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Effect of Calcium Carbonate and Methylethyl Ketone on the Performance of Hardboard Surface Modification by Ultraviolet Radiation Curing Method

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A variety of polymeric films were developed to improve the properties of hardboard surface. Polyester acrylate (M-6100) oligomer, and three different types of monomers and photoinitiator (Irgacure-651) were employed to prepare the polymeric films. The monomers are 2-ethyl hexyl acrylate (EHA), tripropylene glycol diacrylate (TPGDA) and trimethylol propane triacrylate (TMPTA). Pendulum hardness and gel content of films prepared by various formulations of oligomer and monomers under UV radiation were characterized against the number of passes for selection of suitable films. The monomer, TMPTA was selected to apply for surface coating with oligomer on hardboard for their optimum properties. Monomers, various properties, such as, pendulum hardness, gloss, abrasion and adhesion tests, indent length and depth, adhesion chipped off area, etc. of coated hardboard surface were determined. Filler, $CaCO_3$, was incorporated into the solution. The hardness increases with increasing the amount of $CaCO_3$ and then decreases. The effect of an additive, such as MEK was also investigated.

Keywords hardboard, surface modification, UV curing, $CaCO_3$ filler, MEK, UV-radiation

Introduction

Hardboard is one of the cheapest construction materials in Bangladesh, but some of its inherent characteristics hinder its versatile and potential applications. The hygroscopic nature of hardboard is significantly responsible for the dimensional instability with variation of moisture content that eventually results in weeping and uneven distortion. The nonabrasive character and resistance to weather conditions of hardboard are relatively low. Under some favorable conditions, hardboard bores, termites, bacteria, insects, microbes and fungi can destroy a hardboard structure in a short period of time and

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hardboard is susceptible to combustion as well. In order to overcome these drawbacks of hardboard, it is necessary to modify it or its surface. The need to take full advantage of technological improvement to achieve greater efficiency, productivity and economy, is obvious throughout industry. The contribution made by the synthetic resins industry and its ancillaries, particularly in the fields of improved curing rates of surface coatings, radiation curing techniques (1), facilitate the development of systems which offer, as major advantages energy savings, no volatile solvent, very short curing cycle, no heat, one pack systems and space saving. Polymers, though introduced in the materials field in a meaningful manner only very recently, occupy a major place and pivotal position in the materials field today. In performance characteristics and application prospects diversity, they offer novelty and versatility not found in any other kind of materials. Radiation curable coatings (2–4) have become established technologies, and form a relatively small but growing sector of the industry. The ultra violet (UV) curing (5) process initiates vinyl addition polymerization reaction. A UV curing coating contains a mixture of liquid prepolymer, monomers, pigments and extenders, together with a photoactive compound (photo initiator) (6). Because of the multi-functional nature of the monomers and prepolymer used, and the chemical nature of the radical reactions involved (e.g., grafting) rapid conversion to a cross-linked, insoluble network takes place. The film cured by UV radiation mainly adheres on to the surface by the adhesive force, i.e., the vander Waal's force between the substrate (Hardboard) and the coating material. Property of the surface thus depends upon adhesive force as well as on the extent of cross-linking. This force is enhanced by the presence of –OH group in the substrate (Hardboard) and monomer content. Hardboard cellulose has sufficient –OH groups. Among all of its constituents, cellulose is the most sensitive to radiation. Radiation creates a free radical site with the help of photoinitiator, and cellulose is the most sensitive to radiation. Radiation creates free radical site on cellulose bone that initiates the polymerization process. Calcium carbonate ($CaCO_3$) is the most widely used filler or extender pigment in the plastic industry. Polyvinyl chloride, polyolefines, phenolics, polyesters, and epoxies are all resins with which $CaCO_3$ can be compounded. Perhaps no other area has generated more interest in expanding the use of fillers in plastic than the technology of chemical coatings and coupling agents. Coated $CaCO_3$ is currently available ina finer form. Most of the commercial products are coated with steric acid or calcium stearate. Coating leads to improved filler dispersion and superior rheological and physical properties. The present study is related to the modification and characterization of hardboard coated with polyester acrylate (M-6100) mixed with TMPTA (trimethylol propane triacrylate) containing $CaCO_3$ (1–5%) and cured under UV radiation.

Experimental

Materials

M-6100, oligoester acrylate (bifunctional) oligomer underwent an ultraviolet radiation induced photo-fries rearrangement where the aromatic ester structure rearranges to an O-hydroxy-benzophenone, resulting in stabilization of the polymer and performance properties to the degradative effects of UV radiation. This possesses a high glass transition temperature (Tg) of 39°C along with a viscosity of 200–500 cps at 25°C. The general formula of the oligomer is $A{-}(M{-}N)_n{-}M{-}A$ (where A: acrylic acid, M: diol, N: dibasic acid). Monomers used with oligomer were 2-ethyl hexyl acrylate, 2-EHA (monofunctional), tripropylene glycol diacrylate, TPGDA (bifunctional), trimethylol propane triacrylate, TMPTA (trifunctional). Monomers were obtained from Aldrich-Chemie D-7924 (Steinhein), BASF (Hungary), and Ajax Chemical Company (Australia), respectively. Oligomer and monomers were procured from Radcure (Drogenbos, Belgium). The filler, $CaCO_{3f}$ is a product of BDH Ltd. Methyl ethyl ketone (MEK) was used as an anti-bubbling agent, and was obtained from Merck (Germany). Irgacure-369 (IRG-369) has an absorption band of 200–450 nm, and was used as a photo initiator during the UV radiation process to initiate photochemical reactions. It was procured from Ciba-Geigy. Hardboard was collected from the Hardboard Industry of Bangladesh.

Methods

Different formulations were developed with polyester acrylate (M-6100) in combination with reactive monomers (2EHA, TPGDA and TMPTA) in the presence of the filler, $CaCO_3$, anti-bubbling agent MEK, and photoinitiator IRG-369 in various proportions. Thin polymer films were prepared under UV radiation by coating a glass plate ($3'' \times 2''$) with these formulated solutions using a bar coater (No. 0.0018 of Abbey Chemicals Co., Australia). This produced films of 363 μm thickness on the plate. A UV minicure machine (IST Technik Germany, Model Me-200-UV) was used to cure the film on the plate (as well) as on the hardboard surface) using a UV lamp (254-313 nm, 2KW). The substrate was run under the lamp at a speed of 4 m/min with the help of a conveyor belt interlocked with the UV radiation system. The minicure has the efficiency of 1%.

