

Study of UV Curing in the Wood Industry



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Abstract:

Although mass production is the primary demand, the wood finishing must nevertheless conform to certain minimal standards.

The surface should be protected and sealed against heat, dirt and abrasion, and insulated from the ingress and evaporation of moisture which would cause dimensional changes in the timber. The finish should be clear (unclouded) and smooth to enhance the natural beauty of the figure and the grain. The finish should also maintain its appearance, and adhesion, as well as protection given to the wood. The film should not seriously be degrading during the lifetime of the article.

All the standards mentioned above are available in the 100% solid acrylic UV finishing system.

A thorough study of the timber wood anatomy and of the physical and chemical properties of polymerized film is essential in order to match these properties with the wood substrate.

Introduction:

This paper is not meant to uncover any secrets that have not been known before nor establish new facts that have not been recognized, but to affirm these facts in an elaborate and analytical approach required by those who have interest in the subject, and its scientific data are based on approved experiments and observations as a guideline for further study and further research. The UV curable wood coating technique offers obvious advantages over conventional wood finishing systems, and increasingly adopted for a wide range of applications. These advantages in short, as determined by the end- users are:

1- High curing speed

Increased production: example flooring panels coated by UV with an average line running at 12 M/min can produce about 72,000 square meter per month per shift

2- Lower energy cost (compared to the heat generated by gas fir or electric ovens in some conventional coatings).

3- Economic factory space (no space is taken up when drying).

4- Greater ease of use. (one pack system ,no pot life for the lacquer when it is stored away from the UV light ,constant viscosity and no need to clean the application machinery after us)

5- the reduction of atmospheric pollution caused by:

- High energy required by the conventional coatings.
- Volatilization of solvents used in the conventional solvents.
- Disposal of lacquer waste eliminated

	Conventional Up to 50% solids	High solids 60-80 % solids	Water Borne 30-50 % solids	Radiation Curing 95-100 % solids
Solvent Usage	High	Moderate	Low	Low
Pollution Potential	High	Moderate	Low	Low
Energy Usage	High	High	High	Low

A comparison of different type of coatings (1)

Wood Substrate :

The wood finisher is not expected to be a timber technologist but he should be aware of the main features of the materials upon which he operates.(2)

The basic structural component of wood is plant Cellulose (60-75%), bonded and strengthened by the closely related lignin. Lignin is found between the Cellulose cell walls; hence, wood with a high lignin content usually has a high compressive strength .The remaining portion is composed of wood extractives (natural resins, oils, coloring matters. etc.). The cell structures of wood differ little in chemical composition from one tree to another but vary in shape and size. These variations, and those of the by-products of cell metabolism, determine the characters of various woods. Commercial Timber employed in wood industry is classified into softwood (Pine, Fir.. etc.) or needle-leaf trees and hard wood (Oak, Teak, Mahogany...etc.) or broadleaf trees whose cell structure is more complex than that of softwood. Hard woods have less elongated cells more irregularly arranged and are further complicated by the presence of extra strengthening fiber vessels and fiberform cells of various types. The tropical wood is generally hardwood in Malaysia (Marinate, Nyato, Merbau ..etc) is hardwood with the exception of Damar minyak and Podo being softwood .(3,4)

Due to the cost consideration, timber are cut into thin veneer that are glued to cheap man made boards substrate such as chip board and hard board, when not used as solid timber.

UV coatings can be applied on the above substrates as well as fiber boards like MDF.(5)

Applications on Wood substrates:

UV coatings like other coatings on wood substrates can be applied on two shapes :

1. flat panels objects (2 Dimensions): buildings components (parquet flooring, siding panels, doors, partition boards) ,furniture(tabletops ,shelve panels) and any flat wood panels.
2. Irregularly shaped objects(3Dimensions):furniture(chairs,hangers,..etc.),decorative objects , and any other 3D wood articles

the application machinery in use are :

1.Spray Coatings: spraying is a widely used method and this can be either manual or automatic ,high coatings film can be applied depending on the finishing requirement and spraying can be employed on articles of any shape.

