohols. Polyesters based on ethylene glycol tend to become hazy and crystallize upon standing. Resin obtained from propylene glycol shows less tendency to crytallize[4] and is more compatible with styrene[5].

On the basis of the discussions given above, twelve formulations of polyester resins given in Table 1 were prepared in the laboratory and studied for their suitability for wood finishing.

TABLE 1

COMPOSITION AND CHARACTERIZATION OF POLYESTER RESINS

Formulation No.	1	2	3	4	5	6	7	8	9	10	11	12
Charge												
Maleic anhydride												
— mole	1.0	1.0	1.5	1.0	3.0	2.0	3.0	4.0	1.0	1.0	1.0	1.0
— gram	11.5	20.8	14.8	24.6	30.3	34.2	40.0	42.6	15.8	15.8	9.2	9.2
Phthalic anhydride												
— mole	3.0	2.0	3.5	1.0	2.0	1.0	1.0	1.0	—	1.0	—	1.0
— gram	52.5	31.2	49.0	37.2	30.5	25.8	20.0	16.1	—	23.5	—	9.6
Propylene glycol												
— mole	4.0	3.0	5.0	2.0	5.0	3.0	4.0	5.0	3.0	3.0	5.0	5.0
— gram	36.0	48.0	36.4	38.2	39.2	40.0	40.0	41.3	37.0	36.8	35.8	37.4
Adipic acid												
— mole	—	—	—	—	—	—	—	—	2.0	1.0	4.0	3.0
— gram	—	—	—	—	—	—	—	—	47.2	23.9	55.0	43.2
Properties												
Acid value mg KOH/g	45	22	29	29	32	61	50	35	34	25	70	60
Colour*	DLY	DLY	BY	DLY	BY	LSY	DLY	SY	LSY	DrSY	DrB	BY
Physical state at 30°C	Sl	VF	LVF	Sl	Sl	Sl	Sl	Sl	VF	LF	LF	LVF

* D=dirty; Dr=Dark; L=light; Y=yellow; B=brown; Sl=solid; V=viscous; F=fluid; L=light; S=Straw.

Preparation of polyester resin

Weighed quantity of propylene glycol, phthalic anhydride and maleic anhydride with 50 to 100 ml xylene were placed in a four-neck flask fitted with a nitrogen inlet tube, a thermometer, a mechanical stirrer and a distillation head[6]. The contents of the flask were heated over a heating mantle and stirred under an atmosphere of nitrogen at 150-160°C till a homogenous dispersion was obtained. In formulations containing adipic acid[7], a homogeneous mixture of glycol and adipic acid was first obtained, followed by the addition of the mixture of phthalic anhydride and maleic anhydride. The temperature was then raised to 200°C and the polymerization was carried out at this temperature till the acid value dropped down to nearly 50. More of xylene was added at intervals to facilitate the removal of water of condensation. Towards the completion of the reaction a vigorous stream of nitrogen gas was passed and most of the xylene was removed. The flask was allowed to cool and the resin transferred to a wide-mouth bottle.

Application of exposure

Catalyst Q 8013 and accelerator Q 8021 obtained from Bakelite Hylam Ltd., Hyderabad were used for curing the resin. Three millilitres of each was added to 100 g of the resin. Styrene was added equal to the weight of the resin.

Cedar wood panels of size 15x6x1 cm were taken for its application. A coat of epoxy-based sealer was first applied. After it had hardened two coats of polyester were applied in duplicate. The panels were matured for two weeks in the laboratory. Observations for general appearance, gloss and other application defects were then recorded.

For the assessment of the durability of the polyester finish the panels were exposed in the Twin Arc Weather-Ometer for 800 hours. A cycle of 120/18 was used for the exposure test. Observations for the film failures were recorded after every 100 hours.