Properties of the Cured Polymer Films

The pendulum hardness of the film was determined by a pendulum hardness method (7) using a Digital Pendulum Hardness (PH) Tester (model 5458, BYKE, Labotron). The pendulum was deflected to the 6 degree (Konig position). A photocell (supplied by the company) was used and the % of pendulum hardness was determined by the relation: % of pendulum hardness = no. of oscillation for coated plate × 100/no. of oscillation for the photocell. After 24 h of UV radiation, the cured film was used for hardness measurement when the UV cured film was still on the glass plate. Gel content was determined by extracting a known weight of the cured film with hot benzene 48 h in a Soxhlet. For this purpose, the film was wrapped in a stainless steel net that was put into the Soxhlet. The loss of weight of the cured film due to the extraction process yields the gel content. It was calculated using $\% \text{ Gel} = 100 - 100\ (W_0 - W_e)/W_0$, where, W_0 is the weight of the cured film before extraction and W_e is the weight of the extracted film after drying at 105°C until a constant weight was achieved.

Application on Hardboard Surface

The hardboard sample was cut into small pieces (size $4'' \times 4''$). The surface of the hardboard samples was polished smoothly with the help of suitable sand papers (No. 1 and 0). Then, it was first coated with a base case coat using a draw down bar (No. 0.0028) and cured by a single pass under UV lamp. It was polished again and coated with a top coat using a suitable bar (No. 0.0018) and finally, the coating was cured under a UV light of different intensities (number of passes). Treated hardboard surface was used for the experiment after 24 h of conditioning at room temperature. PH of the cured hardboard surface was also determined by the same method as for cured films.

Macro- and micro- scratch hardness was measured by a Universal Hardness Tester (model 413/E, Erichsen, Germany). Micro-gloss of the cured Hardboard surface was determined at two angles 20° and 60° with the help of a digital micro-gloss meter (Sheen-155) from Sheen Co., UK. Calibration was made using a reference plate whose gloss at the angle 20° and 60° was calculated on the basis of these units. % of micro-gloss = gross of cured hardboard surface X100/gross of reference surface. The adhesion test was carried out with a adhesion tester model 525, ASTM D 4541. A test cylinder (dolly) was first stuck to the coating on the hardboard, with an adhesive of adequate adhesive quality and tensile strength. After 8 h, at 23°C, the coating was cut through to the base material rod of the periphery of the dolly. The coating was then pulled off by tightening the central screw of the adhesion tester machine until resistance was felt. The tensile stress required for this and a visual examination of the surface that was separated to provide the required information of adhesive quality of the coating N/mm. The abrasion test was carried out by the Taber abrasion method using a Taber Abraser (Model 5130 of Richness Co., Germany). At first, the cured hardboard specimen of 4 inches squire (1/4 inch thick) with a 1/4 inch center hole was prepared. Immediately before it (modified hardboard) was tested on the Abraser, the specimen was weighed to the nearest tenth of a milligram in a sensitive laboratory balance. At the end of the abrading operation, the specimen was weighed in the same balance. The test was operated at 100 cycles. The results expressed as a wear factor of the Taber Wear index (rate of wear) is the loss in weight in milligrams per thousand cycles of abrasion. The Taber wear index (rate wear) = weight loss in milligram X1000/100 cycles test. Indent length and depth of the cured hardboard surfaces were carried out using a PIG Universal in accordance with DIN 53 153.

Results and Discussion

It is necessary to characterize UV cured polymer films before applying it to the surface of the hardboard. Different formulations were developed in the proportions, as mentioned in Table 1. Most of the data presented in this report are averaged values of at least six different results.

Table 1
Composition of different formulations (%) w/w

	Chemicals				
Formulations	M-6100	Photoinitiator IRG-651	EHA	TPGDA	TMPTA
R1	50	2	48	—	—
R2	50	2	—	48	—
R3	50	2	—	—	48
R4	50	2	24	24	—
R5	50	2	24	—	24
R6	35	2	—	—	63
R7	20	2	—	—	78

Characterization of Polymer Films

Film Hardness. Surface hardness of UV cured thin polymeric films prepared on a glass plate was determined by the pendulum method. Results of pendulum hardness (PH) of the film prepared with seven different formulations against different UV doses represented by a number of passes are graphically shown in Figure 1. The hardness increased with radiation passes. This indicates that the process of curing with UV radiation up to a certain UV dose, at which time it gains the maximum hardness, some are at the tenth pass, while others are at the sixth and eighth passes. After attainment of the maximum, the hardness decreases with radiation. This may indicate that the polymer film prepared at the radiation dose of maximum hardness starts degradation at higher doses (8). This means the polymer chains are decomposed at higher radiation. However, the highest PH value (82%) is obtained with the formulation R6 at the sixth pass that contains TMPTA. The second highest PH value (77%) is imparted by R7 followed by R3 (76%).

Gel Content. The extent of crosslinking among the monomers and between oligomer and monomers is reflected by the gel content of the polymer film. With an increase of UV radiation, the gel content increases within the polymer film. The maximum gel content is achieved at different radiation doses depending on the nature of the formu-