2.Roller Coatings: roller coatings is for flat panels ,with low film weights 5 to 25 gm/M²

3.Curtain Coatings: flat panels are conveyed through a curtain of lacquer falling from a slotted head lays down film weights of 80 to 150 gm/M² ..(6)

The viscosity of the UV co-polymers (oligomers) is high and in order to use the UV lacquers in spray and curtain coating machine applications, reactive diluents (monomers) in a certain percentage are recommended to lower the viscosity. If the lacquer viscosity still not suitable for the applications solvents should be used. These non-reactive and volatile diluents (solvents) must totally evaporate from the film (during "Flash off" period) before it is exposed to UV lamps. The other technique is to heat the lacquer to reduce the viscosity because using monomer alone to get the low viscosity required may lead to loss of properties of the lacquers. Many companies nowadays overcome this problem by producing low viscosity oligomer.

In Malaysia The major application of the UV curing coatings (100% solid acrylic) are for flat panels using the Roller coating machine, the reason behind this is the high cost of conversion to special UV equipment designs for irregularly shaped objects 3D (automatic spray and the three dimensions UV lamps)

Radiation Curable Resins (oligomers) for wood coatings:

- Urethane acrylate UV curable coatings are noted for their high performance. These coatings have gained widespread acceptance because of their overall balance of properties, High Impact and Tensile strength, Abrasion resistance and Toughness combined with excellent resistance to chemicals and solvents.

- Polyester acrylate UV curable coatings are noted for rapid cure and low viscosity (suitable for curtain and spray coatings). The price of resin is reasonable.
- Epoxy acrylate resins are characterized by good chemical resistance, adhesion and rapid cure; the price of resin is also reasonable. ...(7)

Radiation Curable diluent (monomers) for wood coatings:

In radiation, curing formulation monomers are usually used as diluents to reduce oligomer viscosity. However, their presence can also have a great effect on other coating properties such as adhesion promotion or flexibility (either increase or decrease).

These are some monomers, which are commonly used in wood coatings:

- HDDA (1,6-hexanediol diacrylate) low viscosity Difunctional monomer characterized by its high diluting power and excellent adhesion.
- TPGDA (Tripropylene glycol diacrylate) is a Difunctional monomer characterized by good curing speed.
- TMPTA (Trimethylolpropane triacrylate) is a Trifunctional monomer characterized by high curing speed .used in formulations where chemical and abrasion resistance are required ...(8)

Type of acrylic UV curing lacquers for wood finishing:

UV base coat (filler and sealer):

The sealers have a lower viscosity compared to the fillers, but both are similar in function and can be applied directly onto the substrate. The effect of the sealer is to fill the chipboard so that the pores of the substrate are filled to give a smooth surface. An open grain effect is obtained by the sealer on wood and wood veneers. Since sealers are required to proceed through a sanding process, it is clear that in most cases an epoxy acrylate oligomer will be used because of its effective sandability...(10) .In the case of high abrasion resistance required, small amount of Urethane acrylate may be used to modify the overall properties (have a good abrasion resistance) but are seldom utilized as the sole backbone resin...(11)

Fillers and sealers usually have (Calcium carbonate, Barium Sulphate, Calcium Sulphate, Talc, Zinc Oxide, and ATH Aluminum trihydroxide), in low percentage in sealers and high in fillers, these materials are used as fillers and sanding agents which can help for better sanding and also can help to reduce the high glossiness of the 100% solid UV coating .The researches found that the ATH is much better than the rest because it allows the use of significant loading levels without whitening the clear wood fillers...(12)

Silicones or silicone acrylates are not added to wood finishing sealer formulas as they cause poor inter coat adhesion when over coated, even after a sanding operation. Other additives must incorporate slip and flow.

UV Topcoat:

There are conceivable varieties of topcoat formulas, by using different type of oligomers to obtain the properties required for the finishing.

In general, obtaining high gloss has not been a difficult achievement in the UV industry. It is more challenging to obtain a Matt finishing. Choosing the right matting agent is very important because it can increase the viscosity dramatically. In order to achieve a low gloss coating the film thickness is of great importance, the thinner the film the less in gloss where as the thicker the more glossy. In the application of an epoxy acrylate to achieve matt finish, high functionality monomers and amine additives are not recommended. The oligomer for easy matting will be polyester acrylate. Unfortunately, other properties are essential such that other oligomers have to be used in conjunction with the polyester acrylate.