Observations

Resin formulations 1, 8 and 10 did not set hard and the film showed tackiness even after two weeks. Formulations 2 and 7 set fast. In accelerated weathering, the film was examined for loss of gloss, water marks, whitening, surface crazing and cracking. It was observed that almost all the formulations suffered from whitening of the film. Among these 3, 6 and 9 appeared more susceptible to whitening. Formulations 5, 6, 9, 11 and 12 showed uniform whitening, whereas white spots and streaks along the brush stroke appeared on 1, 3, 4, 7, 8 and 10. Formulations 2, 7, 8, 11 and 12 were affected by water stains after 200 hours weathering, while formulations 9 and 10 were affected in 400 hours. Formulation 11 suffered maximum, whereas in formulation 12 the water stains were very mild. Except formulations 7 and 8, other formulations were seriously affected by the loss of gloss. Rapid drop in gloss figures occurred during the first 200 hours weathering. At the end of 600 hours, formulations 1, 2, 6, 9, 11 and 12 had no gloss. Surface crazing and cracking of the film was observed after 400 hours weathering. Formulations 3, 6 and 7 suffered more from this defect. Loss of adhesion and curling of the film at the ends of the test panels were noticed in formulations 6 and 8 after 400 hours and in 1, 4, 9 and 11 after 600 hours weathering. Very slight film erosion was seen in formulations 1 and 8.

Discussion

The reactivity of polyester resin depends mainly on the proportion of maleic anhydride and styrene[2, 5]. Maleic anhydride varies from 9.0 to 42.6 per cent by weight and that the ratio of unsaturated to saturated acid is from 1 to 4. The resin is almost solid when the ratio of maleic to phthalic is more than 1 and also when the ratio of phthalic to maleic is 3 or more. Polyesters prepared from adipic acid, however, remain fluid. From the setting behaviour of the resins it is observed that formulations containing high proportion of phthalic anhydride (Fn. 1), or maleic anhydride (Fn. 8), did not set hard. A small proportion of unsaturated acid in Fn. 1 may be the reason for its delayed setting, whereas the delayed setting of Fn. 8 may be explained by an inadequate amount of styrene added for cross-linking the resin. Adipic acid (Fn. 10) appears to delay the setting of the resin more as compared with phthalic acid.

On weathering, most resins suffer from whiteness. However, the pattern of whiteness appears to be governed by the type and proportion acids. At a fairly high proportion of maleic acid (Fn. 7 and 8) the incidence of whiteness is less. Further maleic and adipic acids favour a uniform pattern of whiteness (Fn. 5, 6, 9, 11 and 12), when phthalic acid causes scattered whiteness. The ester linkages formed by phthalic acid appears to resist hydrolysis better than adipic acid. Presence of adipic acid makes the resin (Fn. 9 to 12) more susceptible to water staining. Resistance of resin to water staining is also decreased, if a high percentage of glycol (Fn. 2) is used. Maleic anhydride considerably improves the durability and gloss retention of the polyester film. In formulations 7 and 8 where the proportion of maleic anhydride is more, the gloss retention is better than those containing greater proportion of phthalic anhydride (Fn. 1 and 2) and apidic acid (Fn. 9, 11 and 12). However, the film cracks more when maleic to phthalic ratio is more than half. This may be attributed to more cross-linking and formation of a rigid structure with maleic anhydride. The film erosion found in Fn. 1 and 8 suggests that when the proportion of any of the saturated or unsaturated acid ex-

ceeds a certain limit, the homogeneity in the formation of the resin network is perhaps not obtained. It results in chalking and erosion on weathering. It may be concluded from the above discussion that a polyester of molar ratio 40:60 of saturated to unsaturated acid gives the best results.

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Summary

Twelve compositions of unsaturated polyester resin consisting of maleic anhydride, phthalic anhydride and adipic acid and propylene glycol were synthesised. The performance of these resins as wood finishing was examined by accelerated weathering tests. It is found that higher proportions of maleic anhydride in the resin considerably improves the durability, gloss retention and water resistance of the film. Adipic acid makes the resin susceptible to water staining. However, the films crack when the maleic to phthalic ratio is more than 2. Further, when the ratio of either maleic to phthalic, or phthalic to maleic is more than 3, the resin suffers from film erosion. A polyester resin molar ratio 40:60 of saturated to unsaturated acids gives the best results.

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