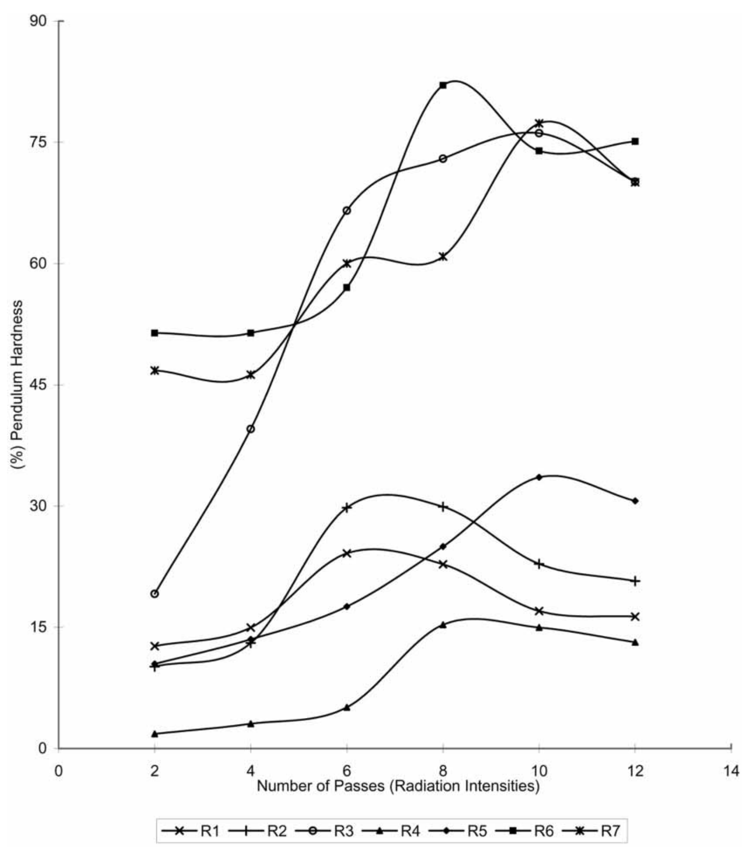

Figure 1. Pendulum hardness of cured films against UV radiation intensities (number of passes) with respect to various formulations.

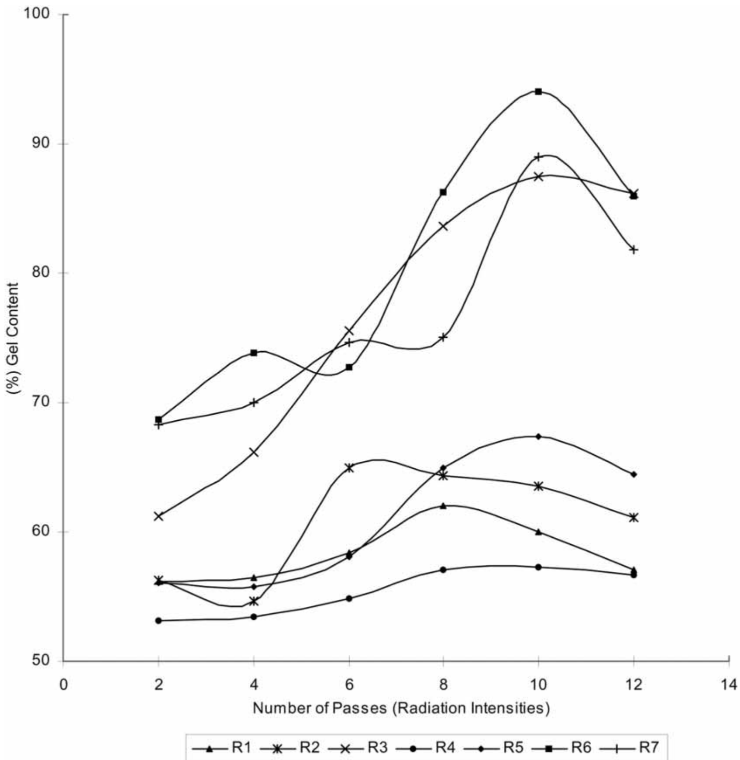

Figure 2. Gel content of cured films against UV radiation intensities (number of passes) with respect to various formulations.

lations. In Figure 2, the film of R1 formulation possesses maximum gel content at the eighth pass, the film of R2 formulation possesses that at the sixth pass and the films of other formulations hold at the tenth pass under the UV radiation. The gel content varies between 50% and 95%. The maximum gel content values are achieved by formulations R3, R6 and R7, because they contain TMPTA (Table 1). TMPTA has tri-functional acrylated groups that have a branching effect (9) and can yield more cross-linking in the cured film. A multifunctional vinyl monomer promotes a rapid free radical propagation reaction (10) leading to network (crosslinking) structures. When the TMPTA concentration is increased, the amount of residual unsaturation is also increased as a consequence of a faster rate of formation of the three-dimensional network, causing restricted mobility at an early stage. The crosslinking rate, especially during the early stage of radiation, is proportional to the TMPTA concentration (11). The formulation R6 shows the highest gel content (94%) at the tenth pass. The second highest gel content (89%) is obtained by the formulation R7 followed by R3 (87%). This is a sign of a very good crosslinking phenomena among the various constituents present in different formulations.

Characterization of UV Cured Hardboard Surface for the Selection of Top Coat

On having characterized the UV cured polymer films, the different formulations were applied on the hardboard surface. TMPTA was chosen as a monomer with a oligomer for its optimum properties to apply on the hardboard. Coatings were cured on the hardboard surface with a different number of passes under a UV lamp. Formulation, R3, was arbitrarily chosen as a base coat due to its higher viscosity and hardness on the glass plate, whereas R6 and R7, were chosen as top coats because of their lower viscosity and anti-bubbling property on the hardboard surface. The base coat was applied to the polished hardboard surface and partially cured with UV radiation. Then, the substrates were polished with sandpaper (No. 0) before the final coating. The top coat was applied on the hardboard surface and cured with UV radiation at a different number of passes. Various physical and mechanical parameters, particularly pendulum hardness, micro-gloss property and macro-scratch hardness were determined as a function of the number of passes.

Surface Hardness. Surface hardness of the film coating measured by Pendulum technique is plotted against the number of passes in Figure 3. The highest PH value (56%) is obtained for A (R3 + R6), and that of (55%) for B (R3 + R7) at the tenth pass. This may indicate that the polymer film starts degradation with the increase of TMPTA.