Benzophenon, Amine/Acrylate system increases the glossiness hence should not be used in matt coating, and also the system had a yellowing effect.⁽¹⁰⁾

Aliphatic urethane acrylate has less yellowing effect than the aromatic urethane acrylate, polyester and epoxy acrylate.

Photoinitiators are generally added in 3-5%. Increasing this percentage may lead to a problem in UV-curing system, because of uncontrolled reactions of the remaining amounts, which cause yellowing effects, and emission of odorous fragments like benzaldehyde.⁽¹³⁾

In general, the points that should be considered by the UV formulator are: low cost, ease of application, Production of matt surface, and fast curing

Mechanical properties of cured film, which can be affected by the wood substrate:

Hardness:

The hardness of the film depends on the hardness of the wood substrate.

Increasing the crosslink density of cured film by increasing the functionality of reactive monomers can help to enhance the hardness of coating, also the structure of the oligomer, aromatic epoxy, urethane and polyester acrylates give harder film than aliphatic urethane and polyester acrylate because the more rigid the prepolymer(oligomer) the more rigid the crosslink, the harder the cured film.⁽¹⁴⁾

Adhesion:

Unlike metal or plastic surfaces, wood presents a substrate that varies in density, porosity, and dimensional stability. Thus good adhesion depends on many factors: wood substrate, the properties of both the wet and cured films that directly influence the adhesion.

The wood moisture content is one of the important parameters which can affect the adhesion, because the wood generally shrinks and swells, and this dimensional instability occurs as the wood gains or loses moistures ...⁽¹⁵⁾, therefore solid 100 % UV formula should be capable of fair degree of elongation, and flexibility, not to forget there is a volume shrinkage that would arise from UV cured film.

The influence of extractive materials in the wood affect the adhesion of the UV curable film

Because of the chemical interaction between the wet film and the substrate. There are tests, which show that the extractive materials of teak and rose wood are soluble in HDDA and TPGDA monomers...⁽¹⁶⁾

Weathering of the wood panels before finishing (preweathering) can lead to chemical and physical changes on the wood surface that weaken the future wood coatings interface. Wood preweathered for several months before being coated showed decreased adhesion and shortened coat service life..⁽¹⁷⁾

The surface free energy of the wood substrate and the surface tension of the liquid coating system are other factors which affect the adhesion and specially for the hard wood substrate. If the surface tension of the wet film is greater than the critical surface tension of the wood substrate, then the coating will not wet the substrate and the cured film will have very poor adhesion. Knowledge of the surface tension of the coating and the critical surface tension of the substrate is important for the formulator. the contact angle of the UV lacquers (liquid) on the wood substrate (solid) is an indicator of the ability of the coating to wet the surface effectively... Acrylated polyester gives a good wetting for the wood grain, therefore it is recommended to be used with wood substrate which have wetting difficulty..⁽¹⁸⁾, also Using proper wetting agents, the surface tension of the lacquer can be reduced and the adhesion and the wetting property enhanced .

Surface Preparation and Coatings :

Sanding :

It should come without saying that almost no coating or finishing can overcome a poorly prepared surface. After proper sanding by 180- 240 g and cleaning by brush roller the wood substrate will be ready to coat. Although the surface is sanded prior to coatings, the substrate presented could be fibrous, and in some cases, still have deep cellular cavities. When the first UV lacquer is applied, the fibers on the surface are raised and project from the dry film to give a rough finish, except in a few instances (open grain), for all practical purpose it is necessary to apply two coats of UV lacquer to achieve a satisfactory finish..⁽⁶⁾. The preparation depends on the finishing desired. If extra smooth surface is specified then sanding and full grain filling is required, but if the finishing required is an open grain then sealer without filler will do the job...⁽¹⁹⁾

Stain:

Stains are made for changing the wood color or highlighting the natural grain of wood substrate. Solvent and water-based stain can be used and this needs flash off period or IR oven to let the stain dry before the UV lacquer is applied. The use of oil based stain is not recommended because of poor adhesion, whereas water base stain is a good choice as it achieves good adhesion...(9)

Classical flooring and panels UV finishing line :