Surface Gloss. The quality of a surface coating can be roughly estimated with visual observation. Gloss determination of a coating is an index of such estimation. Gloss is the reflection of light from the coating at a certain angle with vision. Normally, the gloss of a coating is determined at two angles, such as 20° and 60°. Results of gloss estimation of the UV cured coating of the hardboard surface are shown in Figure 4 for 20° and Figure 5 for 60° against the number of passes. It is observed that the value of gloss increases with curing (12) of the coating that is represented by the number of passes

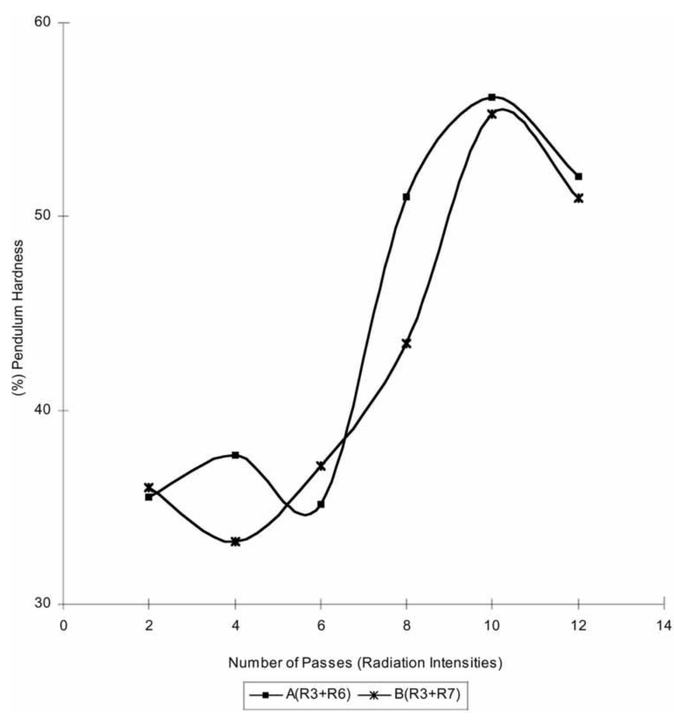

Figure 3. Pendulum hardness of cured hardboard surfaces against UV radiation intensities (number of passes) with respect to base coat and top coat formulations.

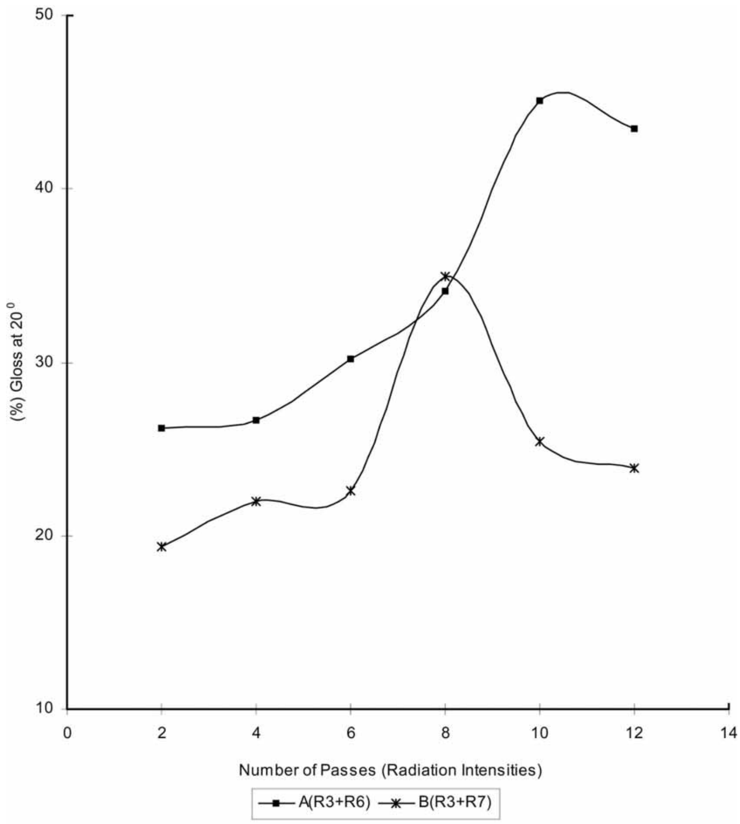

Figure 4. Gloss at 200 of cured hardboard surfaces against UV radiation intensities (number of passes) with respect to base coat and top coat formulations.

under the UV lamp. Thus, the gloss increases with an increase of crosslinking density. Figure 4 indicates that the maximum gloss is obtained at the tenth pass for formulation A with top coat R6 (45%) and at the eighth pass for formulation B with top coat R7 (35%) at 20°. Again, Figure 5 indicates that the maximum gloss is obtained at the tenth pass for both of the formulations A (80%) and B (70%) at 60°.

Macro-Scratch Hardness. Macro-scratch hardness of the coating is measured in terms of load (weight) in gm required to manifest a scratch on the surface of the coating. The more the index of macro-scratch hardness, the better the coating. From Figure 6, it is observed that coating with the top coat R6 appear to possess the highest MSH 850.

Effect of Filler on Base Coat. Different formulations with $CaCO_3$ were developed in the proportions, as mentioned in Table 2. It is necessary to characterize UV cured polymer films before applying to the surface of the hardboard.

Characterization of Polymer Films

Film Hardness. The results of pendulum hardness on glass for the selection of the base coat are shown in Figure 7. The highest pendulum hardness (80%) is observed by the for-

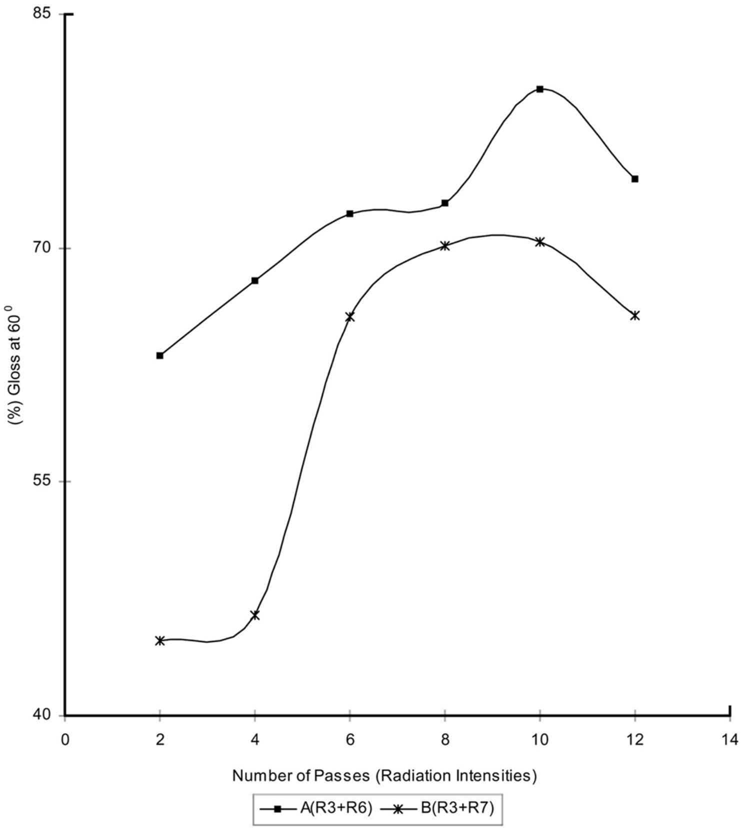

Figure 5. Gloss at 600 of cured hardboard surfaces against UV radiation intensities (number of passes) with respect to base coat and top coat formulations.

mulation R9 containing 2% $CaCO_3$ at the tenth pass. The next highest pendulum hardness (77%) is observed by the formulation R8 containing 1% $CaCO_3$ at the tenth pass, followed by formulation R10 containing 3% $CaCO_3$ (76%) at the tenth pass. The formulation R3 containing no $CaCO_3$ showed the lowest pendulum hardness (19%) at the second pass. As the content of $CaCO_3$ increases into the formulations the PH value decreases, because $CaCO_3$ may prevent the crosslinking process. $CaCO_3$ may act as a free radical scavenger due to its inherent chemical nature (13).

Characterization of UV cured Hardboard Surface for the Selection of Base Coat

After characterization of the UV cured polymer films, different formulations were applied on the hardboard surface. The effect of the additive, $CaCO_3$, on the UV cured hardboard surface with different physical properties (e.g., pendulum hardness, micro gloss, abrasion test, scratch hardness and adhesion test) is shown in the following figures.

Surface Hardness. The results of pendulum hardness of the UV cured hardboard surface are shown in Figure 8. The highest pendulum hardness (68%) is observed by the formulation E (R9 + R6) containing 2% $CaCO_3$ in the base coat at the tenth pass. The next

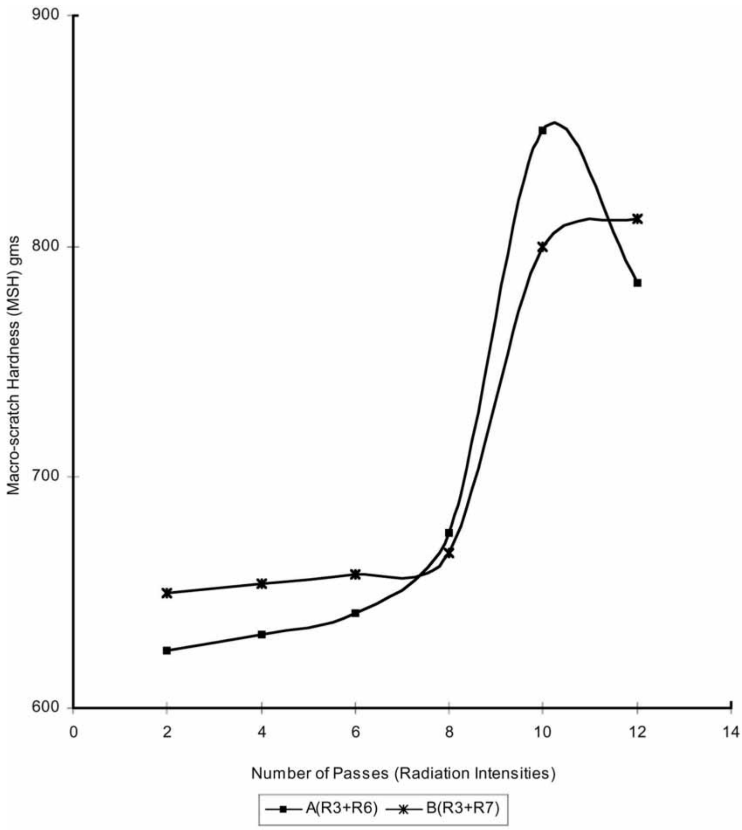

Figure 6. Macro-scratch hardness of cured hardboard surfaces against UV radiation intensities (number of passes) with respect to base coat and top coat formulations.

highest pendulum hardness (67%) is observed by the formulation F (R10 + R6) containing 3% $CaCO_3$ in the base coat at the tenth pass, followed by a formulation containing 1% $CaCO_3$. The formulation H (R12 + R6) containing 5% $CaCO_3$ in the base coat showed the lowest pendulum hardness (20%) at the second pass. In all cases, top coat formulation was the same (formulation R6), but the base coat formulation was different.

Table 2
Composition of different formulations for the Selection of base coat (%)

Formulations	M-6100	IRG-651	TMPTA	$CaCO_3$
R3	50	2	48	—
R8	49	2	48	1
R9	48	2	48	2
R10	47	2	48	3
R11	46	2	48	4
R12	45	2	48	5