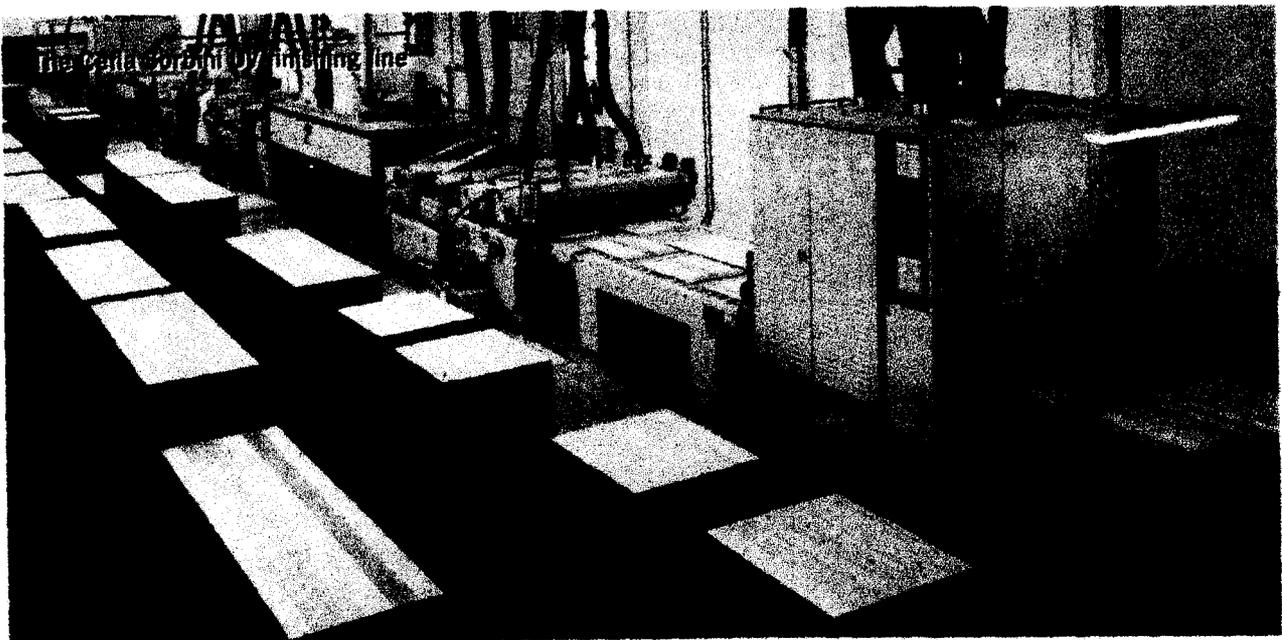
The is a brief of what is widely used as finishing line adopted by flooring and paneling manufacturers in Malaysia.

The production line works at a speed of 12 M/min (maximum potential is approximately 18m/min) producing 3000 M² of coated surface per eight-hour shift. The system uses fillers; Sealer and Topcoats with the highest solid contain (98-100 %) which dramatically reduces the wastage of lacquer typical of other processes.

The working cycle is complete and follows the initial application of stain, UV filler, Sealer and Topcoat. The stain applied can have a solvent or water, as required, after applying the stain by the roller brushes for the stain wiping which insure a uniform application in such a way as to enhance the wood grain. Stain is dried by means of short-wave IR lamps, which must dry out the wood in depth to avoid any accumulation of moisture in the veneer. After staining, the sealer (or fillers) is applied with a filling machine which enables the product to penetrate into the more open pores of the veneer, so as to correct any possible defects in the wood itself. This application is recommended for those difficult species of tropical hardwood .

A further application of UV acrylic sealer is by means of two head machine wet on wet, which is then passed under the UV lamps before sanding. Sanding with granulation 360-400 then cleaning by brushing using a machine with upper and lower brushes which is a fundamental step to ensure the successful application of the top coat The top coat is applied by two rollers with an intermediate UV gelling (semi cure) to obtain greater flexibility of the application...(19). Some Malaysian companies follow this line only to apply UV sealer as for topcoat they use conventional Spray coating (solvent base).

UV finishing line...(19)



Prospective:

Satisfactory performance of wood finishing is achieved when the many factors that affect these are given full consideration. Unfortunately not much of work has been done on the effect of the wood substrate on the (100% solid) UV curable coatings, and thus this will be our consideration for further studies.

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