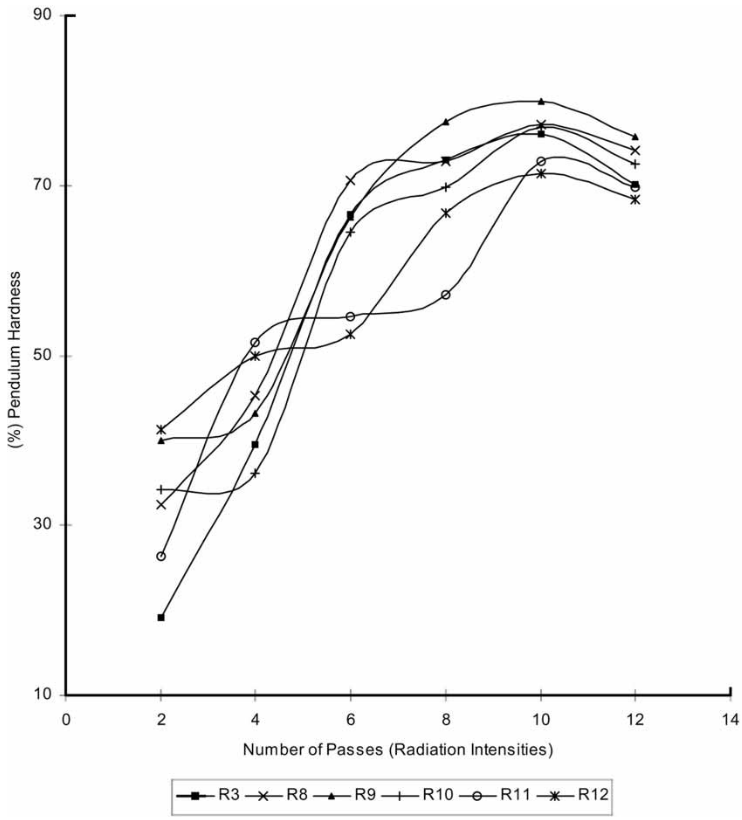

Figure 7. Effect of calcium carbonate on pendulum hardness of cured films against UV radiation intensities (number of passes) with respect to formulations.

Surface Gloss. Results of gloss estimation at both 20° and 60° angles of UV cured coatings on a hardboard surface, are shown in Figures 9 and 10. The highest gloss at the 20° angle is exhibited by the formulation E containing 2% $CaCO_3$ (72%) in the base coat at the tenth pass, where the lowest value (15%) of gloss is exhibited by the formulation H containing 5% $CaCO_3$ in the base coat. The glosses of the same coatings measured at 60° are different. The highest gloss at 60° is (98%) given by formulation E containing 2% $CaCO_3$ in the base coat at the tenth pass and the lowest is (51%) exhibited by the formulation H containing 5% $CaCO_3$ in the base coat. Therefore, it can be concluded that the formulation E containing 2% $CaCO_3$ in the base coat has the best gloss property of UV cured hardboard surface.

Macro-Scratch Hardness. Macro-scratch hardness of the UV cured hardboard surface is shown in Figure 11. The maximum macro-scratch hardness 950 is observed by the formulation E containing 2% $CaCO_3$ in the base coat, while the lowest value (300) of macro-scratch hardness is observed by the formulation H containing 5% $CaCO_3$ in the base coat. As the concentration of $CaCO_3$ increases from 0% to 2%, the values of MSH increase, but from 3% to 5% $CaCO_3$, the values of MSH decrease.

The indent length is the width of the scratch. If the indent length is small, it indicates that there is better cohesion among the polymer matrix. Thus, the smaller the width, the

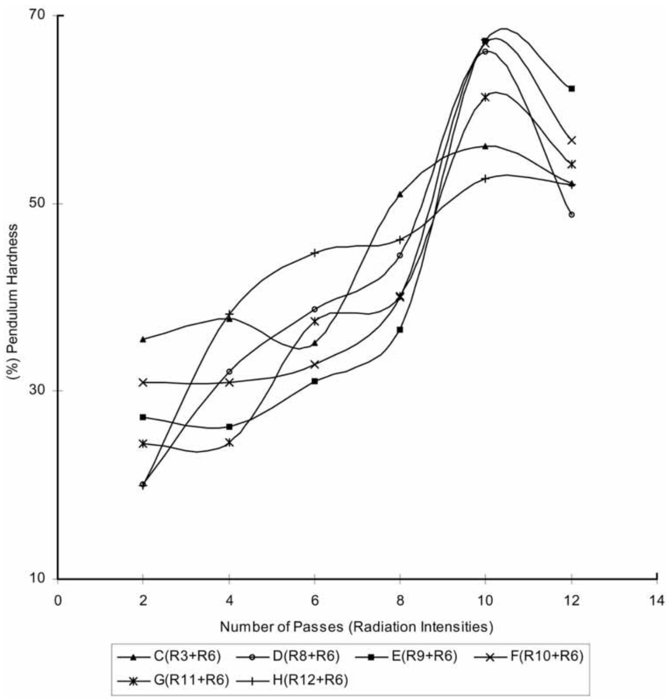

Figure 8. Effect of calcium carbonate on pendulum hardness of cured hardboard surface against UV radiation intensities (number of passes) with respect to formulations.

better the surface with respect to hardness. It is observed that the width decreases with the increase of hardness on the hardboard surface. It is related to the curing of the surface, i.e., cross-linking density on the surface, similarly, the indent depth, i.e., the depth of scratch yield is expected to be smaller for the better film. The fully cured film will have less penetration during the scratch. It is manifested in Table 3 that the formulation E is a better film with respect to indent length and depth.

Taber Abrasion. The coated (modified) hardboard surface was abraded between two abrading revolving wheels applying a load of 100 g/cycle. The weight loss obtained by the sample due to such abrasion between the wheels in 100 cycles is related to the taber wear index. This means that the abrasion resistance is high, when the taber wear index is low. Results of abrasion test of UV cured coatings of hardboard surfaces are shown in Figure 12. It is observed that abrasion resistance increases as the concentration of $CaCO_3$ increases up to 2%, and then the value of the taber index increases. The lowest abrasion value (211) is found by the formulation E containing 2% $CaCO_3$ in the base coat, while the highest value (926) is found by the formulation D containing 1% $CaCO_3$ in the base coat. This means that coating E has the highest resistance pertained by 100 cycles in the revolving wheels compared to other coatings on the hardboard surface.

Adhesion Strength. Adhesion of the UV cured coating on the hardboard surface was measured by the pulling off method. It is observed from Figure 13 that the coating

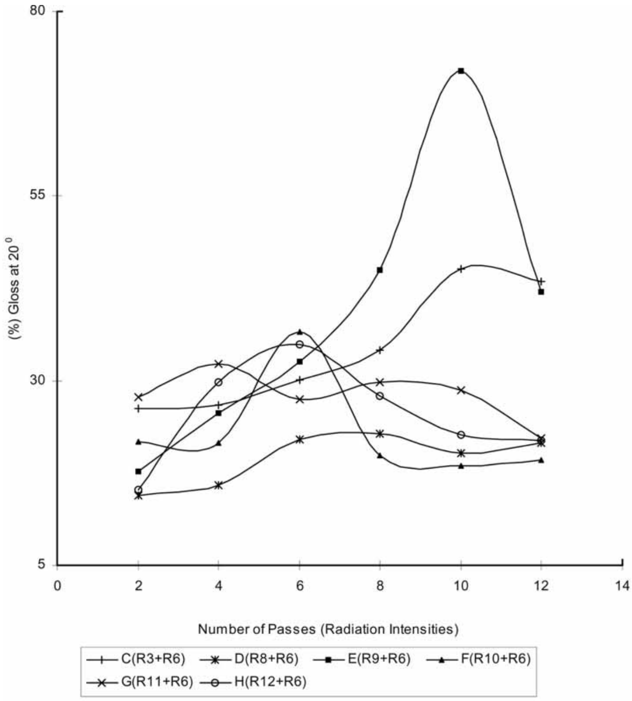

Figure 9. Effect of calcium carbonate on gloss at 200 of cured hardboard surface against UV radiation intensities (number of passes) with respect to formulations.

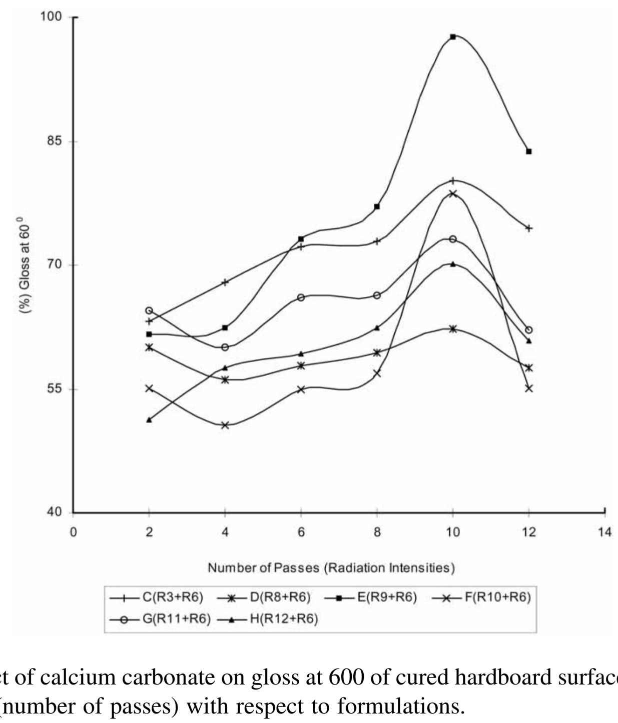

Figure 10. Effect of calcium carbonate on gloss at 600 of cured hardboard surface against UV radiation intensities (number of passes) with respect to formulations.

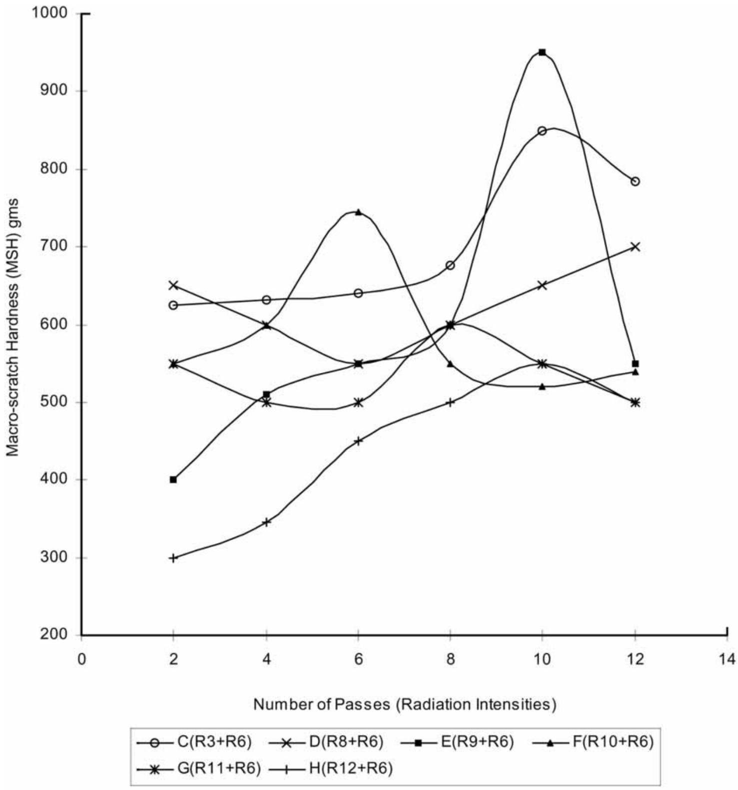

Figure 11. Effect of calcium carbonate on macro-scratch hardness of cured hardboard surface against UV radiation intensities (number of passes) with respect to formulations.

of formulation E has good adhesion. More strength is required for better adhesion. The results of adhesion force required to pull off the coating from the modified hardboard surface are shown in Figure 13. The values of adhesion increases as the concentration of $CaCO_3$ increases up to 2%, then it decreases to 5%. Figure 13 shows the coating E (R9 + R6) containing $CaCO_3$ 2% with base coat has good adhesion, and there is no chipping off area during the crosscut technique. However, the highest adhesion value is observed for formulation E (R9 + R6) containing 2% $CaCO_3$, followed by the formulation D (R8 + R6) with the 1% concentration of $CaCO_3$ in the base coat.

Effect of MEK on Base Coat

It can be concluded, considering the results of various physical parameters of the coating, that the base coat R9 containing 2% $CaCO_3$ has the best properties using R6 as a top coat. Now methyl ethyl ketone (MEK) is added in the base coat R9 with 2% $CaCO_3$ as sealer and the various physical properties are measured. The formulation is shown in Table 4.

The properties of the coated hardboard surface using 2% $CaCO_3$ and 1% MEK as an additive in the base coat are shown in Table 5 using R6 as top coat. From Table 5, it can be observed that pendulum hardness decreases by adding 1% MEK with the formulation R9 containing 2% $CaCO_3$ in the base coat, while the gloss properties at both 20° and 60° increases. The highest pendulum hardness (60%) at the tenth pass, while the highest

Table 3
Various physical properties of UV cured coating on hardboard surfaces using R6 as top coat

Property	Number of passes	Base coat					
		C	D	E	F	G	H
Hardness (Indent length) mm	2	0.85	0.75	0.95	0.85	0.80	1.05
	4	0.70	0.80	0.85	0.80	0.85	1.00
	6	0.75	0.85	0.80	0.65	0.85	0.85
	8	0.60	0.80	0.78	0.85	0.80	0.95
	10	0.65	0.75	0.55	0.80	0.85	0.80
	12	0.80	0.70	0.80	0.85	0.80	0.85
Indent depth (Micro-meter)	2	6	<5	8	6	5	10
	4	5	5	6	5	6	9
	6	<5	6	5	<5	6	6
	8	<5	5	<5	6	5	8
	10	5	<5	<5	5	6	5
	12	5	<5	5	6	5	6
Indent Buchholz resistance	2	118	>125	105	118	125	95
	4	125	125	118	125	118	100
	6	>125	118	125	>125	118	118
	8	>125	125	>125	118	125	105
	10	125	>125	>125	125	118	125
	12	125	>125	125	118	125	118
Adhesion (% chipped off area)	2	0	0	4	4	4	4
	4	0	4	4	4	4	4
	6	0	4	0	0	4	4
	8	4	4	0	0	0	4
	10	4	0	0	0	0	0
	12	4	0	0	4	4	4

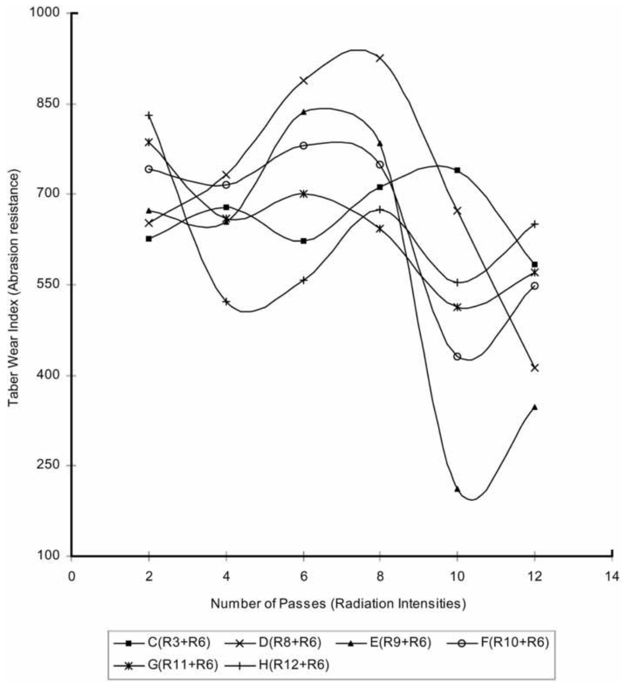

Figure 12. Effect of calcium carbonate on taber wear index (abrasion resistance) of cured hardboard surface against UV radiation intensities (number of passes) with respect to formulations.

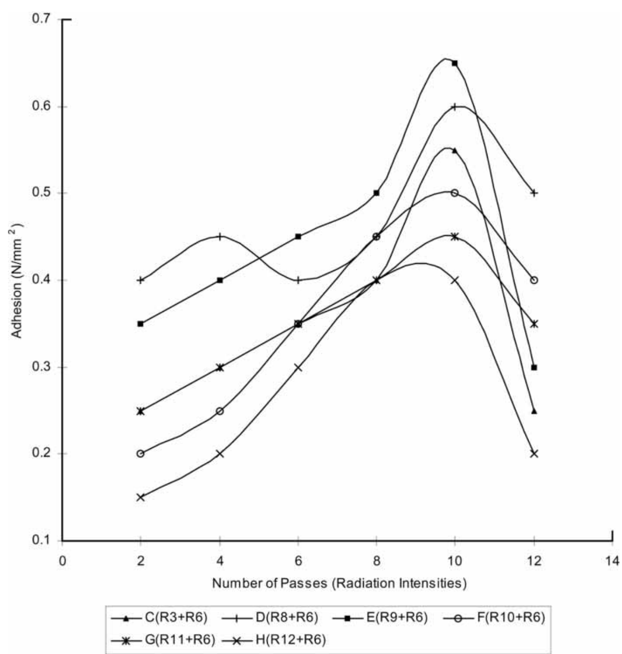

Figure 13. Effect of calcium carbonate on adhesion strength of cured hardboard surface against UV radiation intensities (number of passes) with respect to formulations.

Table 4
Formulation with additive, MEK on base coat (%)

Formulation	M-6100	TMPTA	IRG-651	$CaCO_3$	MEK
R13	48	47	2	2	1

Table 5
Various physical properties of coated hardboard surface using R13 as base coat and R6 as top coat

No. of pass	PH (%)	Gloss at 20° (%)	Gloss at 60° (%)	Abrasion (mg)	Adhesion N/mm^2	MSH (g)
2	36	19	63	820	0.40	500
4	40	29	67	915	0.35	550
6	43	42	75	847	0.45	550
8	48	68	85	823	0.50	600
10	60	73	98	594	0.55	700
12	58	58	88	681	0.60	500

gloss properties at 20° and 60° are (73%) and (98%), respectively at the tenth pass. It can also be observed that the abrasion values increase and the adhesion values and scratch hardness decrease by the addition of 1% MEK.

Conclusions

Various physical and mechanical properties of UV cured polymer coatings on the hardboard surface obtained from formulations R9 to R12 using top coat R6-forming coatings D (R8 + R6), E (R9 + R6), F (R10 + R6), G (R11 + R6), and H (R12 + R6) are shown in Figures 7 to 13 and in Table 3. For better understanding, formulation C (R3 + R6) with no filler ($CaCO_3$) is also shown. The use of filler ($CaCO_3$) reduces the coating costs and increases the pendulum hardness, scratch hardness, and abrasion resistance. All other properties are affected in the presence of $CaCO_3$, but the extent of decrease is not at all appreciable. The additive, MEK, increases the gloss properties of the hardboard surface, but decreases other properties. Considering all the properties of the coatings in the entire work, it can be concluded that the coating E (R9 + R6) with the base coat R9 containing 2% $CaCO_3$ appears to be the best.

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